4.1.2 Recovery Test

(1) Test Period

The recovery test was carried out from October 30th to November 6th.

(2) Observation

Observation results at open holes and the Trench are shown in Fig. 4.1.8.

(3) Total Recovery Height

Total recovery height at the Trench was 2.48 m and those of the open holes became smaller according to the distance from the Trench as shown in Fig. 4.1.9. Rough figures of the recovery heights according to distance from the Trench are:

Distance from Trench	Recovery Height
10 m	0.9 - 1.7 m
30 m	0.5 - 0.8 m
90 m	0.2 - 0.5 m

Recovery height contour lines show that drawdown by abstraction was developed in the eastern side of trench rather than in the western side.

(4) Recovery Percentage in Time

Recovery percentages at the Trench after 25 hrs. (approx. 1 day) and 49 hrs. (approx. 2 days) were 85 and 93 percent respectively, as shown in Fig. 4.1.10.

Recovery percentage of an open hole grew smaller as its location became removed from the Trench.

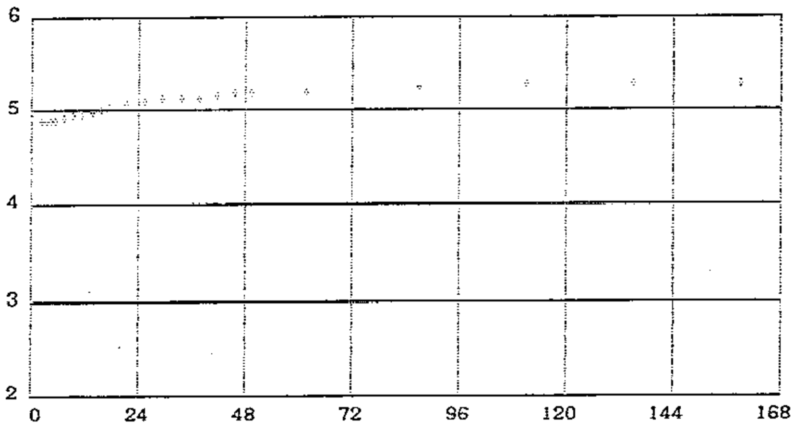


Fig. Recovery Test Results at Rayyan :10/30 - 11/6: TB-18

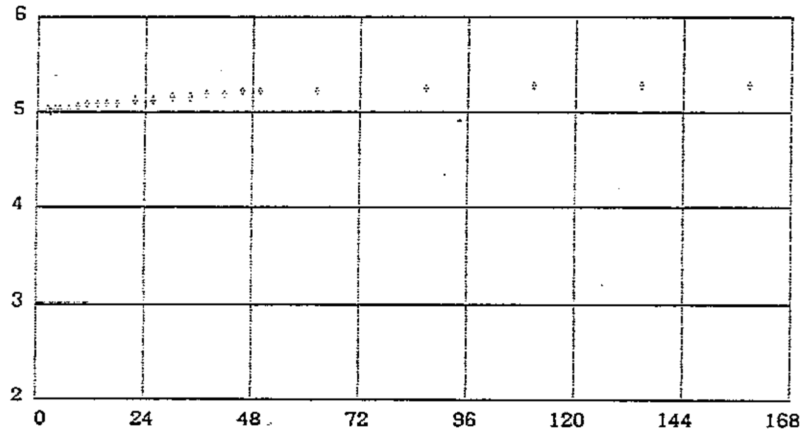


Fig. Recovery Test Results at Rayyan :10/30 - 11/6: TB-20

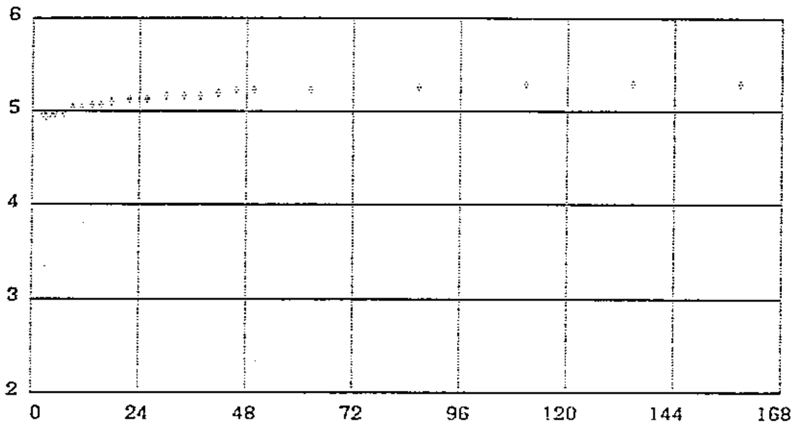


Fig. Recovery Test Results at Rayyan :10/30 - 11/6: TB-19

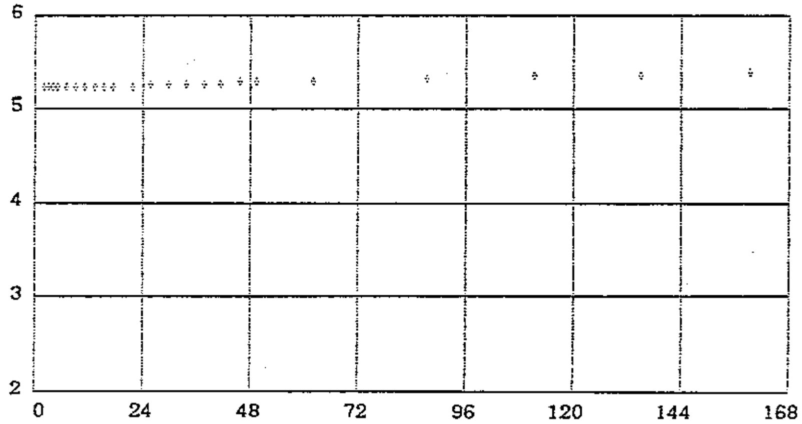


Fig. Recovery Test Results at Rayyan :10/30 - 11/6: TB-21

Fig. 4.1.8 (1) Recovery Test Results at Rayyan

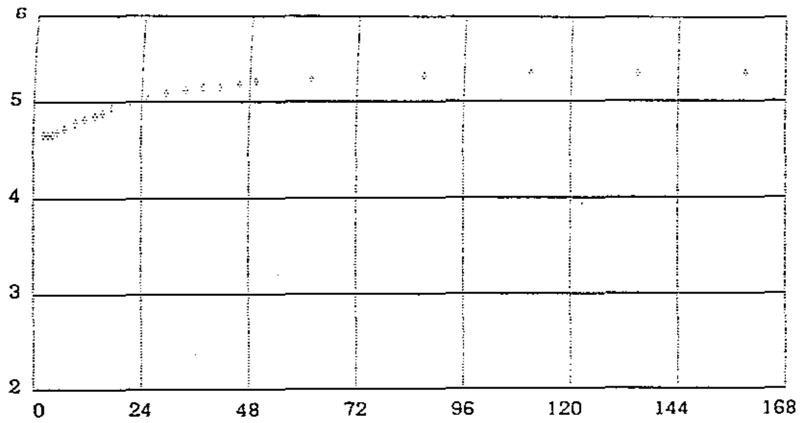


Fig.   Recovery Test Results at Rayyan :10/30 - 11/6: TB-22

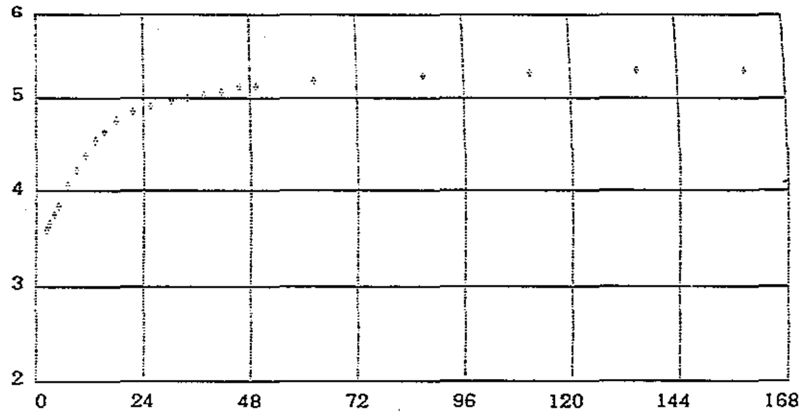


Fig.   Recovery Test Results at Rayyan :10/30 - 11/6: TB-24

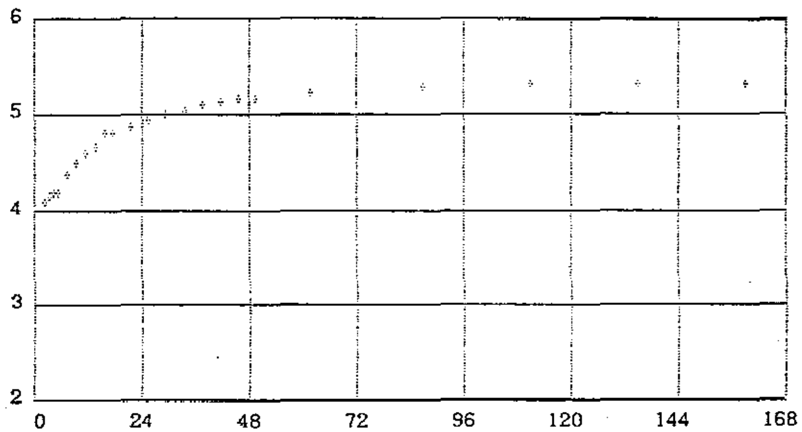


Fig.   Recovery Test Results at Rayyan :10/30 - 11/6: TB-23

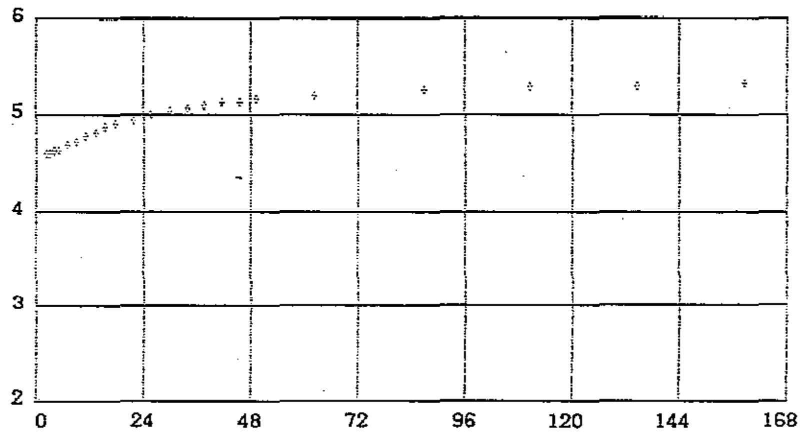


Fig.   Recovery Test Results at Rayyan :10/30 - 11/6: TB-25

Fig. 4.1.8 (2)   Recovery Test Results at Rayyan

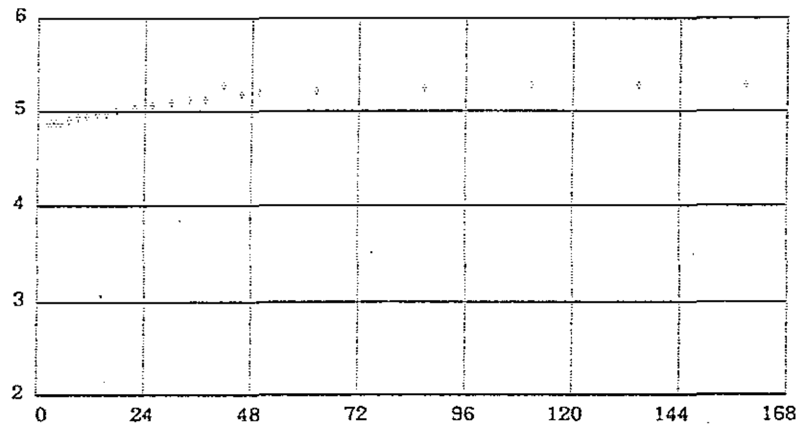


Fig. Recovery Test Results at Rayyan :10/30 - 11/6: TB-26

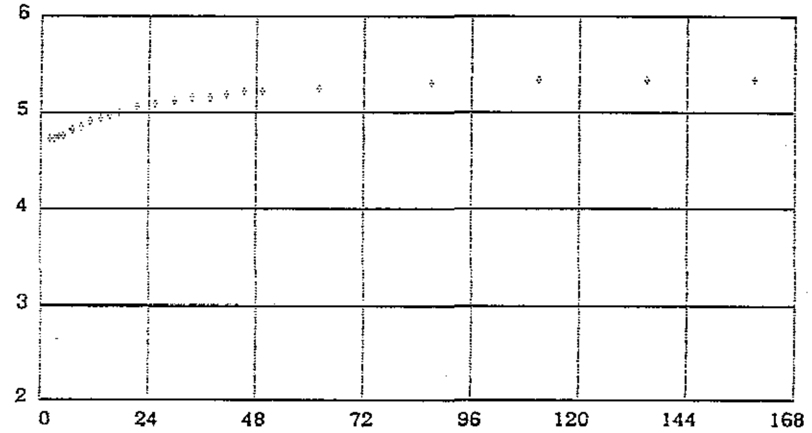


Fig. Recovery Test Results at Rayyan :10/30 - 11/6: TB-28

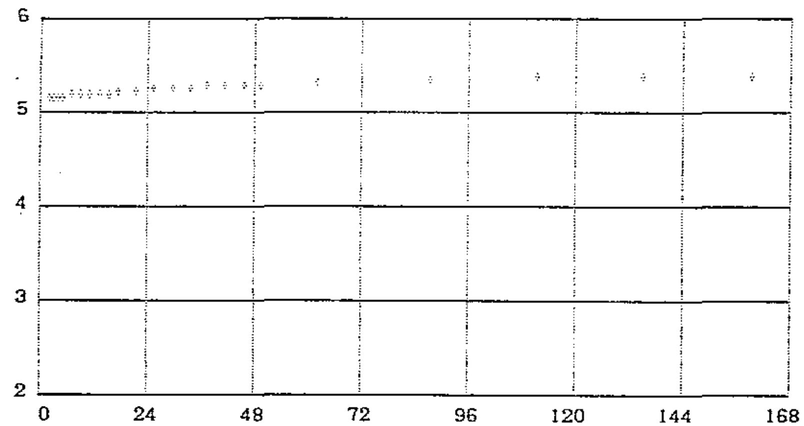


Fig. Recovery Test Results at Rayyan :10/30 - 11/6: TB-27

