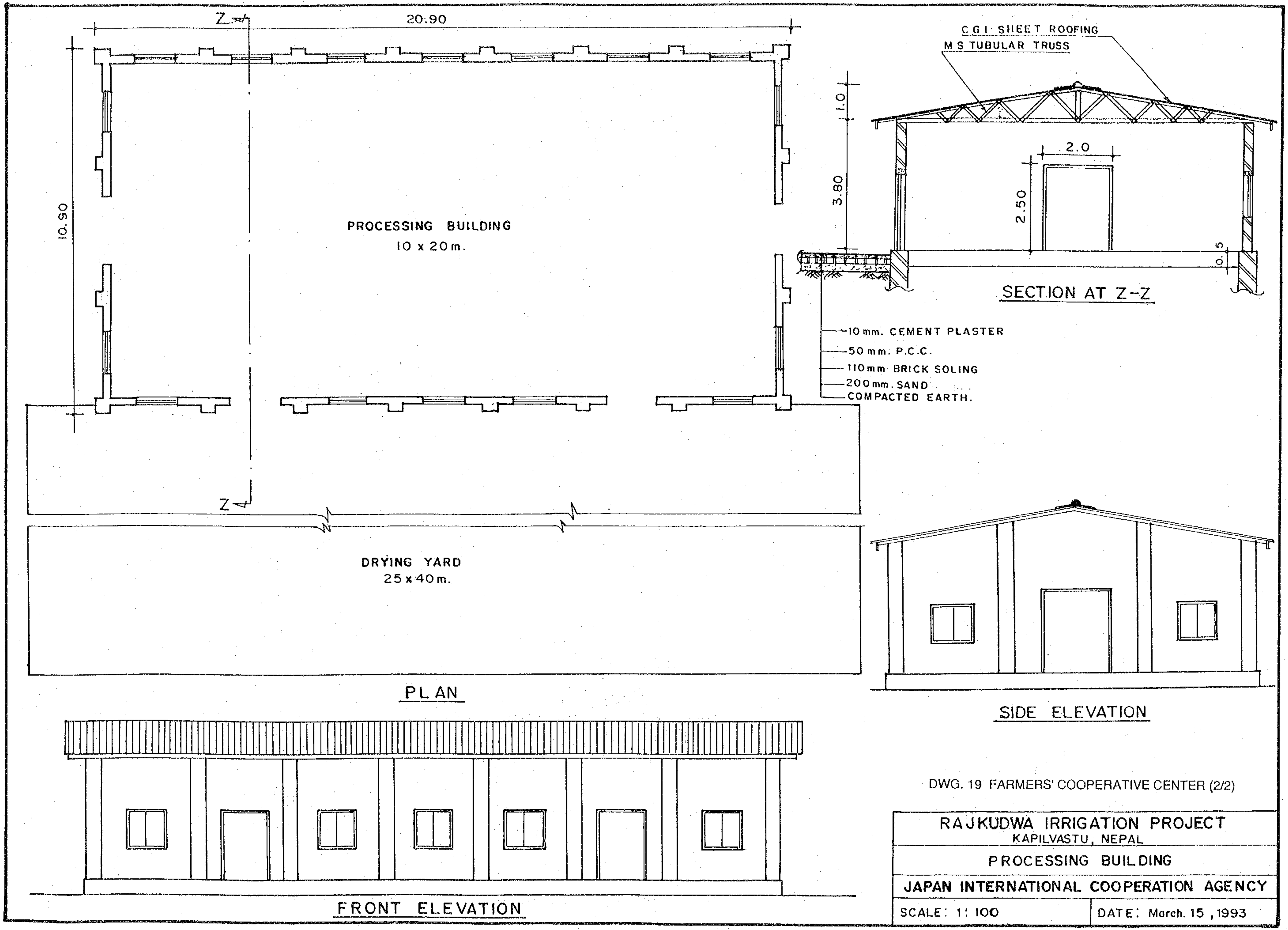
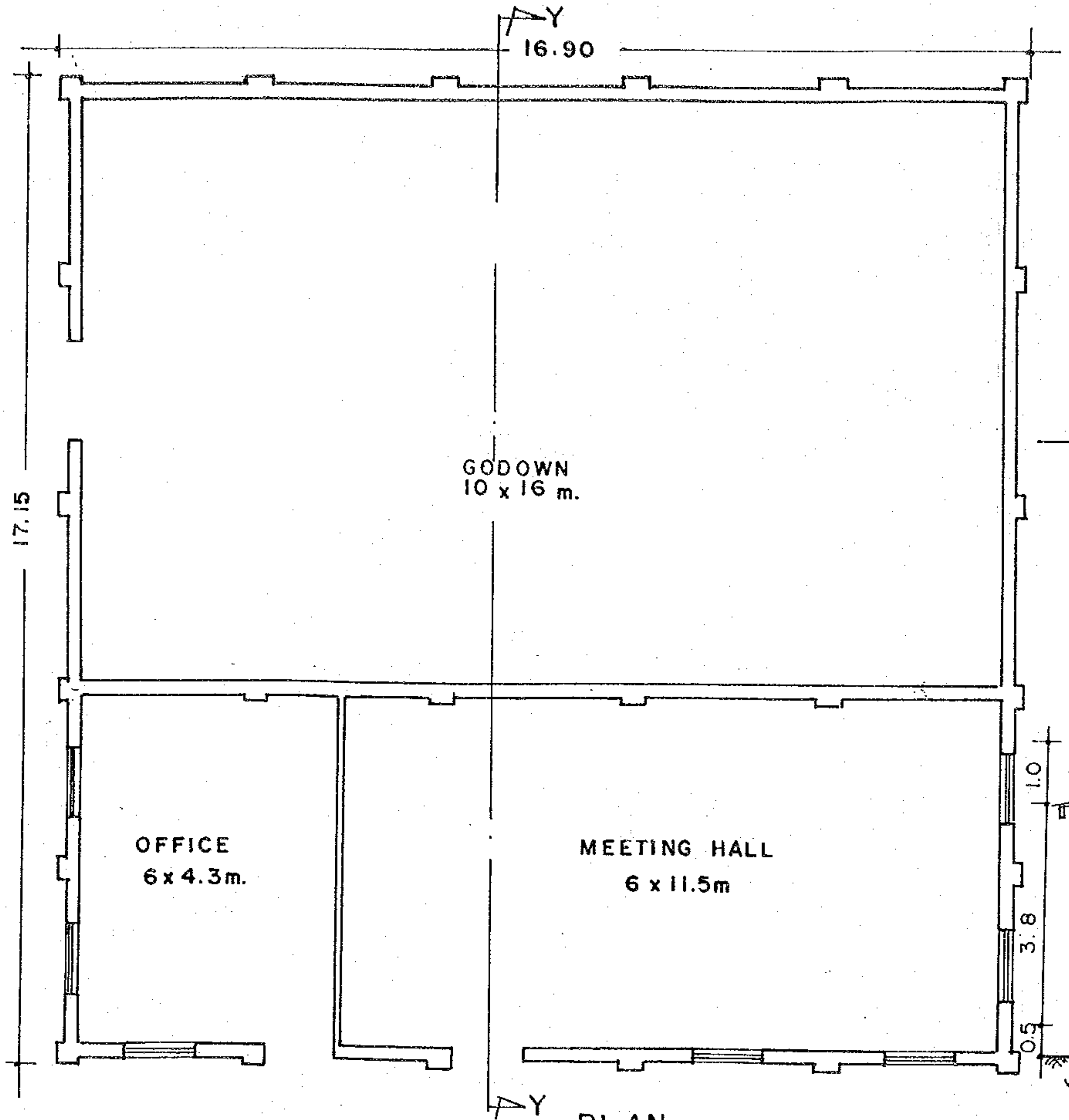
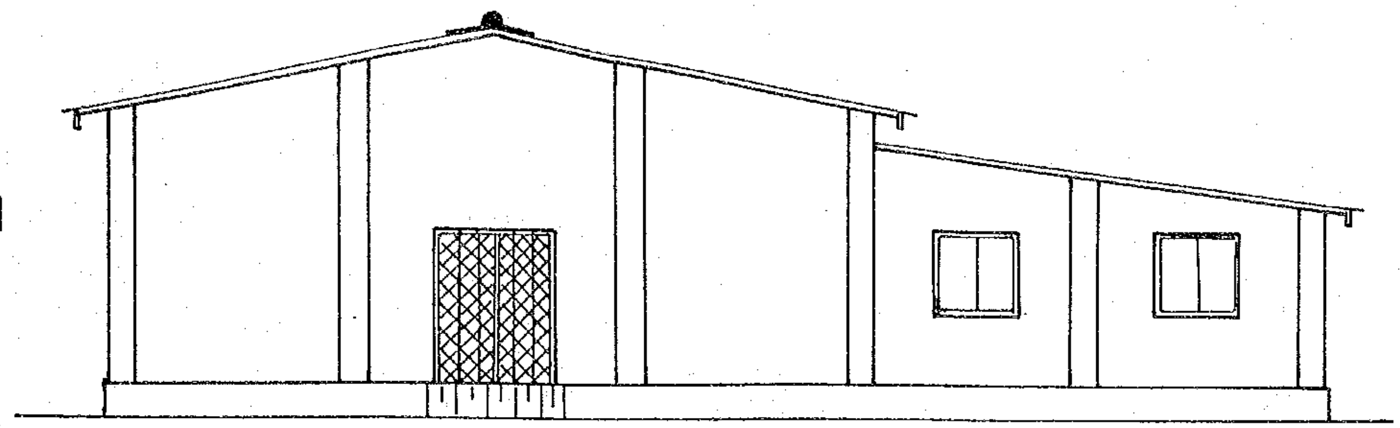