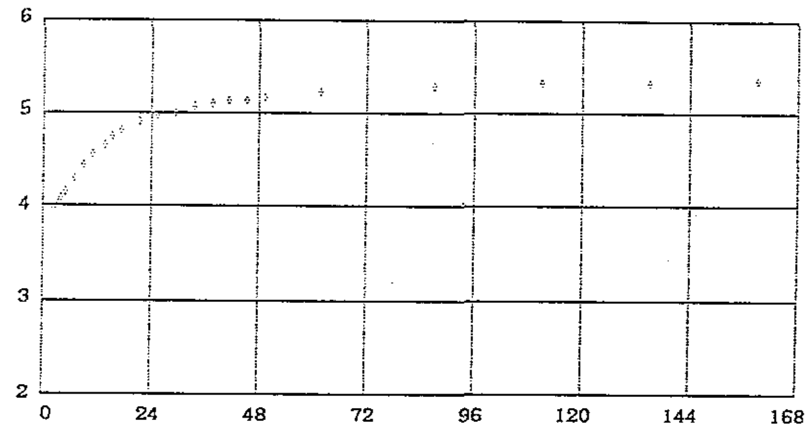


Fig. Recovery Test Results at Rayyan :10/30 - 11/6: TB-29

Fig. 4.1.8 (3) Recovery Test Results at Rayyan

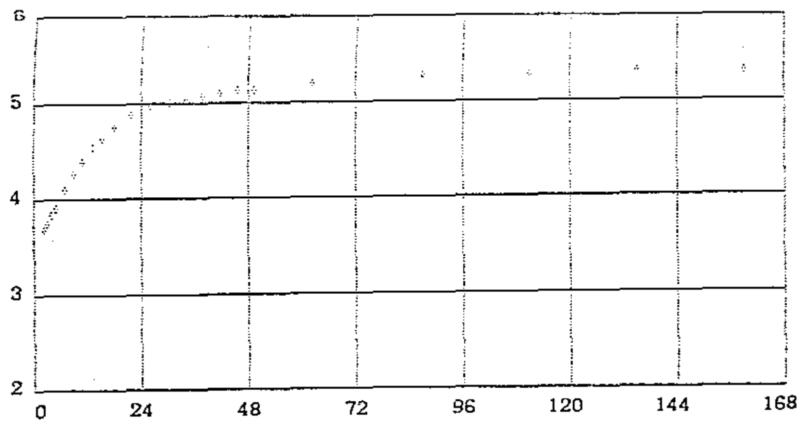


Fig. Recovery Test Results at Rayyan :10/30 - 11/6: TB-30

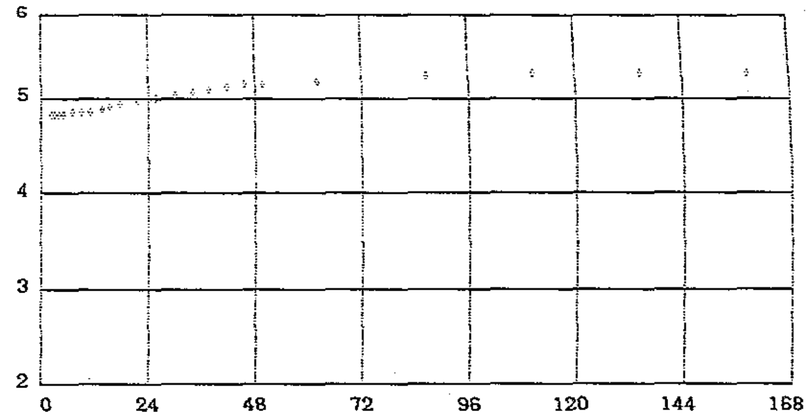


Fig. Recovery Test Results at Rayyan :10/30 - 11/6: TB-32

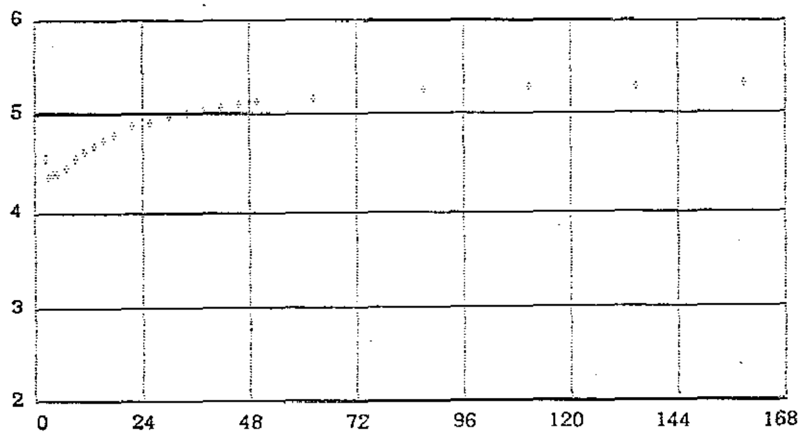


Fig. Recovery Test Results at Rayyan :10/30 - 11/6: TB-31

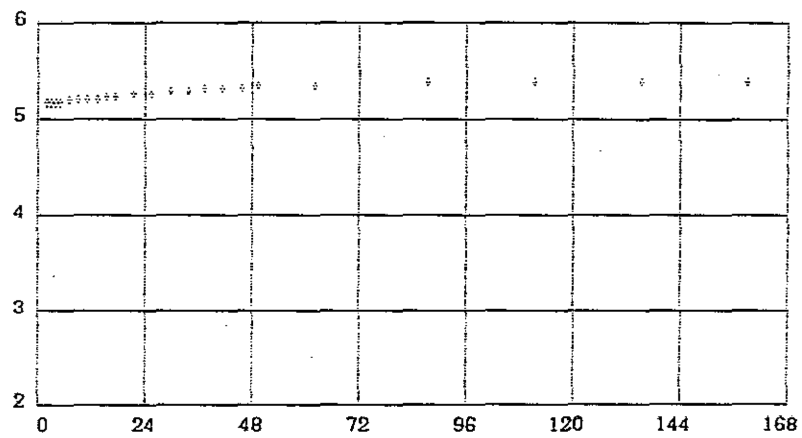


Fig. Recovery Test Results at Rayyan :10/30 - 11/6: TB-33

Fig. 4.1.8 (4) Recovery Test Results at Rayyan

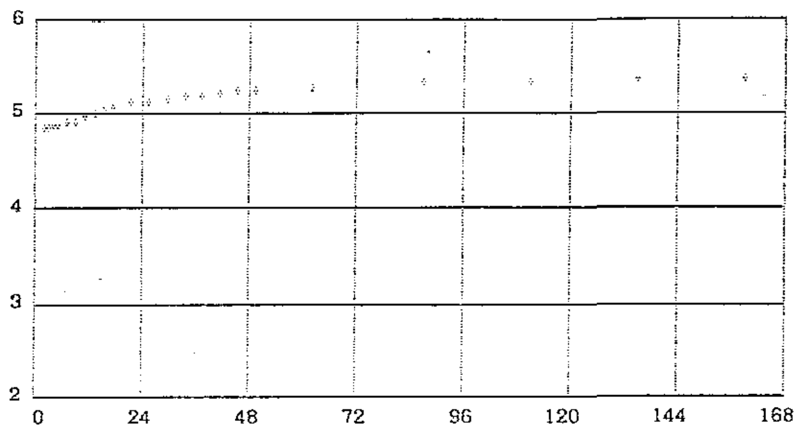


Fig. Recovery Test Results at Rayyan :10/30 - 11/6: TB-34

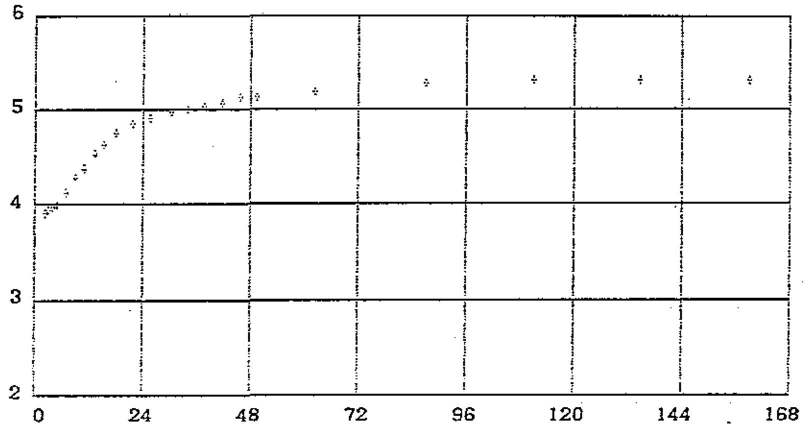


Fig. Recovery Test Results at Rayyan :10/30 - 11/6: TB-36

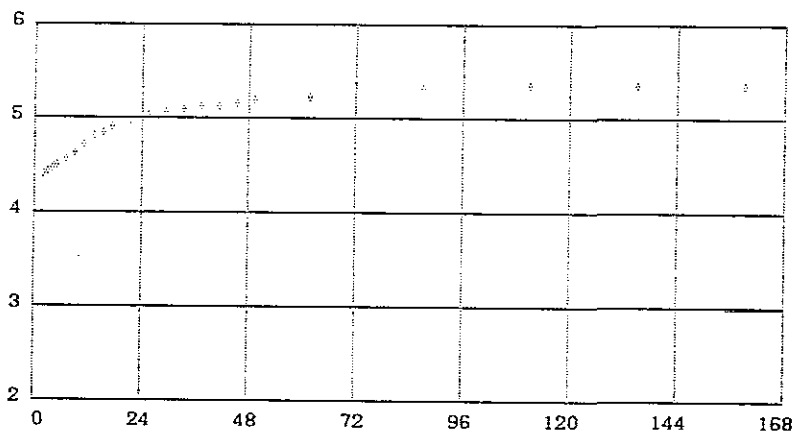


Fig. Recovery Test Results at Rayyan :10/30 - 11/6: TB-35

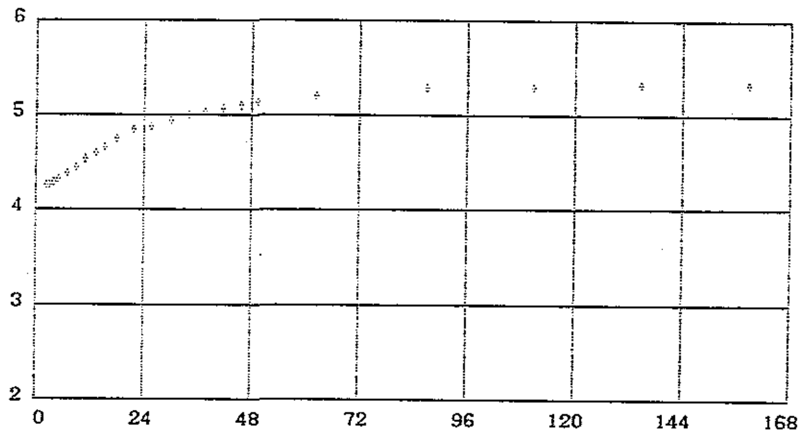


Fig. Recovery Test Results at Rayyan :10/30 - 11/6: TB-37

Fig. 4.1.8 (5) Recovery Test Results at Rayyan

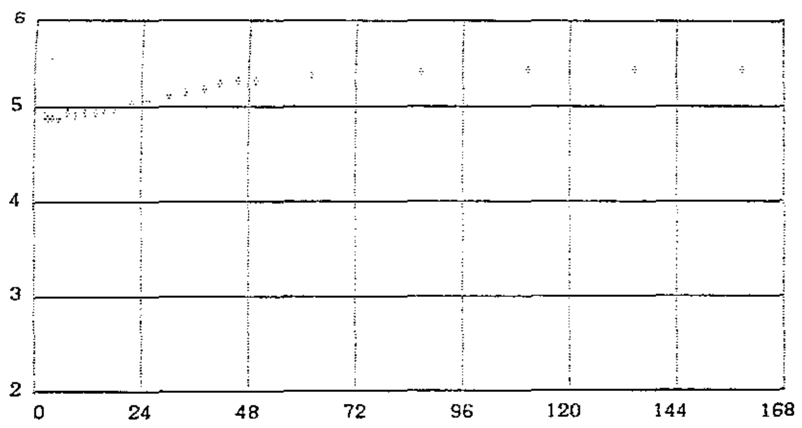


Fig. Recovery Test Results at Rayyan :10/30 - 11/6: TB-38

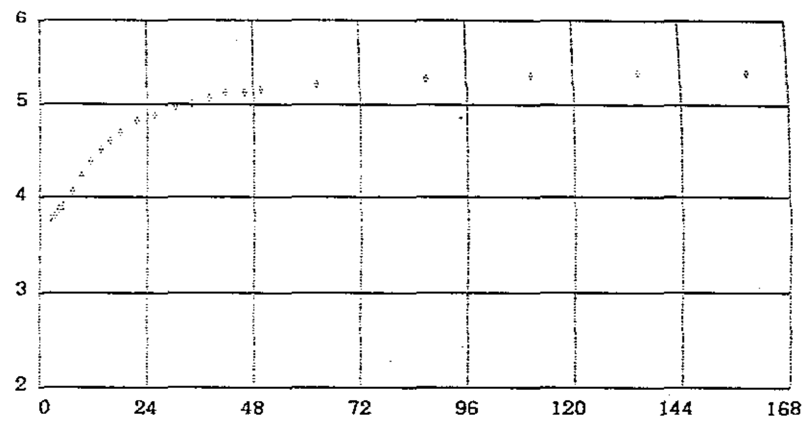


Fig. Recovery Test Results at Rayyan :10/30 - 11/6: TB-40

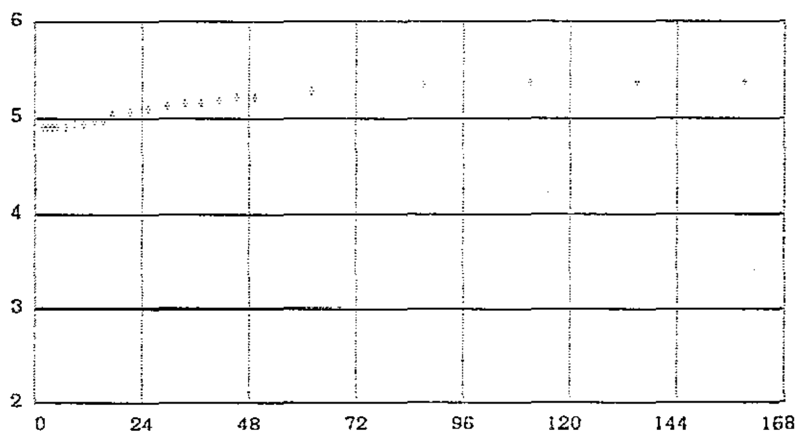


Fig. Recovery Test Results at Rayyan :10/30 - 11/6: TB-39

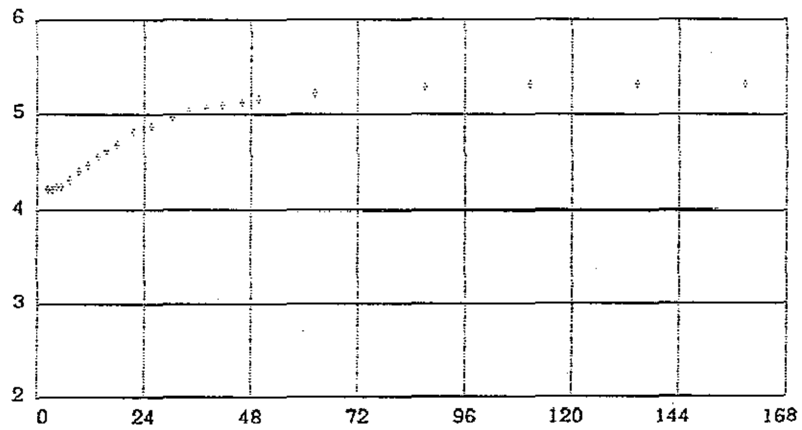


Fig. Recovery Test Results at Rayyan :10/30 - 11/6: TB-41

Fig. 4.1.8 (6) Recovery Test Results at Rayyan

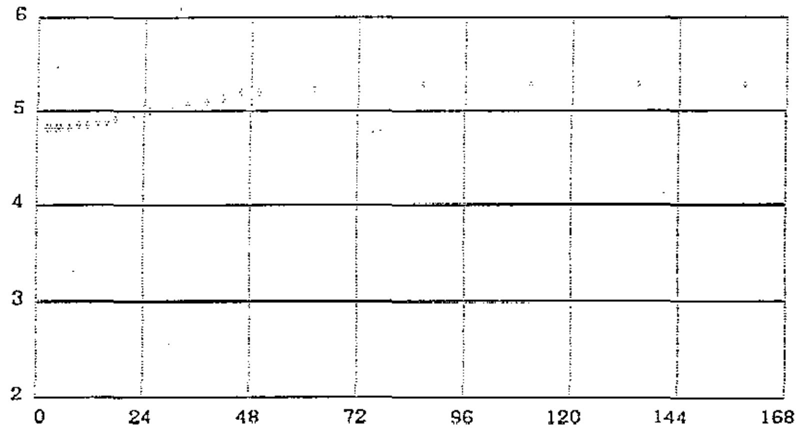


Fig. Recovery Test Results at Rayyan :10/30 - 11/6: TB-42

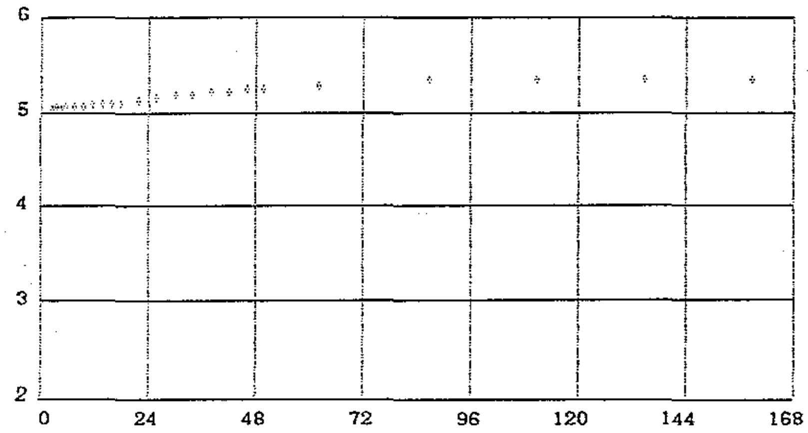


Fig. Recovery Test Results at Rayyan :10/30 - 11/6: TB-44

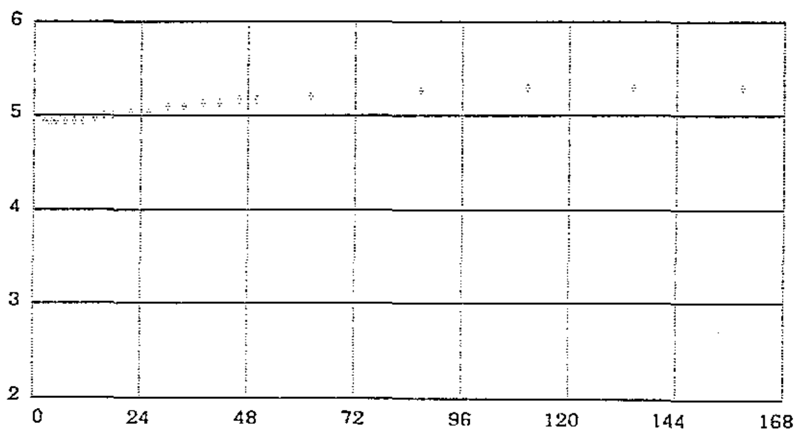


Fig. Recovery Test Results at Rayyan :10/30 - 11/6: TB-43

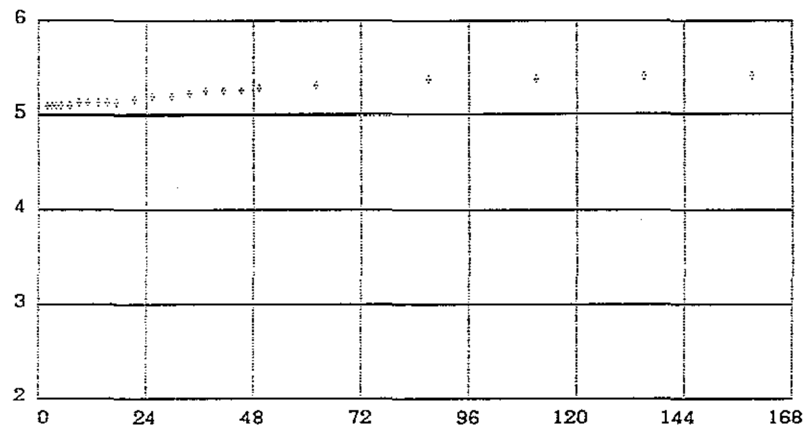


Fig. Recovery Test Results at Rayyan :10/30 - 11/6: TB-45

Fig. 4.1.8 (7) Recovery Test Results at Rayyan

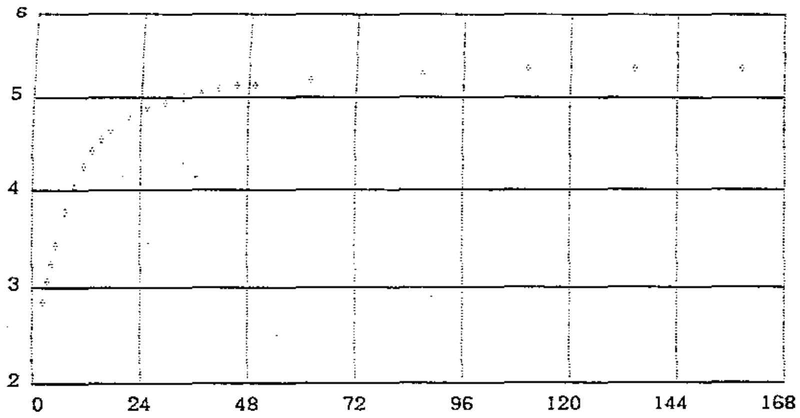


Fig. Recovery Test Results at Rayyan :10/30 - 11/6: TRENCH

Fig. 4.1.8 (8) Continuous Pumping Test with 2 shifts Transportation at Rayyan: 8/30-10/28

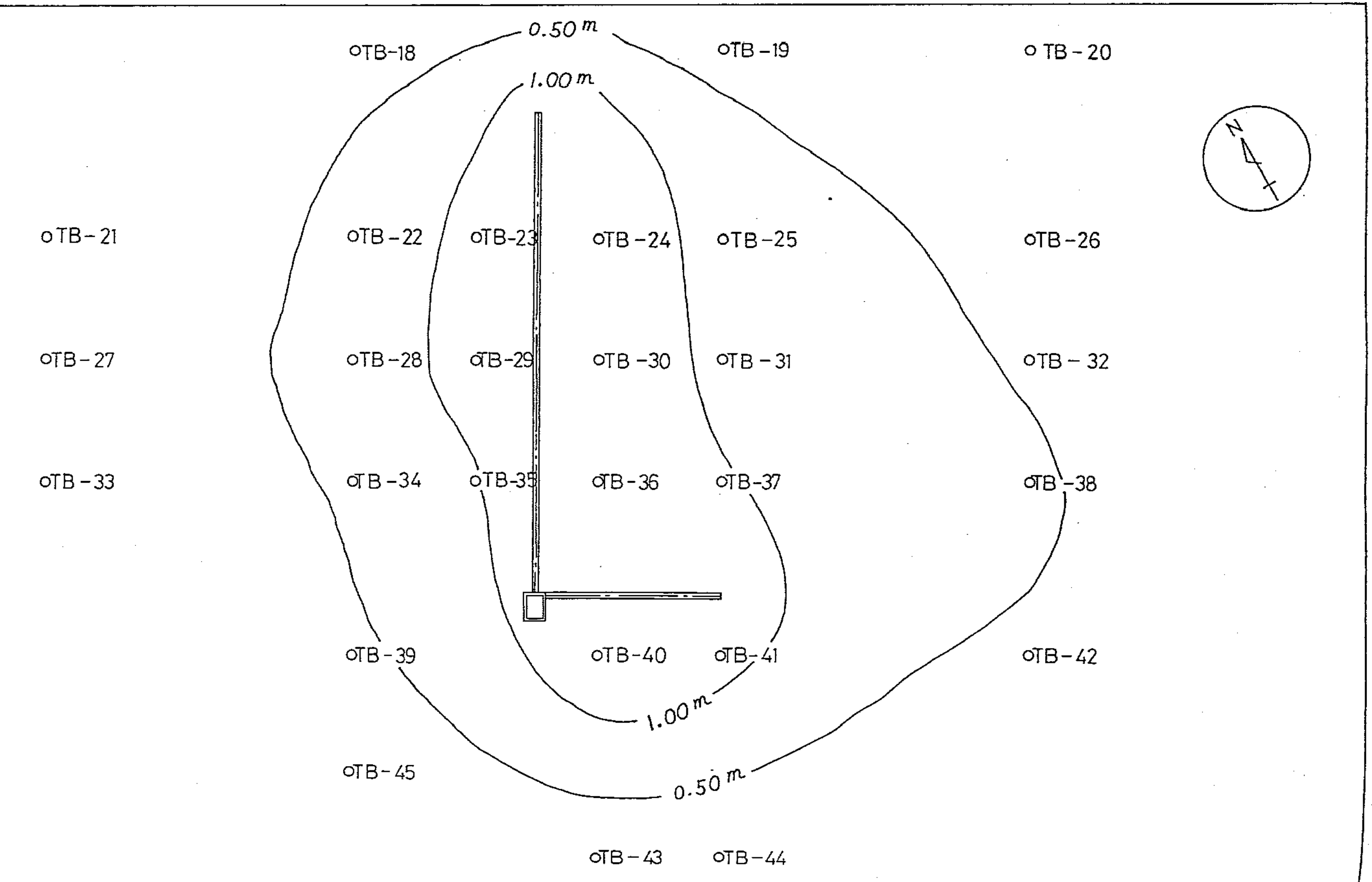


Fig. 4.1.9 Total Recovery Height at Rayyan

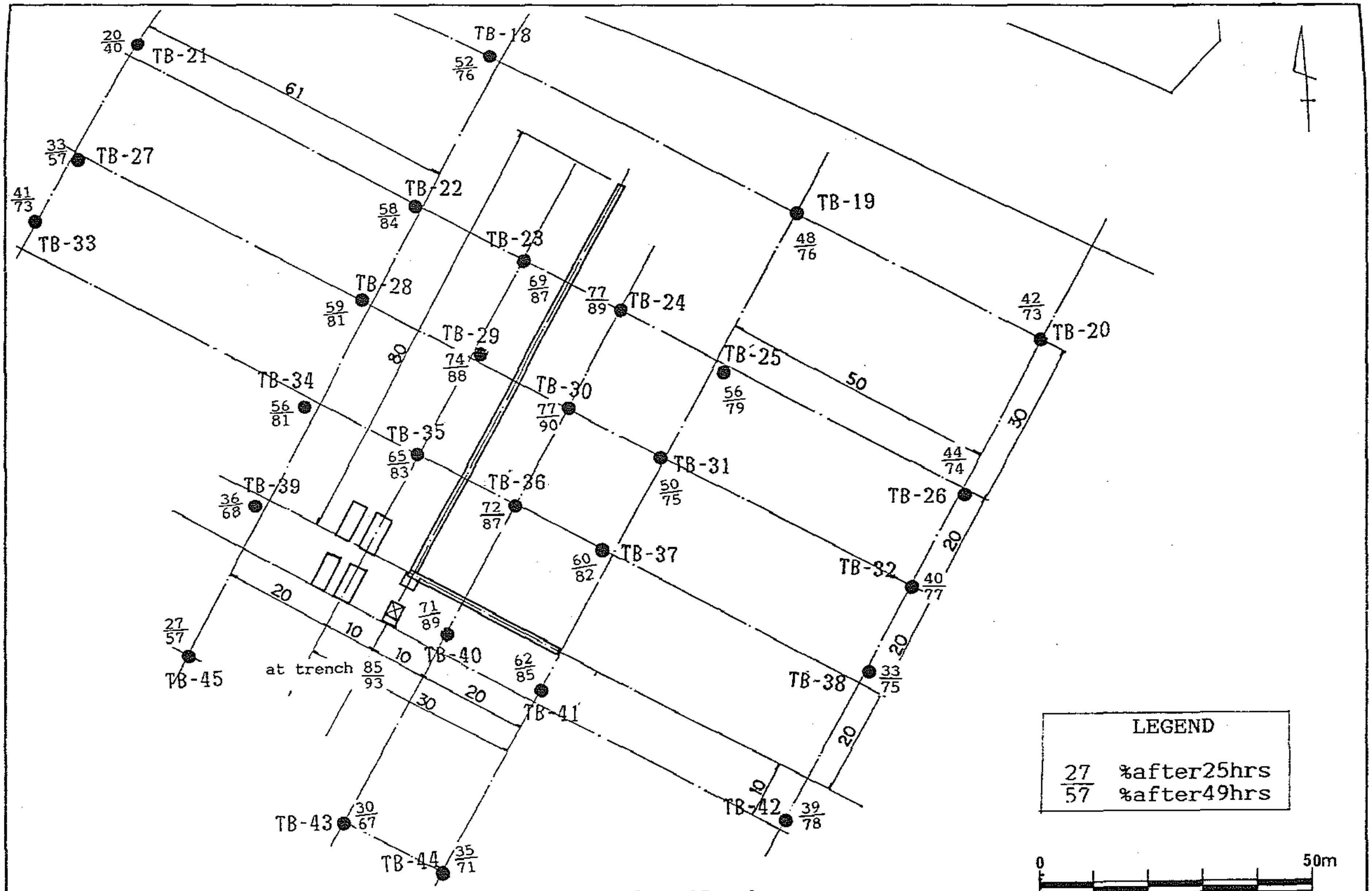


Fig. 4.1.10 Recovery Percentage after 25 and 49 hrs at Rayyan

4.2 Numerical Analysis for Drawdown Simulation

4.2.1 Mathematical Model

The purpose of the drawdown simulation is to determine the hydraulic constants and to evaluate the drawdown effects of drainage system.

The principal simulation model for the trench of which length is much longer than its width is usually the two dimensional vertical plane which is at right angle with the length direction as mentioned in Item 3.2.1.

Generally speaking, the aquifer of limestone has strong heterogeneity as porous media and its permeability should be treated in the stochastic phenomena. This kind of approach demands much information and time for analysis.

The model selected here aims to seek the mean value of permeability corresponding to the stochastic distribution of permeability in the heterogenous field.

The finite element method is used for the present purpose of the study. The initial conditions and the boundary conditions are set in accordance with the purpose of the analysis.

4.2.2 Simulation of Drawdown

(1) Calculation Domain

The calculation domain includes the following three layers which are strictly related with the pumping test by trench abstraction method.

1. First Layer : Strong Weathered Zone of Upper Dammam Formation: 5 m in thickness
2. Second Layer: Weak Weathered Zone of Upper Dammam Formation: 5 m in thickness
3. Third Layer : Lower Dammam Formation: 25 m in thickness

The drawdown effect at a point of 100 m distance from trench is estimated to be negligible and this distance is sufficient to set up the boundary condition.

The calculation domain of two dimensional vertical plane model for drawdown simulation for Wadi Musherib is expressed by the grid system as shown in Fig. 4.2.1.

(2) Calculation Procedure

The tentative permeability coefficient of each layer was evaluated from the mean value of Lugeon value obtained from the Lugeon test.

The judgment condition is the concordance of drawdown depth curve in function of the distance from trench.

The final solution was sought by the trial and error method.

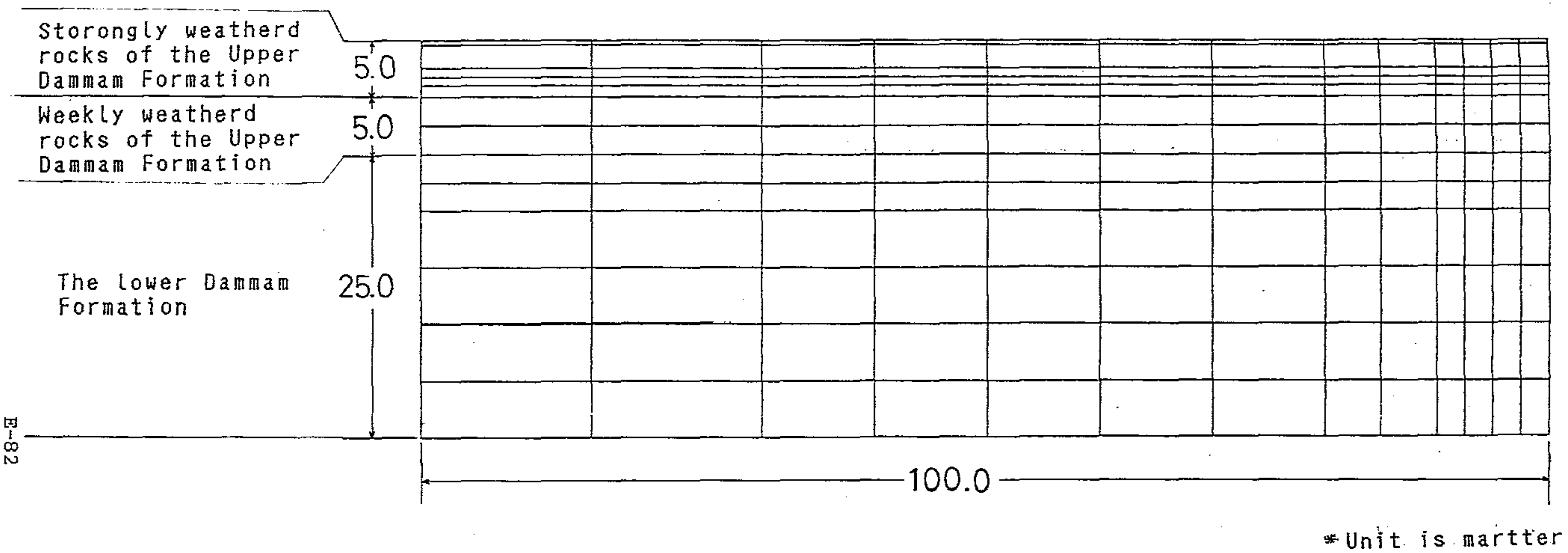


Fig. 4.2.1 Grid Network of Two Dimensional Vertical Plane Model: Rayyan

(3) Initial and Boundary Condition

1 Initial conidition

$h\ (x,\ 0) = ho$

Where, ho : Initial Water Level

2 Boundary condition of Trench

$h\ (x,\ t) = ho - d$

Where, d : Drawdown at Trench

3 Boundary condition beneath the Trench

(Right boundary)

$$\frac{\partial h\ (x,\ t)}{\partial x} = 0$$

4 Bottom boundary

$h\ (x,\ t) = h_b$

Where, h_b: Piezometeric head of bottom
h_b= ho

5 Boundary of Opposite Side (Left boundary)

$h\ (x,\ t) = f(x)$

Where, $f(x)$ is linear interpolation between h_o and h_b according to the position.

6 Upper boundary

No groundwater recharge.

(4) Calculation Results

After having obtained the Lugeon values and core logs, eight runs were carried out, as shown in Table 4.2.1. Some examples of hydraulic head simulation are shown in Fig. 4.2.2.

Table 4.2.1 List of Test Runs for Premeability Coefficient Identification: Rayyan

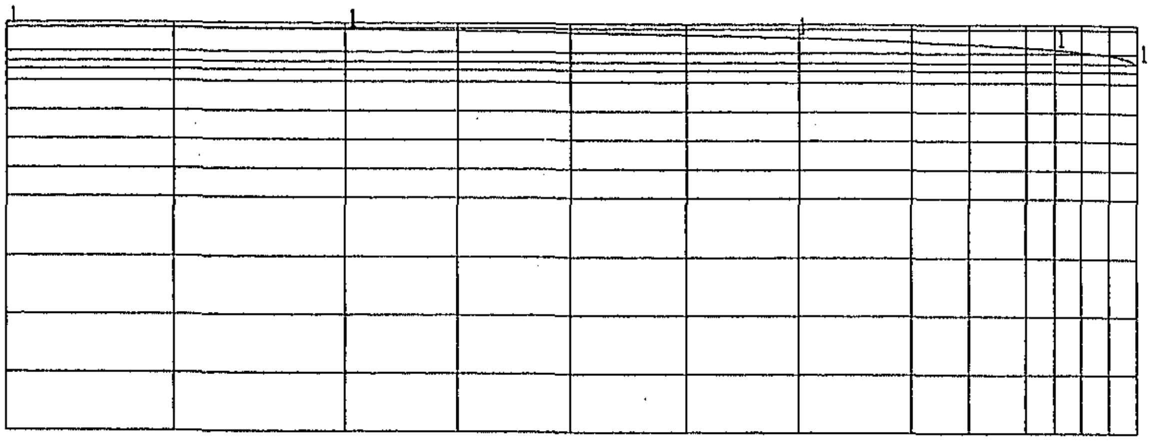
	Permeability Coefficient (m/sec)		
	1st Layer	2nd Layer	3rd Layer
Case 1	2.62×10^{-4}	2.44×10^{-4}	8.11×10^{-5}
Case 2	5.28×10^{-4}	4.93×10^{-4}	1.64×10^{-4}
Case 3	3.95×10^{-4}	3.69×10^{-4}	1.23×10^{-4}
Case 4	9.17×10^{-5}	8.54×10^{-5}	2.84×10^{-5}
Case 5	9.14×10^{-5}	8.54×10^{-5}	4.00×10^{-6}
Case 6	9.14×10^{-5}	8.54×10^{-4}	8.50×10^{-6}
Case 7	9.17×10^{-5}	8.54×10^{-5}	3.60×10^{-5}
Case 8	8.36×10^{-5}	7.79×10^{-5}	3.28×10^{-5}

The permeability coefficient of each layer obtained from final solution is as follows,

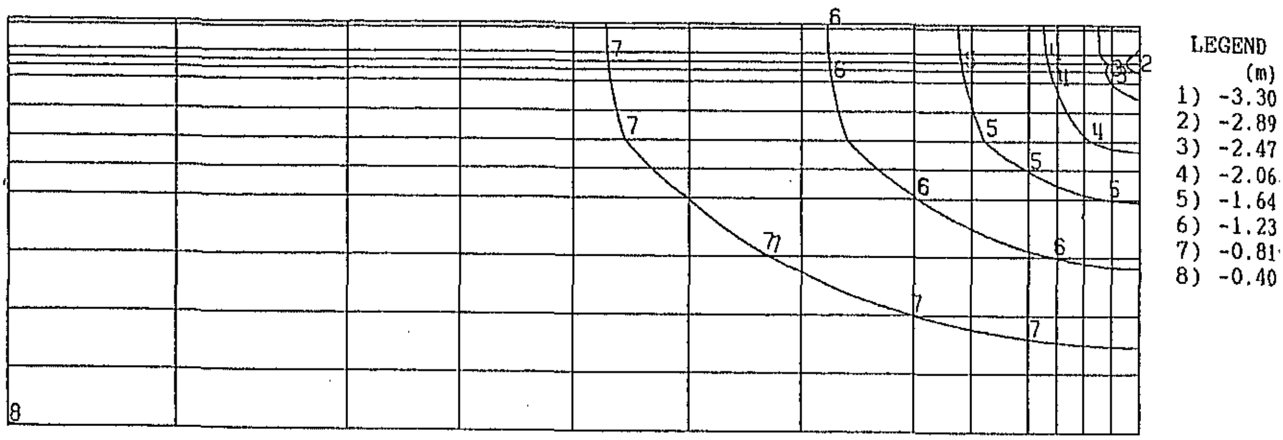
- First layer (Strong weathered layer): 8.36×10^{-5}m/s
- Second layer (Weak weathered layer) : 7.79×10^{-5}m/s
- Third layer (Lower dammam) : 3.28×10^{-5}m/s

The drawdown result of the final solution is as follows;

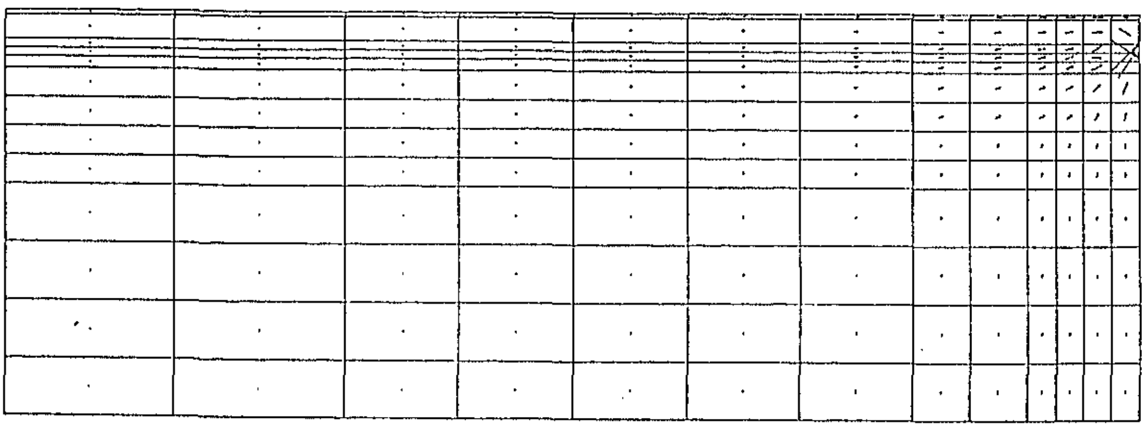
<u>Distance from Trench</u>	<u>Drawdown Depth</u>
10 m	1.56 m
30 m	0.75 m
70 m	0.17 m



(1) Groundwater Table



(2) Hydaulic Head Distribution



(3) Flow Vector Distribution

Fig. 4.2.2 Simulation of Hydraulic Head Distribution by Two Dimensional Plane Model: Rayyan

4.2.3 Numerical Information for Forecasting of Drawdown Effect

(1) Mathematical Model

Two dimension vertical plane steady analysis for which hydraulic parameter was indentified by the trial and error method, was also employed to obtain the numerical information on the determination of interval between neighbouring trenches in Collection System.

1 The shape of the groundwater table cross-section on the central line of the 2 parallel collection trenches is symmetrical. Either the right or the left half of the groundwater table cross-section is analysed.

2 The groundwater table is level on the central line.

3 The shape of the groundwater table cross-section, from the collection trench to the central line, is determined by the groundwater recharge amount.

4 The leakage amount from the bottom is included in the groundwater recharge amount and the bottom is regarded as an aquitard.

The following three types of grid system were used.

- 100 m Model
- 200 m Model
- 300 m Model

(2) Initial and Boundary Conditions

1 Initial condition

$$h\ (x,\ 0) = h_o$$

2 Boundary Condition of Trench

$$h\ (x,\ t) = h_o - d$$

3 Boundary Beneath the Trench (Right Boundary)

$$\frac{\partial h\ (x,\ t)}{\partial x} = 0$$

4 Bottom Boundary

$$\frac{\partial h\ (x,\ t)}{\partial x} = 0$$

5 Boundary of Opposite Side (Left Boundary)

$$\frac{\partial h(x,t)}{\partial x} = 0$$

6 Upper Boundary

$$q = \frac{\varepsilon \cdot b \cdot t}{365 \times 24 \times 3{,}600}$$

Where, q : Groundwater recharge amount given at each node on the upper boundary

ε : Groundwater recharge rate

b : Length given at each node

t : Time step

(3) Calculation Results

The following runs as shown in Table 4.2.2 were carried out under the different conditions of groundwater recharge amount.

Table 4.2.2 List of Simulation Runs for Drawdown Forecasting: Rayyan

Groundwater Recharge Amount	100 m Model	200 m Model	300 m Model
2000 mm/yr	Case 1	Case 2	Case 3
1500 mm/yr	Case 4	Case 5	Case 6
1000 mm/yr	Case 7	Case 8	Case 9
700 mm/yr	Case 10	Case 11	Case 12

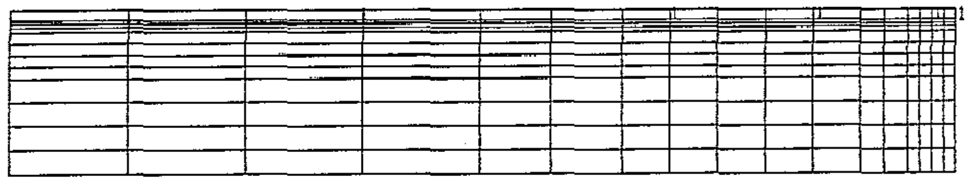
The relationship between the drawdown depth and the distance from collection trench is estimated as shown in Table 4.2.3 and the hydraulic head distributions of each run are shown in Fig. 4.2.3.

Table 4.2.3 Degree of Groundwater Level Lowering given Constant Groundwater Recharge Amount

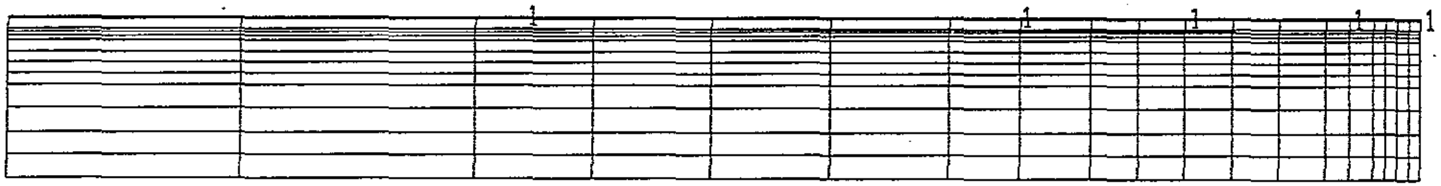
(Unit: m)

Case	Recharge Volume (mm/yr)	Distance from Trench 10	30	70	100	200	300 (m)
1	2000	2.786	2.707	2.626	2.609	-	-
2	"	2.669	2.496	2.284	2.222	1.926	-
3	"	2.553	2.286	1.756	1.635	1.054	0.859
4	1500	2.815	2.765	2.695	2.682	-	-
5	"	2.725	2.597	2.417	2.317	2.271	-
6	"	2.640	2.440	2.242	1.954	1.518	1.374
7	1000	2.843	2.804	2.764	2.755	-	-
8	"	2.785	2.699	2.579	2.512	2.415	-
9	"	2.728	2.595	2.396	2.272	1.983	1.887
10	700	2.860	2.833	2.805	2.799	-	-
11	"	2.820	2.759	2.676	2.629	2.561	-
12	"	2.780	2.595	2.549	2.463	2.262	2.196

(1) 100m Model

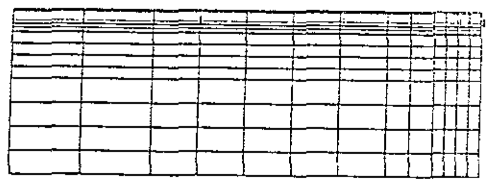


(2) 200m Model

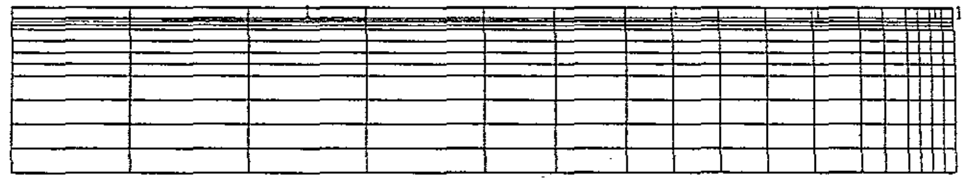


(3) 300m Model

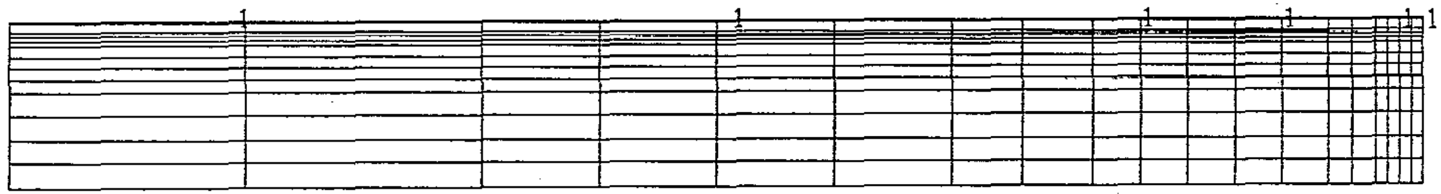
Fig. 4.2.3 Forecasting of Drawdown Depth by Two Dimensional Plane Model:
Rayyan: Groundwater Recharge Amount 700 mm/yr



(1) 100m Model



(2) 200m Model



(3) 300m Model

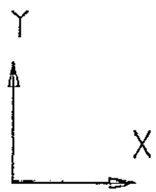
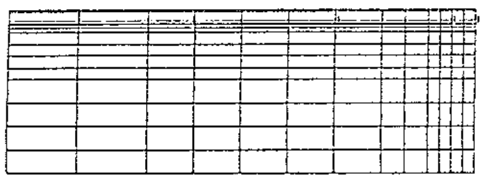
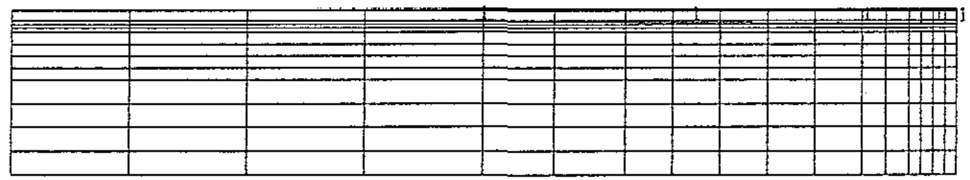


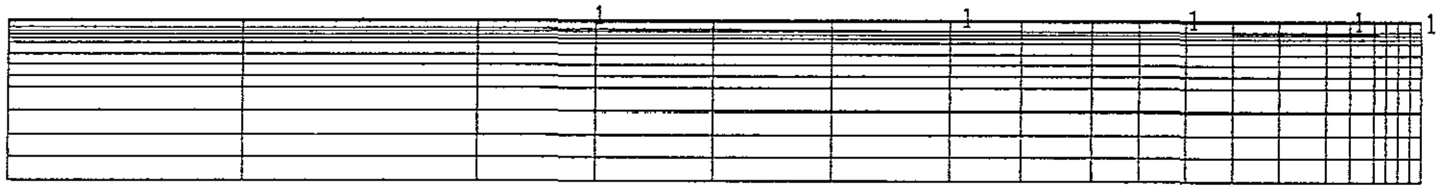
Fig. 4.2.3 Forecasting of Drawdown Depth by Two Dimensional Plane Model:
Rayyan : Groundwater Recharge Amount 1000 mm/yr



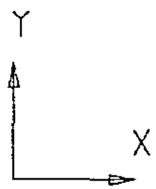
(1) 100m Model



(2) 200m Model



(3) 300m Model



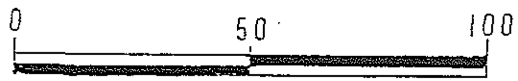
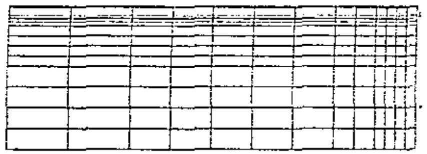
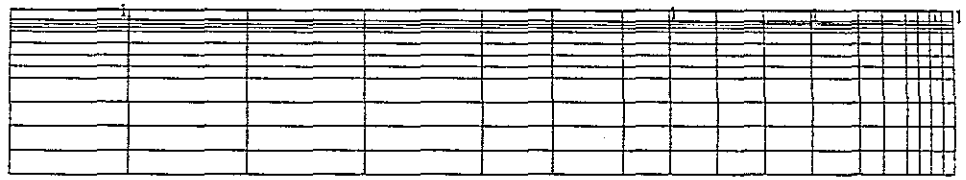


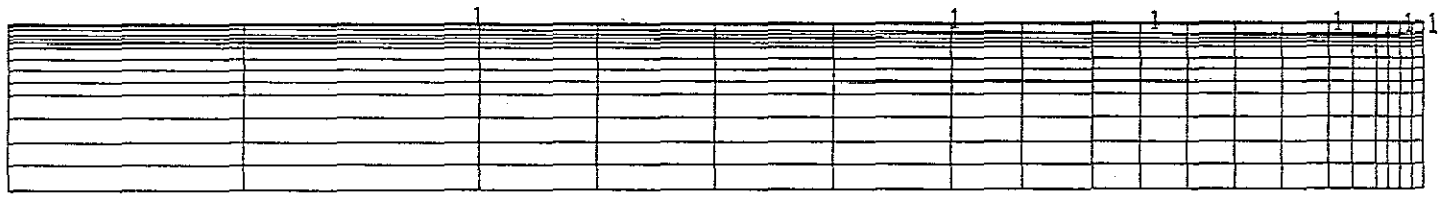
Fig. 4.2.3 Forecasting of Drawdown Depth by Two Dimensional Plane Model:
Rayyan: Groundwater Recharge Amount 1500 mm/yr



(1) 100m Model



(2) 200m Model



(3) 300m Model

Fig. 4.2.3 Forecasting of Drawdown Depth by Two Dimensional Plane Model:
Rayyan : Groundwater Recharge Amount 2000 mm/yr

4.3 Water Quality

4.3.1 Sampling

As the means of transporting the pumped-up water from the Trench in Rayyan took some time before being firmly established, the water sampling schedule was affected, as in the case of the pumping tests. As table 4.3.1 shows, the schedule accordingly became very irregular.

Table 4.3.1 Sampling at Rayyan Test Work Site

Period	Site	Type of Pumping Test
7/11 - 7/18	Pit, TB-23, TB-39	Pumping Test without transportation
8/5 - 10/30	Pit, TB-21, TB-25 TB-42, TB-45	Pumping Test with transportation

The pumping tests between July 11th and July 18th were carried out by dumping the water pumped from the Trench to the east side of the Trench. Although the volume of pumped-up water was sufffícient for sampling, this method was not preferable due to the possibility of the dumped water being circulated.

Transportation by a road tanker commenced in August but the pumped-up volume was low for nearly a month because of there being only one shift. Full-scale pumping tests with two shifts started on August 30th.

The items for the water quality analysis were the same as those for Musherib, as follows.

- o pH, EC, COD
- o Cl^{-}, SO_4^{--}
- o Ca^{++}, Mg^{++}, K^{+}, Na^{+}

4.3.2 Analysis Results

The results of the analysis are shown in Table 4.3.2.

1) Quality of Trench Water

The EC value fluctuated between 13,150 and 17,810 micro mhos/cm in the tests between July 11th and October 30th. The COD value fluctuated between 3.9 and 14.8 mg/l, hitting its highest point on October 14th becoming lower to 9.4 mg/l at the end of test.

Table 4.3.2 Chemical Analysis Results at Rayyan

P I T WATER CHEMICAL ANALYSIS DATA AT RAYYAN TEST WORKSITE (PRELIMINARY TEST)

DATE	7/11	7/12	7/12	7/12	7/13	7/14	7/15	7/16	7/17	7/18
P H	8.1	8.0	7.3	7.3	7.2	7.3	7.9	7.6	7.4	7.5
E C (ms/cm)	17810	14630	15380	15720	16630	16900	16850	15350	16360	16430
C O D (mg/l)	10.0	8.7	7.3	9.3	8.9	12.1	8.4	4.0	3.9	5.6
C l (mg/l)	5800.0	4200.0	4800.0	5100.0	4975.0	4700.0	5200.0	5050.5	5606.1	5353.5
S O4(mg/l)	2913.0	2941.0	2708.0	2465.0	2932.0	2633.0	2727.0	2465.0	2727.0	2820.0
C a (mg/l)	2750.0	2550.0	2400.0	2450.0	2500.0	2500.0	2550.0	2600.0	2650.0	2600.0
M g (mg/l)	1870.0	1610.0	1600.0	1610.0	1700.0	1740.0	1610.0	1650.0	1850.0	1850.0
K (mg/l)	137.0	118.8	107.5	116.2	117.5	118.8	112.5	105.0	117.0	119.7
N a (mg/l)	2820.5	2187.5	2297.7	2447.9	2532.0	2532.0	2474.0	1923.1	2139.4	2283.6
Cl/35.45(em/l)	163.61	118.48	135.40	143.86	140.34	132.58	146.69	142.47	158.14	151.02
SO4/48.03(em/l)	60.65	61.23	56.38	51.32	61.05	54.82	56.78	51.32	56.78	58.71
Ca/50(em/l)	55.00	51.00	48.00	49.00	50.00	50.00	51.00	52.00	53.00	52.00
Mg/50(em/l)	37.40	32.20	32.00	32.20	34.00	34.80	32.20	33.00	37.00	37.00
Na+K(em/l)	126.13	98.15	102.65	109.40	113.09	113.13	110.44	86.30	96.01	102.35
Na/Cl	0.75	0.80	0.74	0.74	0.78	0.83	0.73	0.59	0.59	0.66
SO4/Cl	0.37	0.52	0.42	0.36	0.43	0.41	0.39	0.36	0.36	0.39
SAR	18.04	14.75	15.80	16.70	16.99	16.91	16.68	12.83	13.87	14.88

DATE	8/9	8/11	8/23	8/25	9/4	9/9	9/16	9/23	9/30	10/6	10/14	10/20	10/30
P H	7.8	7.7	7.9	7.5	7.6	7.8	8.1	7.7	7.4	7.5	8.3	7.4	7.4
E C (ms/cm)	16150	14760	13150	13820	13430.0	13480.0	13910.0	13630.0	13180.0	12770.0	14800.0	13930.0	14120.0
C O D (mg/l)	6.4	6.2	5.6	6.8	4.3	6.8	5.4	7.1	8.9	11.9	14.8	6.1	9.4
C l (mg/l)	5075.4	4422.1	3800.0	3800.0	4343.4	3943.7	4882.6	4218.0	5235.8	1886.8	4811.3	4272.3	4703.0
S O4(mg/l)	2839.0	2820.0	2503.0	2708.0	2727.0	2549.0	2839.0	2820.0	2372.0	2521.0	2960.0	2279.0	2633.0
C a (mg/l)	2350.0	2450.0	2500.0	2550.0	2400.0	2225.0	2700.0	2200.0	2350.0	2200.0	2300.0	2340.0	2400.0
M g (mg/l)	1950.0	1500.0	1500.0	1600.0	1350.0	1450.0	1500.0	1650.0	1250.0	1500.0	1600.0	1420.0	1450.0
K (mg/l)	115.4	110.5	99.0	96.1		145.8	118.7	143.0	45.7	41.5	53.8	100.0	105.3
N a (mg/l)	2408.5	2186.7	1888.9	1977.8		1111.1	1938.8	1956.5	949.3	882.3	1205.5	2290.3	2341.5
Cl/35.45(em/l)	143.17	124.74	107.19	107.19	122.52	111.25	137.73	118.98	147.70	53.22	135.72	2390.0	2447.0
SO4/48.03(em/l)	59.11	58.71	52.11	56.38	56.78	53.07	59.11	58.71	49.39	52.49	61.63	47.45	54.82
Ca/50(em/l)	47.00	49.00	50.00	51.00	48.00	44.50	54.00	44.00	47.00	44.00	46.00	46.80	48.00
Mg/50(em/l)	39.00	30.00	30.00	32.00	27.00	29.00	30.00	33.00	25.00	30.00	32.00	28.40	29.00
Na+K(em/l)	107.67	97.90	84.66	88.45	0.00	52.04	87.33	88.72	42.44	39.42	53.79	102.14	104.50
Na/Cl	0.73	0.76	0.77	0.80	0.00	0.43	0.61	0.71	0.28	0.72	0.39	0.04	0.04
SO4/Cl	0.41	0.47	0.49	0.53	0.46	0.48	0.43	0.49	0.33	0.99	0.45	0.02	0.02
SAR	15.97	15.13	12.99	13.35	0.00	7.97	13.01	13.71	6.88	6.31	8.39	16.24	16.41

T R - 2 1 WATER CHEMICAL ANALYSIS DATA AT RAYYAN TEST WORKSITE (PRELIMINARY TEST)

DATE	8/5	8/10	8/21	8/25	9/2	9/8	9/15	9/22	9/29	10/6	10/13	10/20	10/30
P H	7.3	7.4	7.4	7.3	7.5	7.6	8.1	7.6	7.4	7.4	8.2	7.4	7.5
E C (ms/cm)	9420	8820	9830	10360	10250	9690	9610	9910	9600	9720	9580	9580	9430
C O D (mg/l)	11.4	11.7	8.0	9.9	8.0	7.1	6.0	7.5	7.0	7.0	8.7	6.1	6.9
C l (mg/l)	2236.2	2160.8	2350.0	2400.0	2727.3	2300.5	2300.5	2606.6	1981.1	4150.9	2429.2	2394.4	2401.0
S O4(mg/l)	2465.0	2400.0	2493.0	2811.0	2997.0	2615.0	2820.0	2792.0	2839.0	2372.0	2689.0	2437.0	2615.0
C a (mg/l)	1850.0	2050.0	2075.0	2025.0	1950.0	2050.0	2050.0	2000.0	1850.0	2000.0	1900.0	1920.0	2000.0
M g (mg/l)	1150.0	775.0	875.0	1025.0	900.0	750.0	925.0	900.0	1100.0	850.0	1650.0	1020.0	950.0
K (mg/l)	64.4	56.3	74.2	162.9	0.0	73.4	77.1	133.3	42.0	40.0	42.5	84.2	87.2
N a (mg/l)	1142.0	1160.0	1413.3	1466.7	0.0	833.3	732.9	847.8	659.4	647.0	650.7	1411.3	1365.8
Cl/35.45(em/l)	63.08	60.95	66.29	67.70	76.93	64.89	64.89	73.53	55.88	117.09	68.52	67.54	67.73
SO4/48.03(em/l)	51.32	49.97	51.91	58.53	62.40	54.45	58.71	58.13	59.11	49.39	55.99	50.74	54.45
Ca/50(em/l)	37.00	41.00	41.50	40.50	39.00	41.00	41.00	40.00	37.00	40.00	38.00	38.40	40.00
Mg/50(em/l)	23.00	15.50	17.50	20.50	18.00	15.00	18.50	18.00	22.00	17.00	33.00	20.40	19.00
Na+K(em/l)	51.30	51.87	63.35	67.94	0.00	38.11	33.84	40.27	29.74	29.15	29.38	63.51	61.61
Na/Cl	0.79	0.83	0.93	0.94	0.00	0.56	0.49	0.50	0.51	0.24	0.41	0.91	0.88
SO4/Cl	0.81	0.82	0.78	0.86	0.81	0.84	0.90	0.79	1.06	0.42	0.82	0.75	0.80
SAR	9.07	9.49	11.31	11.55	0.00	6.85	5.84	6.84	5.28	5.27	4.75	11.32	10.93

R-25 WATER CHEMICAL ANALYSIS DATA AT RAYYAN TEST WORKSITE (PRELIMINARY TEST)

DATE	8/5	8/10	8/21	8/25	9/2	9/8	9/15	9/22	9/29	10/6	10/13	10/20	10/30
P H	7.4	7.5	7.6	7.5	7.8	7.7	8.1	7.7	7.6	7.4	8.3	7.4	7.4
E C (ms/cm)	18960	19100	19040	19250	17180	24840	24320	24640	21400	23040	24320	19900	19440
C O D (mg/l)	6.4	6.4	6.4	7.0	5.3	7.8	7.7	9.2	8.7	16.8	30.0	14.2	14.7
C l (mg/l)	6180.9	6733.7	5950.0	5700.0	5959.6	7323.9	10328.6	7488.2	8679.2	6792.5	7641.5	6807.5	7128.7
S O4(mg/l)	2932.0	2820.0	2904.0	3100.0	3072.0	3363.0	3549.0	3493.0	4072.0	2969.0	3455.0	2867.0	3081.0
C a (mg/l)	2550.0	2800.0	2900.0	2950.0	2750.0	2600.0	2850.0	2500.0	2800.0	2850.0	2300.0	2800.0	2700.0
M g (mg/l)	2300.0	2050.0	2200.0	2100.0	2250.0	2575.0	2600.0	2800.0	2200.0	2350.0	2900.0	2300.0	2450.0
K (mg/l)	130.3	142.1	135.0	136.1		144.7	150.0	153.0	76.6	72.0	72.5	140.8	146.8
N a (mg/l)	2785.7	3120.0	3040.0	3040.0		2611.0	2397.3	2552.6	1750.0	1727.3	1657.5	3403.2	3390.2
Cl/35.45(em/l)	174.36	189.95	167.84	160.79		206.60	291.36	211.23	244.83	191.61	215.56	192.03	201.09
SO4/48.03(em/l)	61.05	58.71	60.46	64.54	63.96	70.02	73.89	72.73	84.78	61.82	71.93	59.69	64.15
Ca/50(em/l)	51.00	56.00	58.00	59.00	55.00	52.00	57.00	50.00	56.00	57.00	46.00	56.00	54.00
Mg/50(em/l)	46.00	41.00	44.00	42.00	45.00	51.50	52.00	56.00	44.00	47.00	58.00	46.00	49.00
Na+K(em/l)	124.45	139.29	135.63	135.65	0.00	117.22	108.07	114.90	78.05	76.94	73.92	151.57	151.15
Na/Cl	0.69	0.71	0.79	0.82		0.55	0.36	0.53	0.31	0.39	0.33	0.77	0.73
SO4/Cl	0.35	0.31	0.36	0.40		0.34	0.25	0.34	0.35	0.32	0.33	0.31	0.32
SAR	17.39	19.48	18.51	18.60	0.00	15.78	14.12	15.24	10.76	10.41	9.99	20.72	20.54

R-42 WATER CHEMICAL ANALYSIS DATA AT RAYYAN TEST WORKSITE (PRELIMINARY TEST)

DATE	8/5	8/10	8/21	8/25	9/2	9/8	9/15	9/22	9/29	10/6	10/13	10/20	10/30
P H	7.5	7.7	7.7	7.7	7.6	7.7	8.2	7.8	7.4	7.9	8.2	7.4	7.5
E C (ms/cm)	21340	20000	19660	19120	21720	16070	14450	14140	13460	13500	13430	13120	13620
C O D (mg/l)	9.3	9.2	9.2	7.9	5.0	7.9	6.2	8.1	7.4	9.6	13.8	10.7	8.4
C l (mg/l)	7336.7	7185.9	6100.0	6100.0	8080.3	4976.5	5023.5	4455.0	4905.7	4150.9	4481.1	4225.4	4752.0
S O4(mg/l)	3624.0	3333.0	2792.0	3035.0	3941.0	2671.0	2633.0	2643.0	2521.0	2428.0	2699.0	1999.0	2245.0
C a (mg/l)	2950.0	2850.0	2900.0	2850.0	2700.0	2425.0	2700.0	2650.0	2650.0	2800.0	2900.0	3120.0	3250.0
M g (mg/l)	2150.0	2250.0	2100.0	2200.0	1850.0	2025.0	1700.0	1650.0	100.0	1600.0	1700.0	1440.0	1550.0
K (mg/l)	156.9	161.8	143.0	131.4	0.0	140.6	148.6	136.0	32.4	28.0	26.9	48.8	51.1
N a (mg/l)	3428.6	3500.0	3133.3	2933.3	0.0	2440.5	1989.8	1983.7	884.0	830.9	842.5	1677.4	1792.0
Cl/35.45(em/l)	206.96	202.71	172.07	172.07		140.38	141.71	125.67	138.38	117.09	126.41	119.19	134.05
SO4/48.03(em/l)	75.45	69.39	58.13	63.19	82.05	55.61	54.82	55.03	52.49	50.55	56.19	41.62	46.74
Ca/50(em/l)	59.00	57.00	58.00	57.00	54.00	48.50	54.00	53.00	53.00	56.00	58.00	62.40	65.00
Mg/50(em/l)	43.00	45.00	42.00	44.00	37.00	40.50	34.00	33.00	2.00	32.00	34.00	28.80	31.00
Na+K(em/l)	153.08	156.31	139.89	130.90	0.00	109.70	90.31	89.73	39.26	36.84	37.32	74.18	79.22
Na/Cl	0.72	0.75	0.79	0.74		0.76	0.61	0.69	0.28	0.31	0.29	0.61	0.58
SO4/Cl	0.36	0.34	0.34	0.37		0.40	0.39	0.44	0.38	0.43	0.44	0.35	0.35
SAR	20.87	21.31	19.27	17.95	0.00	15.91	13.04	13.15	7.33	5.45	5.40	10.80	11.25

R-45 WATER CHEMICAL ANALYSIS DATA AT RAYYAN TEST WORKSITE (PRELIMINARY TEST)

DATE	8/5	8/10	8/21	8/25	9/2	9/8	9/15	9/22	9/29	10/6	10/13	10/20	10/30
P H	7.5	7.5	7.6	7.6	7.5	7.6	8.3	7.9	7.3	7.6	8.2	7.3	7.5
E C (ms/cm)	7590	7560	7370	7590	7380	7260	7150	7260	7690	6960	6770	6640	6730
C O D (mg/l)	2.2	2.2	2.9	3.5	2.3	3.9	3.2	4.6	4.7	5.3	5.1	2.6	2.5
C l (mg/l)	1783.9	1809.0	1625.0	2425.0	1792.2	1643.2	1643.2	1635.1	1650.9	1533.0	1556.6	1525.8	1608.9
S O4(mg/l)	2269.0	2027.0	2064.0	2055.0	2167.0	2064.0	2148.0	1999.0	1867.0	1961.0	1933.0	1775.0	1699.0
C a (mg/l)	1350.0	1375.0	1400.0	1350.0	1300.0	1300.0	1425.0	1300.0	1500.0	1300.0	1150.0	1240.0	1240.0
M g (mg/l)	650.0	800.0	800.0	825.0	675.0	725.0	625.0	750.0	500.0	700.0	1300.0	840.0	820.0
K (mg/l)	70.2	73.7	69.6	69.6	0.0	68.1	70.3	70.3	35.2	34.0	37.0	65.0	72.3
N a (mg/l)	316.3	996.7	946.7	946.7	0.0	964.3	908.2	880.4	448.9	420.4	436.2	911.3	865.8
Cl/35.45(em/l)	50.32	51.03	45.84	68.41	0.00	46.35	46.35	46.12	46.57	43.24	43.91	0.00	45.39
SO4/48.03(em/l)	47.24	42.20	42.97	42.79	45.12	42.97	44.72	41.62	38.87	40.83	40.25	36.96	35.37
Ca/50(em/l)	27.00	27.50	28.00	27.00	26.00	26.00	28.50	26.00	30.00	26.00	23.00	24.80	24.80
Mg/50(em/l)	13.00	16.00	16.00	16.50	13.50	14.50	12.50	15.00	10.00	14.00	26.00	16.80	16.40
Na+K(em/l)	15.55	45.22	42.94	42.94	0.00	43.67	41.28	40.08	20.42	19.15	19.91	41.28	39.49
Na/Cl	0.27	0.85	0.90	0.60		0.90	0.85	0.83	0.42	0.42	0.43	0.00	0.83
SO4/Cl	0.94	0.83	0.94	0.63		0.93	0.96	0.90	0.83	0.94	0.92	0.00	0.78
SAR	3.08	9.29	8.78	8.83	0.00	9.32	8.72	8.45	4.36	4.09	3.83	8.69	8.29

2) Quality of TB-21 (NW corner)

Initial and final EC values were 9,400 micro mhos/cm, slightly lower than the average value of 9,700 micro mhos/cm. COD values ranged between 11.7 to 6.0 mg/l. Initial and final values for Cl, SO_4 and Ca showed very slight change.

3) Quality of TB-25 (NE corner)

Initial and final EC values were 18,960 and 19,440 micro mhos/cm. During the period from September 8th to October 13th values averaged 23,800 micro mhos/cm with a peak value of 24,840 micro mhos/cm on September 8th, which was the highest EC value recorded at Rayyan. COD values fluctuated between initial and final values of 6.4 and 14.7 mg/l respectively with a peak reading of 30 mg/l on October 13th. Initial and final values for Cl, SO_4, Ca, and Mg showed little differences.

4) Quality of TB-42 (SE corner)

The highest EC value of 21,340 micro mhos/cm was on August 8th which gradually fell to its lowest value of 13,120 micro mhos/cm on October 20th. COD values fluctuated between 5.0 to 13.8 mg/l. Cl value averaged 7,000 mg/l during the month of August, and 4,600 mg/l during September and October with little variations.

5) Quality of TB-45 (SW corner)

EC values did not vary much ranging from 7,690 to 6,640 micro mhos/cm. Initial and final values of COD were 2.2 and 2.5 mg/l respectively, with a peak of 5.3 mg/l on October 6th. Final values of Cl, SO_4 and Ca showed small decrease from those measured at the start of the pumping test.

4.3.3 Water Quality Assessment

After the start of the continuous pumping up of groundwater from the Trench, the EC of Trench water and those of observation wells TB-21 and TB-45 seemed stable in comparison to those for observation wells TB-25 and TB-42, both of which are situated east of the Trench. Fig. 4.3.1 shows the electric conductivity of Trench and observation holes at the initial and final stages of the pumping test.

In the case of Rayyan, the values for Ca and SO_4 seemed more stable than the values for Na-Cl, maybe by the reason of higher solubility of Na-Cl or lower solubility (and saturation) of Ca-SO_4. The water quality of wells in the east side of the Trench seemed to be showing tendency of almost always higher salinity with EC than those on the western or west-south side of the Trench.

In comparison to the Test Work Result of Wadi Musherib, the water quality fluctuation of each item in the test period seemed wider and more frequent, in Rayyan. At Wadi Musherib there seemed to be little mixing between water of the surrounding observation wells and that of the Trench, probably because of lower permeability of shallow geological formation (perphaps strongly weathered zone).

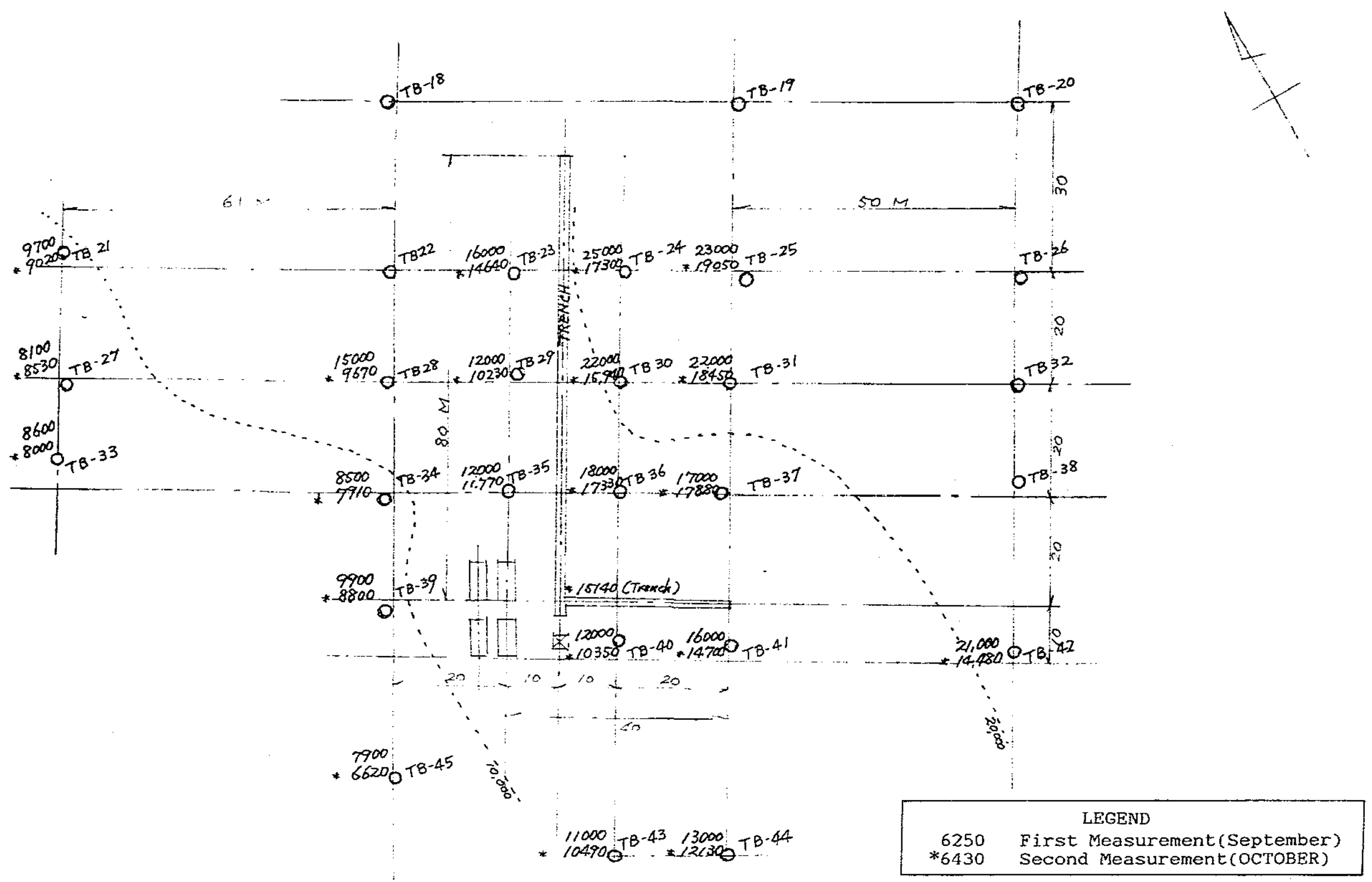


Fig. 4.3.1 Electric Conductivity Distribution Map at Rayyan

On the contrary, at Rayyan, the water quality of Trench seemed almost the average of the four observation wells as shown in Table 4.3.3. Figures in the table are the averages of 23 samples tested during August 5th to October 27th.

Table 4.3.3 Water Quality from Test Trench and Four Observation Wells on Rayyan Test Work Site

Analytical Items	Test Trench	Average values of four obs. wells
EC (micro mhos/cm)	13,985	13,657
Cl (mg/l)	4,261	4,802
SO_4 "	2,659	2,621
Ca "	2,382	2,477
Mg "	1,517	1,486
K "	98	91
Na "	1,762	1,582
COD "	7.8	7.8

This fact suggests that permeability of the underground conditions is nearly homogenous thus facilitating the mixing to shallow surrounding groundwater in various directions.

5. Additional Studies

5.1 Aggregate Test

In order to establish the influence of saline groundwater on gravel a test was conducted during the Test Work at the Wadi Musherib and Old Rayyan sites. Gravel was hung in a net sack below water level and was so exposed to the groundwater flow in the test trench. The variation in mass was checked at the end of pumping test.

Details of the Test

Materials	:	Grade-2 crushed aggregate; size 20 mm (Poor quality aggregate was chosen for apparent results)
Sample	:	2 samples for each site Weight of each = 3.0 - 3.5 kg
Test Period	:	3 months: July 1st, 1986 - November 2nd, 1986
Method of Weighing	:	Submerged weight determined by digital balance (0.1 g accuracy) at the Material Testing Laboratory, Ministry of Public Works

Table 5.1.1 Results of the Aggregate Test

Sample \ Date	July 1st, 1986	November 2nd, 1986
Wadi Musherib		
No. 1	3,348.8 g	3,349.0 g
No. 2	3,049.3 g	3,050.2 g
Old Rayyan		
No. 1	3,490.0 g	3,490.3 g
No. 2	3,090.8 g	3,090.1 g

5.2 Survey of Ground Levels before and after Pumping Test

To know the effect of groundwater abstraction by pumping test, levels of top of open holes were surveyed before commencement and after completion of pumping test, i.e. May 1986 and December 1986 at Wadi Musherib and Old Rayyan test sites and results are as follows.

Table 5.2.1 Measurement of Elevation at Wadi Musherib

Hole No.		Top of Pipe (m in QND) May	December '86
TB-1		5.83	5.831
TB-2		5.86	5.865
TB-3		5.97	5.970
TB-4		5.77	5.773
TB-5		5.97	5.971
TB-6	.... damaged	5.88	5.893
TB-7	.... damaged	5.94	5.953
TB-8		5.72	5.722
TB-9		6.09	6.091
TB-10		6.06	6.067
TB-11	.... damaged	5.92	5.977
TB-12		5.71	5.712
TB-13		5.95	5.950
TB-14		6.20	6.203
TB-15		5.91	5.914
TB-16		5.99	5.990
TB-17		5.92	5.920

Table 5.2.2 Measurement of Elevation at Rayyan

Hole No.		Top of Pipe (m in QND) May	December '86
TB-18		6.15	6.160
TB-19		6.43	6.435
TB-20		6.29	6.290
TB-21		6.45	6.452
TB-22		6.67	6.661
TB-23		6.30	6.294
TB-24	.... damaged	6.48	6.393
TB-25		6.23	6.232
TB-26		6.51	6.506
TB-27		6.20	6.188
TB-28		6.27	6.266
TB-29		6.24	6.236
TB-30		6.44	6.439
TB-31		6.39	6.390
TB-32		6.35	6.348
TB-33	.... damaged	6.40	6.404
TB-34		6.37	6.361
TB-35		6.47	6.463
TB-36		6.37	6.364
TB-37		6.53	6.528
TB-38		6.38	6.238
TB-39	.... broken	6.46	-
TB-40		6.32	6.315
TB-41		6.36	6.359
TB-42		6.21	6.209
TB-43	.... damaged	6.71	6.621
TB-44		6.26	6.256
TB-45		6.54	6.535

PART : F

Wadi Musherib Urgent Drainage Improvement Plan

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F. DRAINAGE PLAN AT WADI MUSHERIB

1. Basic Conditions for Drainage Plan

(1) Project Area for Drainage Schemes

Wadi Musherib which is located almost center of Doha city, has a wadi formation (as named) descending from west to east, with lengths of approximately 4.0 km in the east-west direction and 1.5 km in the north-south direction.

The Project area the drainage schemes at Wadi Musherib, as described in Chapter 6, is the area where the groundwater level is less than 1.5 m below ground surface.

Specifically the project area runs through Wadi Musherib, west along Sadd Road, towards Cable and Wireless Roundabout in the east. It encompasses a strip of width varying 400 to 500 m, length 3,500 m with an area of approximately 150 ha. Ground elevation varies from QND + 4.4 m at Cable & Wireless Roundabout to +7.4 m at Sadd Road with an average gradient of approximately 1/1000.

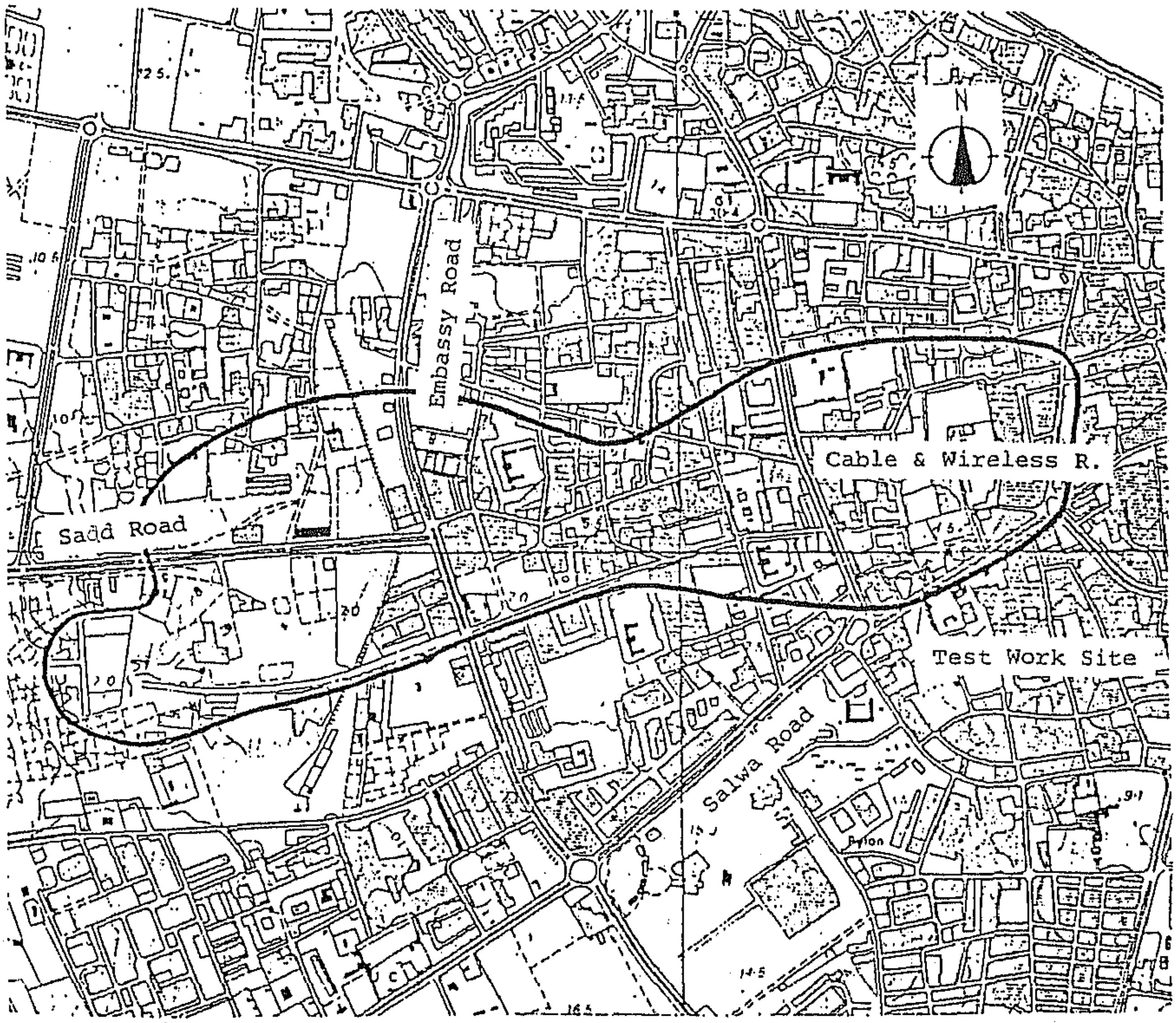


Fig. 1.1.1 Project Area for Drainage Schemes at Wadi Musherib

(2) Proposed Groundwater Level

Groundwater level for all the project area is to be kept below 1.5 m from ground.

(3) Discharge Amount

With the provision of lateral drainage network within the project area and maintaining groundwater level at 5.0 m below ground level at the lateral drains, amount of groundwater to be discharged is 1,500,000 m^3/year in accordance with the groundwater analysis presented in Chapter 6.

(4) Location of the facility

Public road area were basically used for this project.

(5) Water Quality

Estimates of water quality for the groundwater to be discharged by this drainage plan are as follows;

EC value	5,000 micro mhos/cm
COD value	Max. 5 mg/l
pH	8.0

(6) Staged Construction

When the first phase construction is completed hydrogeological analysis shall be checked by the actual figures of discharge amount and drawdown effect including local characteristics so that the first and/or second phase schemes can be modified accordingly.

2. Alternatives of Drainage Systems

Drainage systems are divided into three subsystems by their functions, i.e. collection, transfer and disposal or re-use and there are alternatives considered for respective subsystems as summarized in Table 7.2.1 below.

Table 2.1.1 Alternatives of Drainage System at Wadi Musherib

Collection	Transfer	Disposal
Lateral Drainage-1 (Perimeter arrangement)	Pumping-up	Stormwater drainage trunk line
Lateral Drainage-2 (Comb arrangement)	Discharge by gravity	Sewerage line
		Re-use

2.1 Collection System

For collection system in this project area two methods were considered suitable as described in Chapter 6, i.e. lateral drains and shallow wells. However, quantity of water abstracted from shallow wells for reuse may decrease should its quality be unsuitable, therefore as a collection system, shallow wells are unreliable. Consequently as a major drainage system large lateral drains were eventually considered.

2.1.1 Lateral Drainage-1
(Perimeter arrangement)
(Refer Fig. 2.1.1 & 2.1.3)

The outer lateral drains forming the perimeter of the project area will be laid where the groundwater level is at a depth of 1.5 m from the ground level or slightly deeper. Groundwater contour map will be used to identify these locations. In such a way groundwater which would otherwise flow into the project area will be collected by the perimeter lateral drains. In addition to this, lateral drains within the project area will drain the enclosed groundwater, therefore an effective drainage and lowering of level are expected.

Depth of the lateral drains is 4-6 m depending upon location. Such depths posed no problems during the construction of test work trench.

At the same time the stormwater trunk line which is planned in the center of the project area, is to be modified partially. The addition of groundwater drainage pipes are to be provided at the corner of the excavated trench for main stormwater pipes, giving this stormwater drainage an added function of groundwater drainage.

Outline of this scheme

Total length of lateral drains	:	12,900 m
Diameters of perforated pipe	:	350 mm, 450 mm
Manhole pitch	:	100 m
Depth of drains	:	4-6 m

2.1.2 Lateral drainage-2
(Comb arrangement)
(Refer Fig. 2.1.2 & 2.1.3)

Project area and method of water collection are the same as for Lateral drainage-1. However, arrangement and relation to the stormwater trunk line are different. In this arrangement the lateral drains cross the trunk line at right angles and connect to a transfer pipe running parallel to it.

This arrangement has an advantage of laying a larger number of lateral drains, because of the ease of connection, therefore achieving an effective lowering of groundwater levels, but has the disadvantage of making the trunk line complicated and less efficient in water collection due to parallel arrangement to the flow line. At the upstream part of the area, the groundwater transfer pipe is considerably lower than the trunk line.

Outline

Total length of lateral drains	:	13,000 m
Diameters of perforated pipe	:	300 mm, 450mm
Manhole pitch	:	100 m

2.1.3 Shallow well/small lateral drains

At areas where groundwater quality is found to be good enough for use in irrigation, it is possible to construct shallow wells and small lateral drains independently and transfer and disposal are not required for this system.

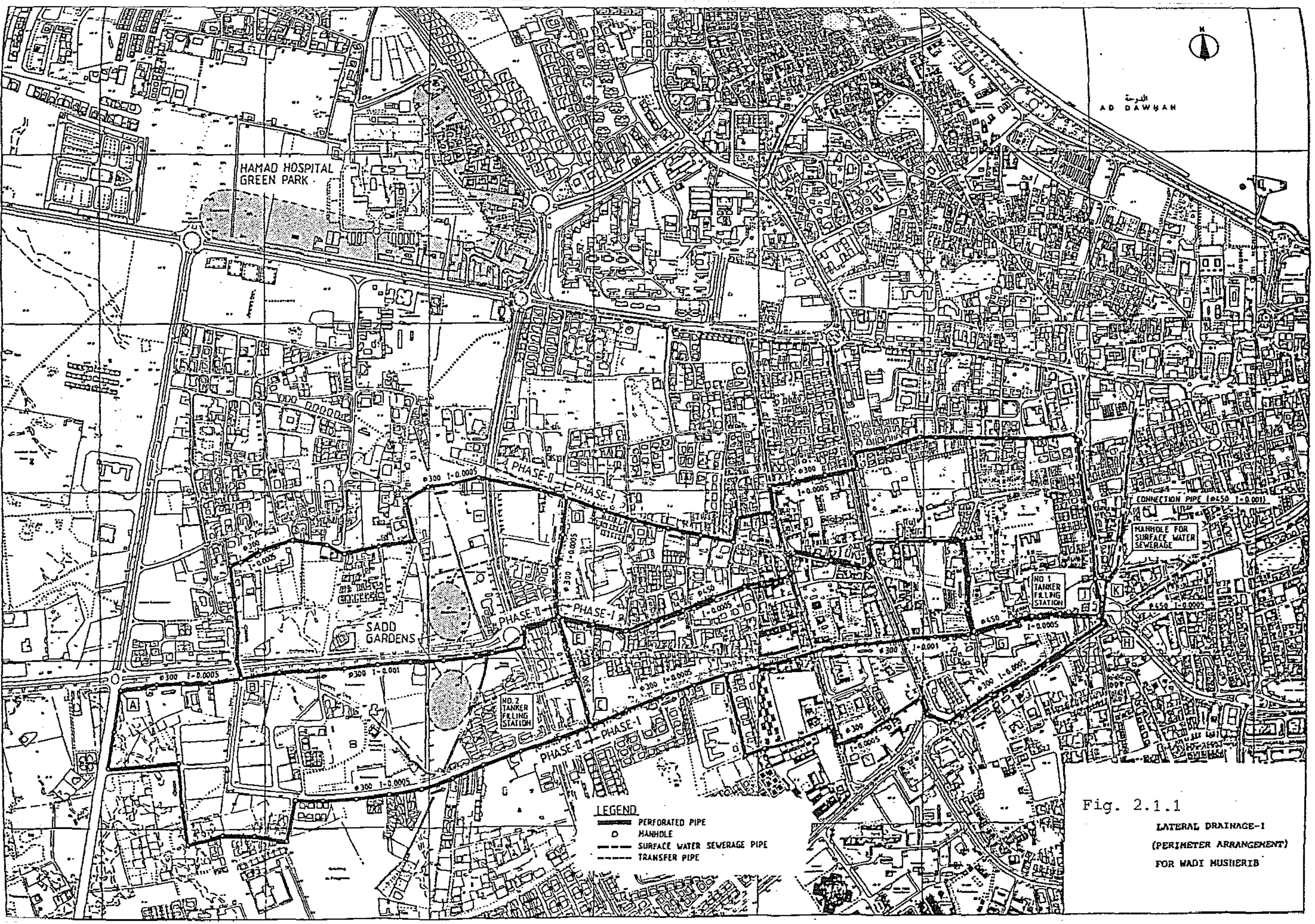


Fig. 2.1.1

LATERAL DRAINAGE-1

(PERIMETER ARRANGEMENT)

FOR WADI MUSHERIB

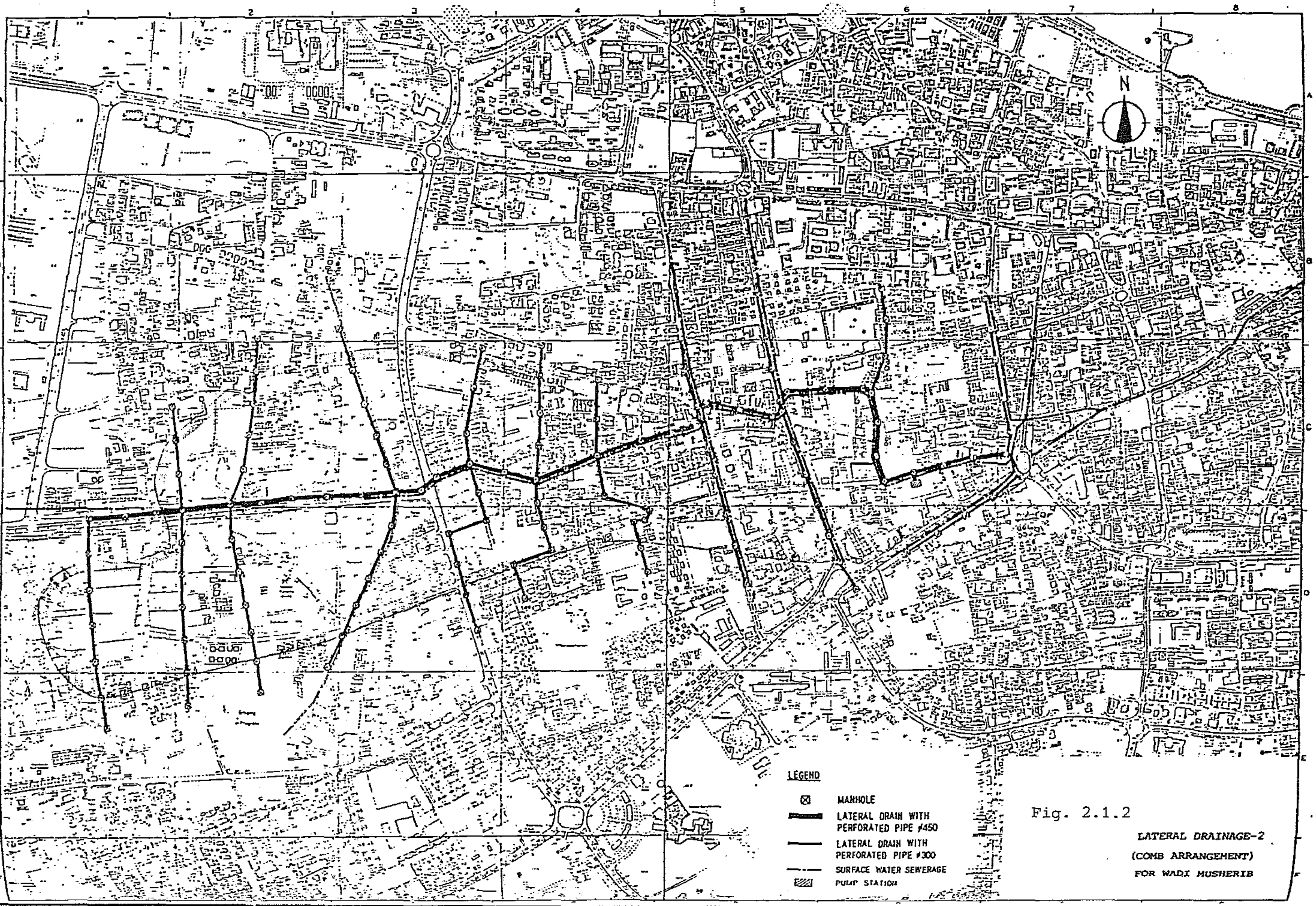
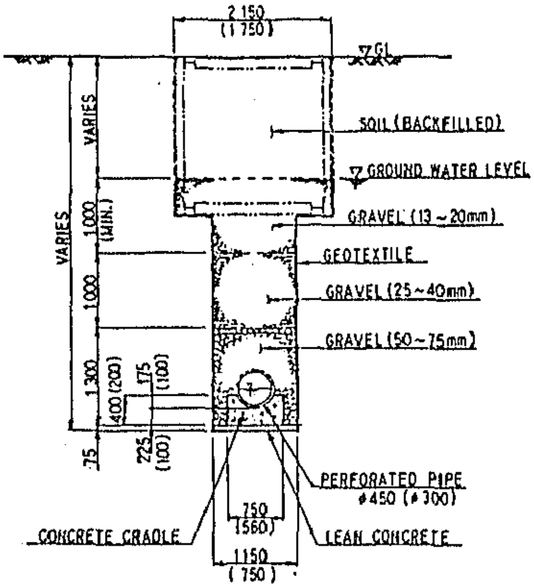


Fig. 2.1.2

LATERAL DRAINAGE-2
(COMB ARRANGEMENT)
FOR WADI MUSHERIB

Typical Section



Modification of Stormwater Trunk Line for Land Drainage

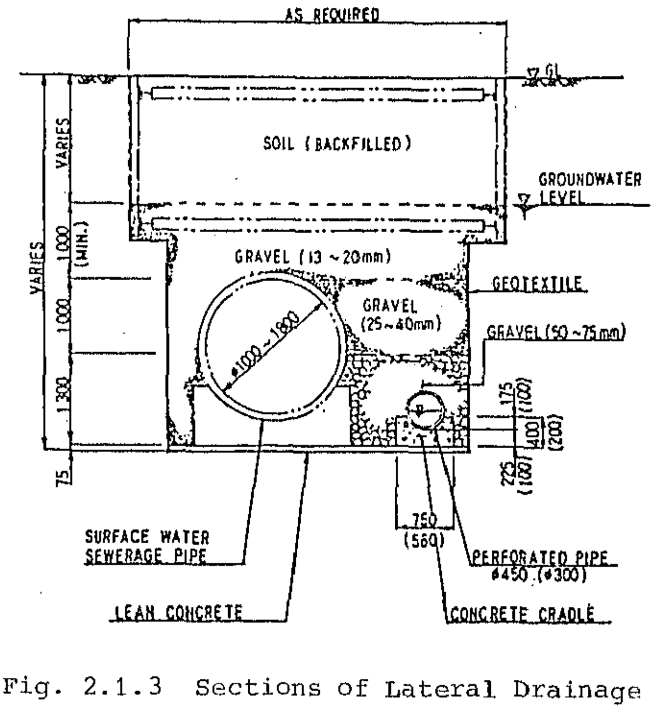


Fig. 2.1.3 Sections of Lateral Drainage

2.2 Transfer System

In this project area, for both alternatives water will be collected by lateral drains which will connect with the stormwater trunk line. The Wadi Musherib Stormwater Trunk Line may also be referred to as the surface water sewerage pipe line.

2.2.1 Transfer pipe line

Two methods are considered for the pipe line, one is main transfer pipe with lateral drains and the other is using lateral drain pipe as transfer. In case of this project area the latter is considerd more efficient because of network arrangement.

2.2.2 Connection to the stormwater trunk line

(1) Pumping up

The water abstracted will be pumped up to the stormwater trunk line.

(2) Gravity flow

Selecting suitable pipe diameter and gradient, it is possible to connect the groundwater piping to the stormwater trunk line at the same pipe invert level.

However in this case the possibility of reversal flow in the groundwater drain pipe is presumed when stormwater runs in the main pipe because of the difference in diameters. But it is anticipated that stormwater may happen only a few days per year and also considering the recovery of the groundwater level week long movement, this reversal flow can be allowed for groundwater drainage scheme.

2.3 Disposal Point

Since the water contamination is not serious at Wadi Musherib area as described before, there is a possible alternative to discharge abstracted groundwater into sewerage line however the capacity of the line and treatment works are limited. On the contrary in case of stormwater trunk line, the groundwater discharge amount can be accommodated. It is therefore considered that disposal to the Doha Bay through stormwater trunk line is the most rational solution.

2.4 Cost Estimation of the Alternatives

Regarding all the alternatives proposed in Section 2.2, rough cost estimation was made based upon the cost data obtained in Doha and information in Japan. Prior to cost estimation, quantities of the works for each alternative were also calculated.

2.4.1 Unit rates

Unit rates for the works were based upon the following;

a. Data by quantity surveyors in Doha

For general items in civil and building works, data obtained from Langdon & Every stationed in Doha were used.

b. Data by PENCOL

Cost of typical drainage work were obtained from PENCOL Consultants through the Civil Engineering Department, M.P.W.

c. Actual cost for Test Work

For reference purpose, contract rates paid to a contractor in Doha for the test trench construction were considered.

d. Statistical data published in Japan

For special items, such as water shut off sheet, PVC pipe, retailing prices in Japan were also considered.

The applied unit rates are listed in Table 2.4.1.

Table 2.4.1 Unit Rates for Cost Estimation

Item	Specification		Unit	Rate (QR)	Remarks
Excavation	Including dewatering and supporting structures		m^3	200	
Disposal of surplus soil			"	30	
Backfilling			"	30	
Gravel filling	Dia. 13-20, 25-40 and 50-75 mm		"	45	With compaction
Structural concrete	Sulphate resistant cement, GRADE 25		"	300	
Lean concrete	Sulphate resistant cement, GRADE 15		"	260	
Reinforcing bar			ton	3,000	
Shuttering			m^2	20	
Peforated pipe	ESVC pipe	ø300	m	150	
		ø450	"	200	Material and installation
Closed pipe	Concrete pipe	ø450	"	200	
Manhole	Precast concrete manhole, ø900 (inner diameter)	H=4-5 m	no.	6,000	
		5 -6 m	"	7,000	Material and installation
		> 6 m	"	8,500	
Reinstatement of road	Asphalt pavement		m^2	75	
Embankment			"	10	
Internal road	Asphalt pavement		"	75	
Fence			m	400	
Gate			no.	5,250	
Intake pipe	Concrete pipe	ø500	m	500	
Pump house			m^2	3,500	

2.4.2 Bill of Quantities

Quantities of the major works for both drainage systems are as follows;

Table 2.4.2 Bill of Quantities for Alternatives at Wadi Musherib

Item		Spec.	Unit	Perimeter arrangement	Comb arrangement
Pipe	ø450	ESVC perforated pipe	m	2,180	3,180
	ø300	"	m	10,695	9,460
Manhole			no.	142	131
Excavation			m^3	100,770	100,490
Gravel filling			"	38,820	39,250
Concrete work			"	2,820	2,550

2.4.3 Construction cost

From unit rates and quantities of the works construction cost for both alternatives were derived as follows;
(In these construction costs, land requisition cost and engineering fee are not included.)

Table 2.4.3 Construction Cost for Alternatives at Wadi Musherib

Unit: Qatar Riyal ($x10^3$)

Item \ Alternative		Perimeter Arrangement	Comb Arrangement	Remarks
Pipe laying	Earth work	22,210	22,480	Excavation, disposal of surplus soil, backfilling, supporting structures and dewatering
	Pipe Installation	4,700	4,910	Pipe material, concrete cradle, gravel and concrete bed
Manhole		2,020	1,870	Material, installation and earth work
Road reinstatement		1,820	2,150	
Pump station		0	1,000	Equipment, building and pump pit
Tanker filling station		1,050	1,050	
Total		31,800	33,460	

2.5 Comparison of Alternatives

In case of the two alternatives for drainage systems, comparative features for each are derived from the difference of lateral drains arrangement and are summarized as follows;

Table 2.5.1 Comparison Table for Alternatives at Wadi Musherib

Perimeter arrangement	Comb arrangement
Suitable shape to flow from both north and south groundwater mounds.	Drains from center of the project area.
Connection to the stormwater drainage is possible by gravity flow.	Pump up is required for the connection to the stormwater drainage.
	Electric power cost is necessary as running cost.
Interventions with stormwater drainage are few.	Interventions with stormwater drainage are frequent.
Total length of drains is relatively short. (12.9 km)	Total length of drains is relatively long. (13.0 km)
Construction cost is relatively a little lower.	Construction cost is a little higher.

Considering the above features, cost including running cost are almost the same, and natural shape for groundwater drainage that is to place drains parallel to groundwater contour lines is preferable, therefore perimeter arrangement is recommended.

3. Preliminary Design

According to the comparison of alternatives in 2.5, preliminary design for the perimeter arrangement alternative is performed hereinafter.

3.1 Lateral Drainage Facilities

3.1.1 Outline of Drainage Facilities

Quantities of the lateral drainage facilities are as follows;

- Perforated pipe	:	ø300 - 10,695 m
		ø450 - 2,180 m
		Total 12,875 m
- Connection pipe to stormwater trunk line	:	ø450 - 30 m
- Manhole	:	142 nos.
- Tanker filling station	:	2 nos.

General plan of the lateral drainage system is shown on DWG. No. DRP-2001 and detailed plans on DWG. Nos. DRP-2020 thru 2023. The transversal and longitudinal sections are on DWG. Nos. DRP-2002 thru 2008.

3.1.2 Outline of Drainage Plan

The Lateral drainage facilities are designed to be located to cover and surround the project area. At Cable & Wireless Roundabout, the end of the network, they shall be connected to the stormwater trunk line of which the construction is under way. The connection detail is shown in Fig. 3.1.1.

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 will collect less groundwater than the perimeter pipe once the groundwater is lowered, it shall be used for the purpose of transferring the abstracted water.

The construction of the lateral drainage network may be divided into two phases, Phase-I for the lower part of network and Phase-II for the upper part. This is because the construction of the central drainage pipe may proceed in parallel with that of the stormwater trunk line and thereby reduce the construction cost. For the order of construction, the drawing No. DRP-2001 shall be referred to.

The direction of flow is so determined that the collected groundwater can be obtained from the middle and end of the network in order to reuse the groundwater.

The network is also designed for the collected water to flow downstream.

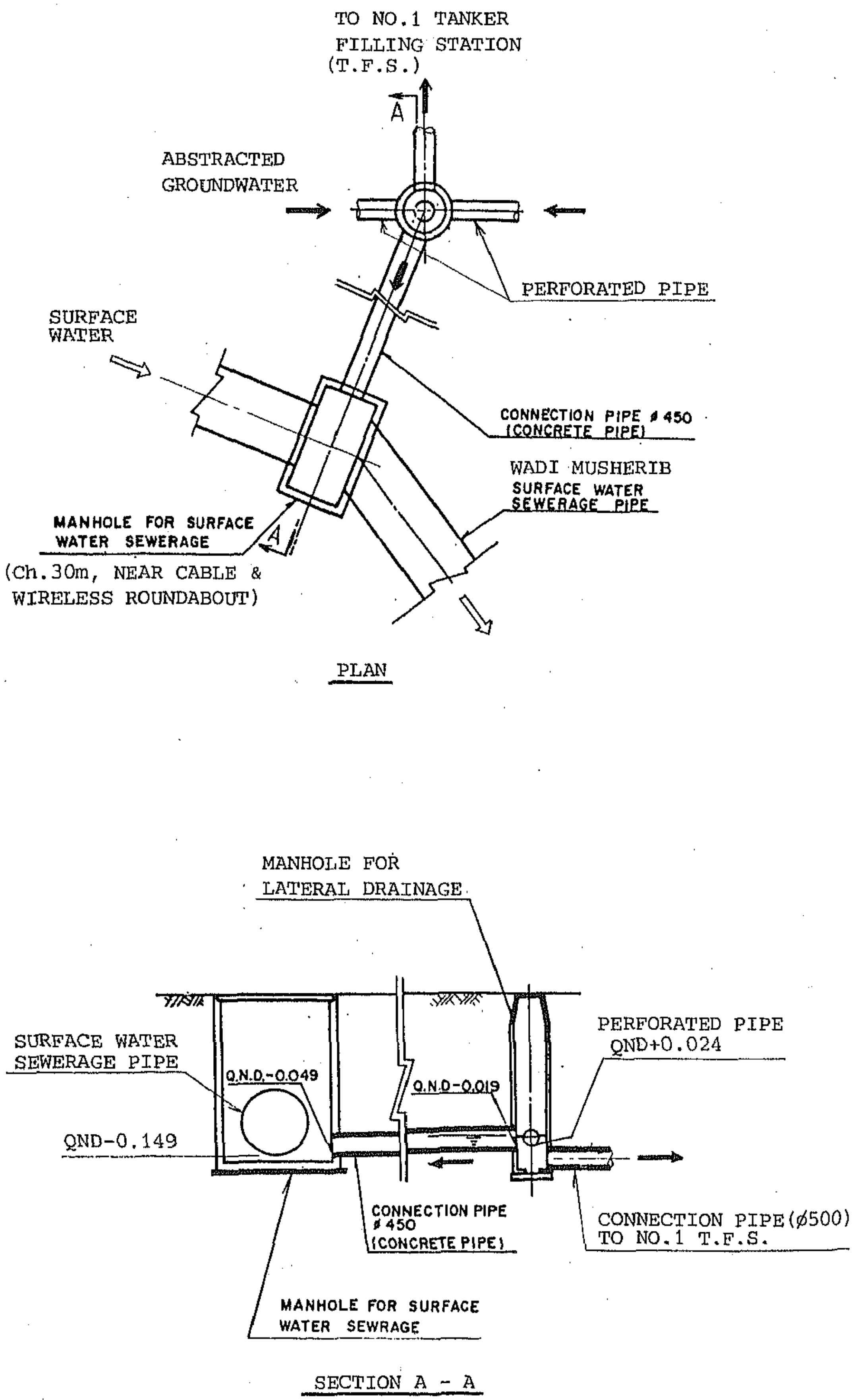


Fig. 3.1.1 Connection to Surface Water Sewerage

(1) Determination of Route

The lateral drainage pipe shall be placed

- to surround and cover the area where the groundwater level is 1.5 m below the ground level,
- in principle along the secondary roads so that the land acquisition may not be required and the hindrance to traffic by the construction can be minimized,
- where the stormwater trunk line exists, close to the line in consideration of the parallel construction,
- 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.

In general, road hierarchy drawings (DRP-2030 and 2031) shall be referred to for the route determination.

(2) Depth of Lateral Drainage Pipe

The groundwater level in the drainage area ranges from QND + 5.5 m (the upper reaches) to QND + 4.0 m (the lower reaches) with a gradient of about 1/2,000.

The invert level of the lateral drainage pipe at the end of the network is set above that of the pipe in the manhole for the stormwater trunk line and thereby the collected groundwater can be discharged into the trunk line.

Thus the invert level of the whole pipeline is set up so that the invert depth of pipe can be kept 4.0 m from the groundwater level with the constant gradient of 1/2000, the same gradient as that of the groundwater.

As a result, the invert level is set ranging from QND + 2.0 m to QND + 0.024 with an earth cover of 4 to 6 meters.

(3) Design of Pipe

Since most of the abstracted groundwater, discharge of which is taken as 1,500,000 m^3/year or 0.0476 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 amount and the discharge of groundwater in the pipe is calculated per linear meter.

The diameter of pipes is calculated for the discharge at the point concerned of the network. The discharge at each point is shown on Fig. 3.1.2.

For the calculation of the diameter, the following formula shall be applied, assuming for calculation purposes that the quality of groundwater is considered nearly the same as that of the water supply.

(Unit : m^3/sec)

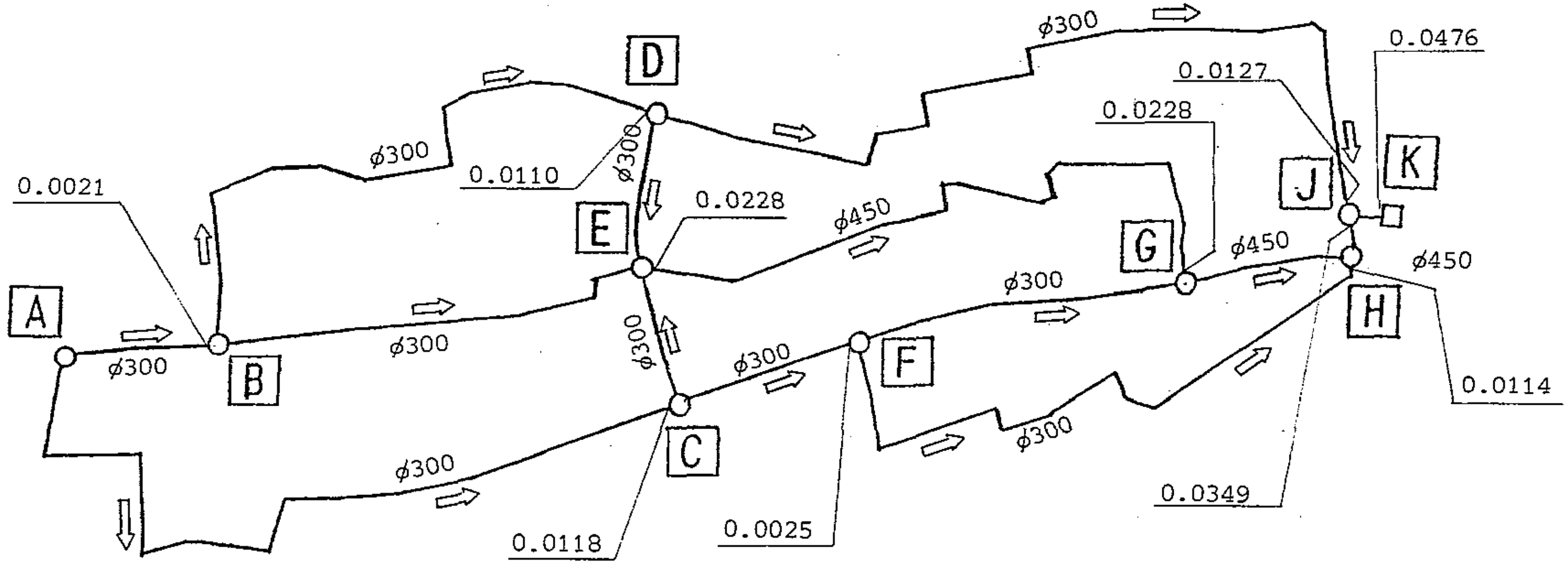


Fig. 3.1.2 Volume of Abstracted Groundwater at Each Point

$$Q = AV$$

$$V = \frac{23 + \frac{1}{n} + \frac{0.00155}{I}}{1 + (23 + \frac{0.00155}{I}) \cdot \frac{n}{\sqrt{R}}} \times \sqrt{RI}$$

where, Q = discharge (m^3/sec)
A = cross sectional area of flow (m^2)
I = hydraulic gradient
R = hydraulic mean depth (m)
n = roughness coefficient (0.013)

In this drainage system, perforated pipes shall be used as the lateral drainage pipe. They have two functions of collecting the groundwater and transferring it.

For that purpose, pipes with holes on the upper half shall be used and the cross sectional area of flow shall be taken as half depth of the pipe.

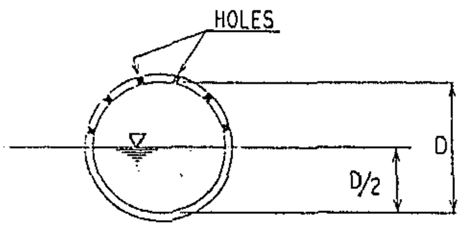


Fig. 3.1.3 Section of Perforated Pipe

Carrying capacities for different diameters of pipe are listed below;

Table 3.1.1 Carring Capacity of Pipe

Diameter (mm)	Hydraulic gradient	Velocity (m/sec)	Discharge (m^3/sec)
ø300	0.0005	0.490	0.0168
ø450	0.0005	0.637	0.0508

(4) Typical Section of Lateral Drainage

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

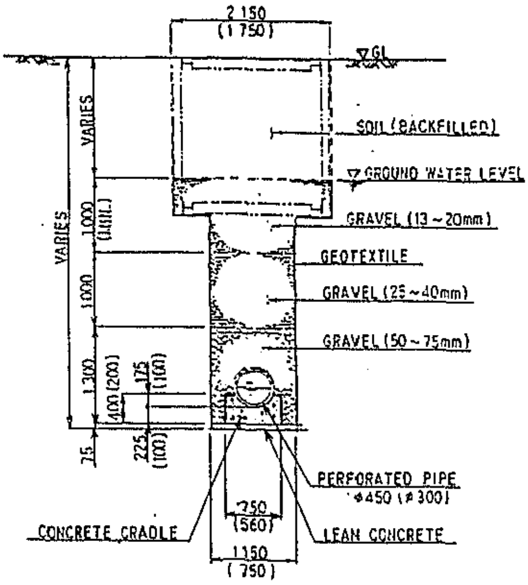


Fig. 3.1.4 Typical Section of Lateral Drainage

At depth of 1.5 to 2.0 meters below the ground, supporting structures shall be provided to prevent collapse of highly weathered soil layer.

At the greater depth, excavation can be done vertically because of the hard limestone layer where no collapse is considered is found there and thereby the earth pressure can be reduced.

After pipe laying and prior to backfilling, geotextile sheets shall be applied to the excavated surface above the groundwater level. The purposes of the geotextile are

- to prevent soil particles from coming into the lateral drain channel when the groundwater is abstracted from the surrounding soil and thereby protect the soil from the deformation such as settlement, and

- to prevent soil particles from coming into the lateral drain channel and thereby keep the holes of perforated pipe from clogging.

Around the perforated pipe, three kinds of gravel having different sizes of 50 to 75 mm, 25 to 40 mm and 13 to 20 mm respectively are filled upward in the order of the size. The third gravel layer (grain size of 13 to 20 mm) shall be at least 1.0 meter in thickness and shall be laid above the groundwater level. On top of the third gravel layer, ordinary (or excavated) soil shall be backfilled.

(5) Pipe Foundation for Piping

The buried pipes are subject to moments and shear forces created by the backfill material and/or surcharge load on the ground. When the bearing surface is unevenly finished in the construction, pipes may be damaged by these forces. Therefore to resist the external forces by the combination of pipe and foundation, the concrete foundation as attached below was considered.

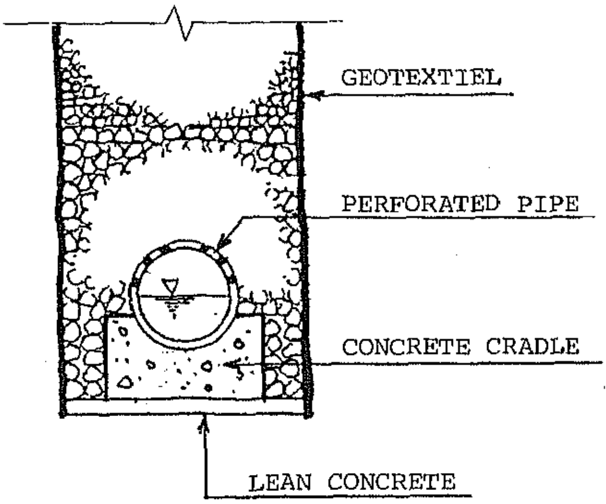


Fig. 3.1.5 Pipe Foundation

(6) Materials for Pipe

As materials for the pipe, vitrified clay and centrifugal reinforced concrete pipe are considered.

Taking into account the fact that the vitrified clay pipe is usually used in Qatar and is strong against salt attack, extra strength vitrified clay (ESVC) pipe shall be employed.

However, the concrete pipe, which has the advantage over the vitrified clay pipe in view of the availability should it be produced in Qatar in the future, can be considered for the material.

(7) Manhole
(Refer DRP-2009)

Manholes shall be provided where the piping direction is changed and several pipes meet and branch. In the straight line, they are located about 100 meter apart.

The distance between manholes is determined taking into account the following;

- The range possible to preform maintenance work of the lateral drain pipes will be 50 to 60 meters from the manhole.

- In case that countermeasures for the land drainage are needed locally (when it is needed to lower groundwater for special purposes or when it is required to be drained in construction sites), it is necessary that the distance has an allowance to facilitate the connection with the proposed network. A distance of around 100 meters is enough for this purpose.

3.2 Tanker Filling Station

3.2.1 Outline of the plan

It is expected that the water quality of groundwater from the proposed lateral drainage system at Wadi Musherib can be re-used for irrigation purpose. However for the actual re-use plan, it is necessary to obtain reliable figures of water quality and quantity based on long term observation during the drainage operation. Therefore step by step re-use is considered. For the first stage, total discharge to the stormwater drainage trunk line is considered and groundwater can be partially taken from the lateral drainage line and loaded to road tankers for re-use based on observation results. During this simple re-use system, possibility of total re-use can be studied where direct transfer system by pumps to the consuming places are considered.

Two tanker filling stations are considered, one each in the first and second phases of drainage construction, thereby making it possible to deal with the local water quality variation in the drainage network.

Green belts at center islands of major roads are considered among the suitable places where the abstracted groundwater can be utilized for irrigation. However at present irrigation system for these green belts consists of piping and sprinkler nozzle and thus discharge from road tankers may not be suitable. In conclusion transportation to Hamad General Hospital and Sadd garden, where large scale plantation projects are in progress, is considered.

Locations of tanker filling stations and outline of facilities are shown on the drawings DRP-2001, 2010 and 2011.

3.2.2 Conditions of facility plan

(1) Groundwater intake

Quantity of groundwater intake is 300 m^3/day per one station.

a. Total amount of discharge in Wadi Musherib lateral drainage network, 1,500,000 m^3/year is used for both tanker filling stations.

b. Seasonal variation can be considered to be 50%.

c. Timing of extraction is 6 hours from 6 am to 12 am and at other times water will be discharged downstream.

d. Amount to be used

$$\frac{1,500,000}{2} \times \frac{6}{365 \times 24} \times 0.5$$
$$= 300 \ m^3/day$$

(2) Road tankers

Road tankers to be used for transportation are 2,000 Imp. gallon tankers as standard vehicles, while in the design of movement plan within the station 3,000 Imp. gallon tankers are considered.

(3) Consuming place

Hamad General Hospital on the corner of 'C' Ring Road and Rayyan Road where the distance and returning time for transportation from the No. 1 tanker filling station are 3,000 m and 20 minutes respectively.

3.2.3 Outline of the facility

(1) Required land area

Area of 30 m x 30 m is necessary for one taker filling station and arrangement of facilities is shown on the Drawing DRP-2010.

(2) Loading system

Groundwater loading system from intake to outlet nozzles consists of the following;

- Intake and pump pit

  Intake pipe and pit are lower than the required level of the lateral drainage network so that the groundwater is taken when necessary and discharged downstream as usual when pumping is stopped.

- Submerged pump

  Pumps transferring groundwater from pit to the elevated tank have the characteristics below.

  Type : Submerged sewerage pump
  Total head: 20 m
  Capacity : 0.71 m^3/min.
  Motor : 7.5 KW

- Pump house

  For automatic operation without the need for full time operator. All the equipment are accommodated in a pump house having an area of 5 m x 6 m.

- Elevated tank

  An elevated tank, 20 m^3 is to be provided in order to buffer the irregular operation of the road tankers.

- Piping and valve

  From the elevated tank, piping with hand operated valve and nozzle discharge into the road tankers.

(3) Required road tankers

Five number, 2,000 Imp. gallon, (9 m^3) road tankers are required for 300 m^3/day transportation in working hours.

a. Loading time for one tanker
Flow rate at outlet, 0.9 m^3/min

$$t = \frac{9}{0.9} = 10 \text{ min}$$

b. Transportation

Distance between tanker filling station and Hamad General Hospital is 3,000 m and return trip is 20 min.

c. Unloading time
15 min

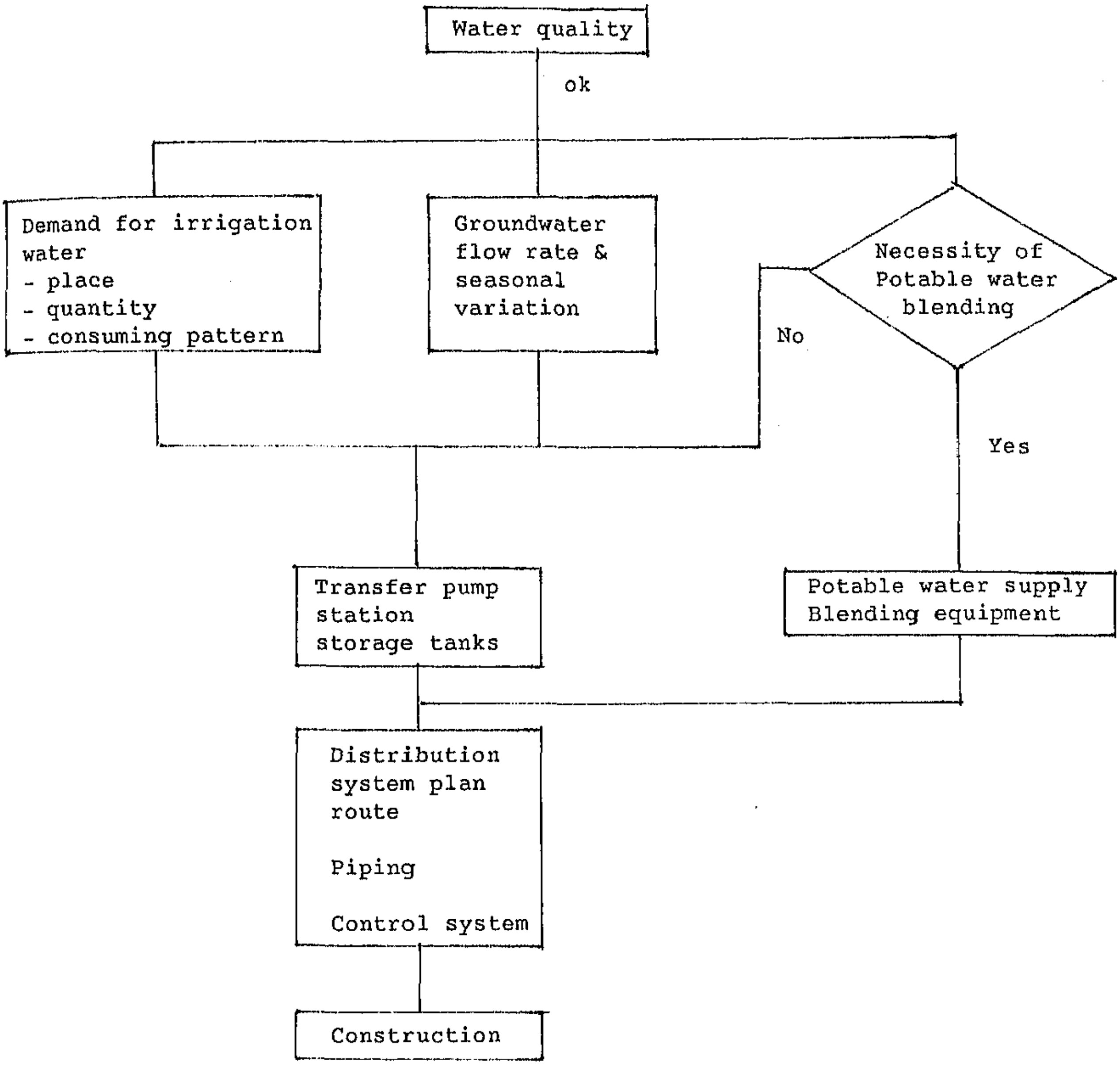
d. Total one cycle time including 5 min margin is 50 min.

e. Required number in 6 hours
One tanker can operate 7 cycles in 360 min and transport 63 m^3. For 300 m^3, 5 tankers are required.

3.3 Direct Transfer Line

Should groundwater intake at tanker filling station and road tanker transportation succeed, and water quality and quantity which shall be monitored for at least two years show good results, direct transfer line without road tankers may then be examined.

Procedures and items for planning are as the flow sheet shown herein below.



Meantime, as an example, routes from tanker filling stations to Hamad General Hospital and Sadd Gardens are shown on the Drawing DRP-2001.

Total length of pipe line	:	3,000 m from No. 1 station to Hamad General Hospital
		350 m from No. 2 station to Sadd Garden
Pipe diameter	:	150 mm
Demand at green park in Hamad General Hospital (estimated by Doha Municipality Planning Section 80 m^3/day)	:	35,000 Imp. gallon/day

3.4 Specifications of Construction Work and Material

The standard specifications for civil works, 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.

3.4.1 Investigation before excavation

Excavation in this project is deep and near to existing structures in the developed city area. Investigation before excavation is essential for the following items

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

3.4.2 Dewatering

All the excavation shall be executed in dry conditions with necessary dewatering. Throughout the 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 stormwater trunk line and sand settling basin shall be provided.

3.4.3 Monitoring points

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

3.4.4 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.

3.4.5 Horizontal boring

At crossing points with main road as shown on the drawings, pipes shall not be installed in open-cut excavation but horizontally bored from both sides of road. In these parts, steel pipes with internal coating shall be inserted with external grouting method.

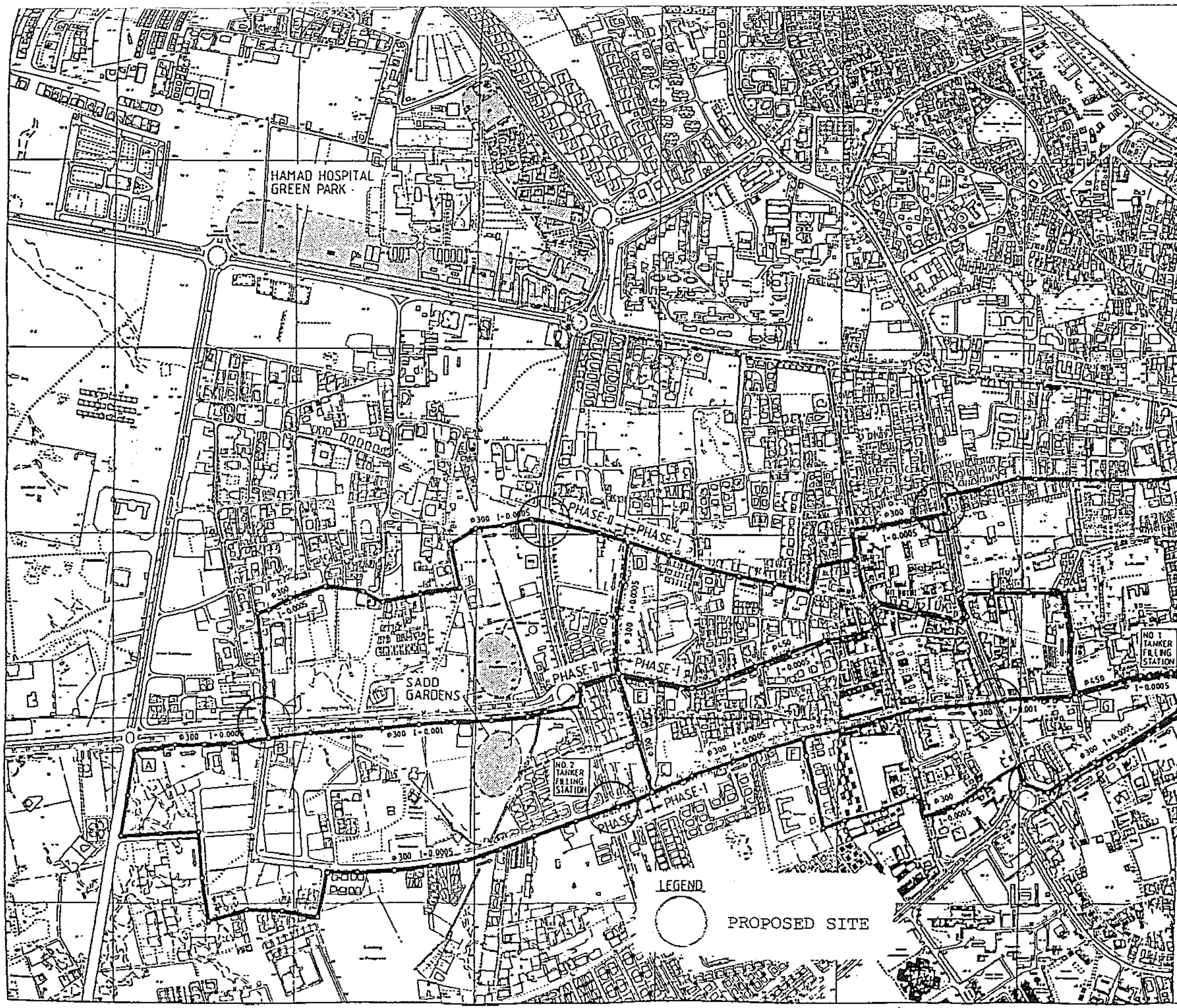


Fig 3.4.1

PROPOSED LOCATIONS OF
HORIZONTAL BORING

As shown on Fig. 3.4.1 (or DRP-2001), 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 shutting-off the traffic during the construction.

Application of the thrusting method has been limited so far 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.

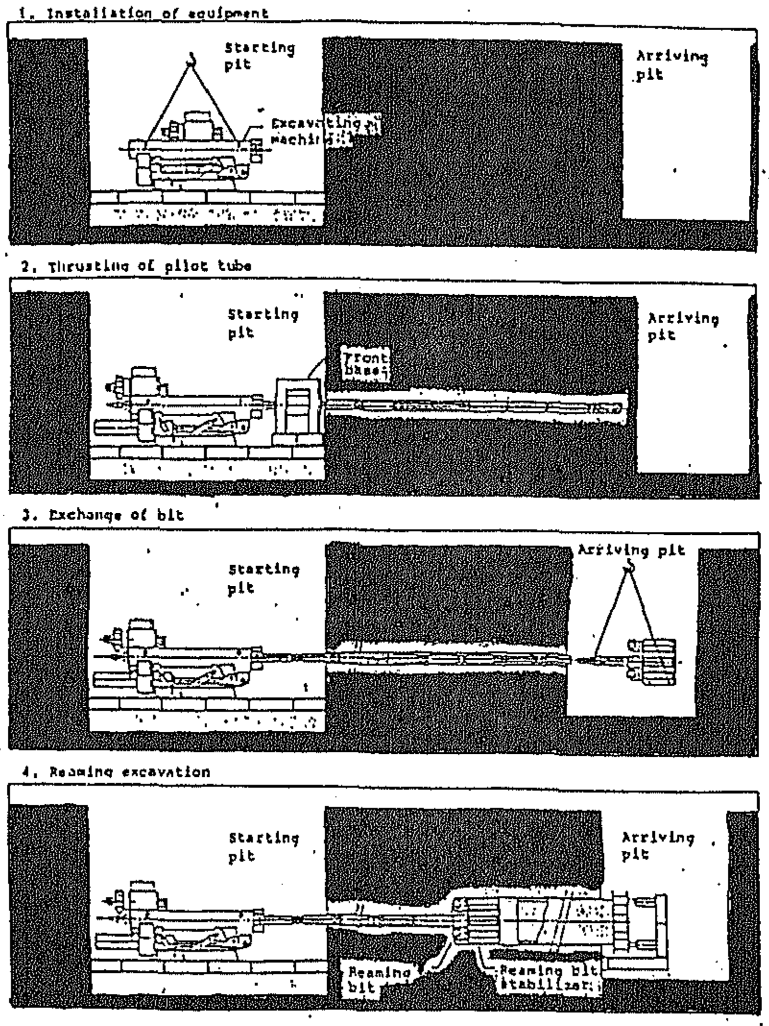


Fig. 3.4.2 Briefing of Procedure for Horizontal boring and Thrusting Method

3.4.6 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 used are;

300 mm
450 mm
600 mm

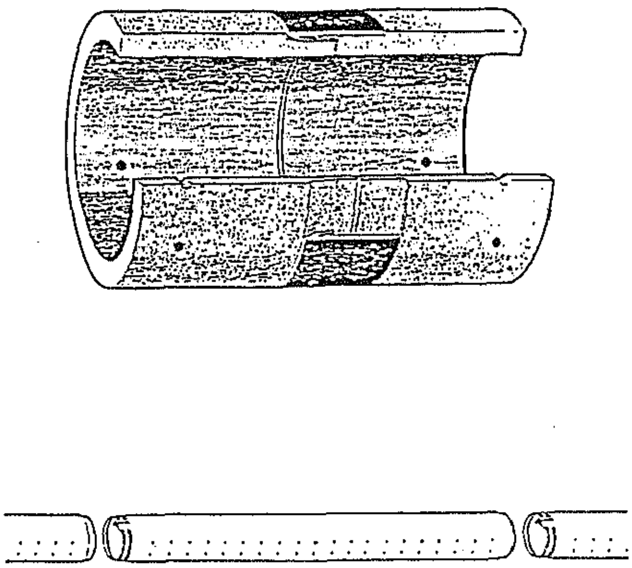


Fig. 3.4.3 Detail of Perforated Pipe

3.4.7 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

3.4.8 Geotextile

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

3.5 Cost Estimation

The drainage system for Wadi Musherib district is composed of the following;

a. Lateral drainage facilities
b. Tanker filling stations

3.5.1 Unit Rates

Sources of unit rates applied to the cost estimation are referred to in Article 2.4.1.

3.5.2 Bill of Quantities

(1) Lateral Drainage Facilities

Lateral drainage facilities are composed of ESVC perforated pipes (diameters 300 and 450 mm), a short length (30 m) of concrete closed pipe (diameter 450 mm and manholes (diameter 900 mm).

Bill of quantities for Lateral drainage facilities are shown in Table 3.5.1.

Table 3.5.1 Bill of Quantities for Lateral Drainage Facilities

Item		Unit	ø300		ø450		Subtotal	MANHOLE			Subtotal	Total
			3-5 m	5-7 m	3-5 m	5-7 m		4-5 m	5-6 m	> 6 m		
Excavation		m^3	8,830	67,372	8,994	11,410	96,561	525	1,867	1,814	4,206	100,767 m^3
Disposal of surplus soil		"	5,351	26,737	5,910	5,141	43,139	95	307	281	683	43,822 "
Backfilling		"	3,479	40,590	3,084	6,269	53,442	430	1,560	1,533	3,523	56,495 "
Gravel filling		"	4,874	24,354	5,116	4,450	38,794	5	13	10	28	38,822 "
Structural concrete		"	198	988	420	366	1,972	-	-	-	-	1,972 m^3
Lean concrete		"	99	494	118	103	814	5	13	10	28	842 "
Shuttering		m^2	707	3,530	934	813	5,984	-	-	-	-	5,984 m^2
Reinstatement of road		"	3,091	15,442	2,511	2,184	23,228	182	481	372	1,035	24,263 "
ESVC perforated pipe	ø300	m	1,766	8,824	-	-	10,590	-	-	-	-	10,590 m
"	ø450	"	-	-	1,138	1,016	2,154	-	-	-	-	2,154 "
Concrete pipe	ø450	"	-	-	30	-	30	-	-	-	-	30 "
Precast concrete manhole		no.	-	-	-	-	-	25	66	51	142	142 nos.

Note: Figures below pipe diameters and manholes indicate excavation depths

(2) Tanker Filling Stations

Tanker filling stations (No. 1 and No. 2) consist of the following;

1) Civil work

   a. Foundation
      - For elevated water tank
      - For pipe supports
   b. Pump pit
   c. Intake pipe
   d. Surrounding works
      - Embankment
      - Internal road
      - Fence & gate

2) Building work
   - Pump house (foundations, structure and building facilities)

3) Equipments

   a. Elevated pump
   b. Water pump
   c. Transfer pump
   d. Pipe support
   e. Instrumentation

Bill of quantities for Tanker Filling Stations are shown in Table 3.5.2.

Table 3.5.2 Bill of Quantities for Tanker Filling Station (2 nos.)

Item	Unit	Civil Work					Building Work	Equipments	Total
		Found for Elevated Water Tank	Found for Pipe Support	Pump pit	Intake Pipe	Surrounding Works			
Excavation	m^3	51.0	18.0	116.2	104.0				289 m^3
Disposal of surplus soil	"	22.4	3.2	35.0	2.6				63 "
Backfilling	"	28.6	14.8	81.2	101.4				226 "
Structural concrete	"	20.6	3.2	18.8					43 "
Reinforcing bar	ton	1.64	0.24	1.88					3.8 ton
Lean concrete	m^3	2.0	0.4	0.4					3 m^3
Shuttering	m^2	23.6	16.8	143.2					184 m^2
Concrete pipe ø500	m				10.0				10 m
Embankment	m^2					2,280			2,280 m^2
Internal road	m^2					648			648 m^2
Fence	m					164			164 m
Gate	no.					4			4 nos.
Pump house	m^2						24		24 m^2
Elevated water tank	no.							2	2 nos.
Water pump	no.							4	4 nos.
Transfer pipe	m							70	70 m
Pipe support	ton							2.0	2.0 ton
Instrument	set							2	2 set

3.5.3 Construction Cost

Construction cost of the drainage system for Wadi Musherib is obtained using the unit rates in Table 2.3.1 and bill of quantities in Table 3.5.1 and 3.5.2.

Summary of the construction costs is shown in Table 3.5.3.

Table 3.5.3 Construction Cost for Wadi Musherib

Item		Unit	Rate (QR)	Lateral Drainage Pipe		Tanker Filling Station	
				Quantity	Amount (x 10^3QR)	Quantity	Amount (x 10^3QR)
Excavation		m^3	200	100,767	20,153	289	58
Disposal of Surplus soil		"	30	43,822	1,315	63	2
Backfilling		"	30	56,945	1,708	226	7
Gravel Filling		"	45	38,822	1,747	-	-
Structural concrete		"	300	1,972	592	43	13
Lean concrete		"	260	842	219	3	1
Shuttering		m^2	20	5,984	120	184	4
ESVC perforated pipe	ø300	m	150	10,590	1,589	-	-
	ø450	"	200	2,154	431	-	-
Concrete pipe	ø450	"	200	30	6	-	-
	ø500	"	500	-	-	10	5
Manhole (precast concrete)	H= 4-5m	no.	6,000	25	150	-	-
	5-6 m	"	7,000	66	462	-	-
	>6 m	"	8,500	51	434	-	-
Reinforcing bar		ton	3,000	-	-	3.8	11
Road (reinstatement or construction)		m^2	75	24,263	1,820	648	49
Embankment		"	10	-	-	2,280	23
Fence		m	400	-	-	164	66
Gate		no.	5,250	-	-	4	21
Pump house		m^2	3,500	-	-	24	84
Elevated water tank		no.	122,000	-	-	2	244
Water pump		"	29,000	-	-	4	116
Transfer pipe		m	515	-	-	70	36
Pipe support		ton	12,000	-	-	2	24
Instrument		set	145,000	-	-	2	290
Subtotal					30,750		1,050
Total			31,800 (x10^3QR)				

4. Implementation Program

4.1 Implementation program

This project consists of the following two major facilities;

- Lateral drainage facility
- Tanker filling stations

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 as shown on Table 4.1.1.

The major points to be noted in this program are the following. This project is divided into two construction phases considering volume of the construction work and the relation with Wadi Musherib stormwater drainage trunk line project being executed by Ministry of Public Works. The downstream portion is implemented in the first phase to connect the discharge to the stormwater trunk line the upstream portion is the second phase.

It is essential that before the commencement of the first phase construction the part down from the connection point at Cable and Wireless Roundabout shall be completed including the pumping system. In both first and second phases, there are parts where lateral drainage pipe are laid along the stormwater trunk line and therefore these works shall be executed at the same time.

Tanker filling stations are located one each in the first and second phase areas. After their completion water quality will be monitored for one or two years and according to the result of monitoring, plan on transfer to direct distributing system without road tanker transportation shall be started in sequential program.

Table 4.1.1 IMPLEMENTATION PROGRAM FOR WADI MUSHERIB

No.	Description	1st year (1 – 6 – 12)	2nd year (1 – 6 – 12)	3rd year (1 – 6 – 12)	4th year (1 – 6 – 12)	5th year (1 – 6 – 12)
1.	Lateral Drainage					
	(1) Topographic Survey & Underground Facility Survey	Phase-1	Phase-2			
	(2) Detail Design & Tender Documents					
	(3) Tender		Contract	Contract		
	(4) Civil Works					
		Construction of Storm Water Drainage Downstream of Lateral Drainage System				
			Joint Work of Lateral Drainage and Storm Water Drainage	"		
2.	Tanker Filling Station					
	(1) Detail Design & Tender Documents	No.1	No.2			
	(2) Tender		Contract	Contract		
	(3) Land Acquisition					
	(4) Civil & Building Works					
	(5) Equipments					
	(6) Monitoring of Water Quality & Quantity					
						Planning of Direct Transfer System

4.2 Expenditure for Each Fiscal Year

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

Lateral drainage	33.8 MNQRS
Tanker filling station	3.5 MNQRS
Total	37.3 MNQRS

Above figures consist of;

- Topographic survey and investigation of underground facilities
- Detail design, Tender and Construction Management
- Land acquisition for tanker filling stations
- Equipment procurement and electrical and mechanical erection works

On the other hand following costs are not considered;

- Governmental administrative cost
- Compensation by residents (if any) for inconvenience during construction

Cost breakdown by each fiscal year are tabled in Table 4.2.1 below.

Table 4.2.1 Expenditure for Each Fiscal Year

(Unit: x10^3QR)

Item \ Year	1st	2nd	3rd	Total
1. Engineering Services	1,600	1,600	-	3,200
2. Land Acquisition	-	1,150	1,150	2,300
3. Civil & Building Works	-	15,550	15,550	31,100
4. Equipments	-	350	350	700
Total	1,600	18,650	17,050	37,300

Note:

1) Cost of engineering services were devived from 10 percent of construction cost (item 3 + item 4).

2) Land acquisition for tanker filling stations only was considered and unit rate per square meter is 1,000 QRS.

3) Breakdowns of each item in the table are shown on Table 4.2.2 and allocation to each year is shown on Table 4.2.3.

Table 4.2.2 Cost Breakdown

(Unit: x 10^3 QR)

Item	Construction Cost	Engineering Fee	Land Acquisition
1. Lateral Drainage		3,100	-
(1) Pipe Work	28,600		
(2) Manhole	2,100		
Sub Total	30,700	3,100	0
2. Tanker Filling Station		100	2,300
(1) Civil & Building	400		
(2) Equipments	700		
Sub Total	1,100	100	2,300
Total	31,800	3,200	2,300
Grand Total	37,300		

Table 4.2.3. COST ALLOCATION FOR WADI MUSHERIB

No.	Description	1st year	2nd year	3rd year	4th year	Total x 10^3 QRS
1.	Lateral Drainage					
	(1) Topographic Survey & Underground Facility Survey	Phase-1	Phase-2			
	(2) Detail Design & Tender Documents	1,550	1,550			3,100
	(3) Tender		Contract	Contract		
	(4) Civil Works		15,350	15,350		30,700
		Construction of Storm Water Drainage Downstream of Lateral Drainage System				
			Joint Work of Lateral Drainage and Storm Water Drainage	"		
2.	Tanker Filling Station					
	(1) Detail Design & Tender Documents	No.1	No.2			
	(2) Tender	50	50	Contract		100
	(3) Land Acquisition		1,150	1,150		2,300
	(4) Civil & Building Works		200	200		400
	(5) Equipments		350	350		700
	(6) Monitoring of Water Quality & Quantity					
						Planning of Direct Transfer System
	Total	1,600	18,650	17,050		37,300 10^3 QRS