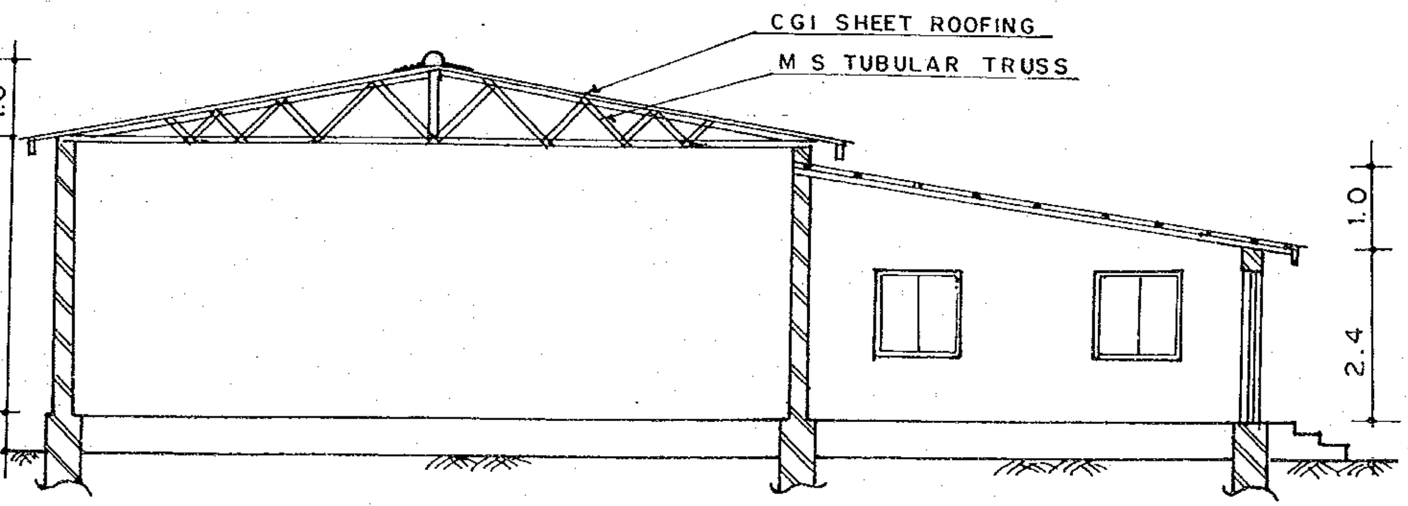
DWG. 19 FARMERS' COOPERATIVE CENTER (2/2)



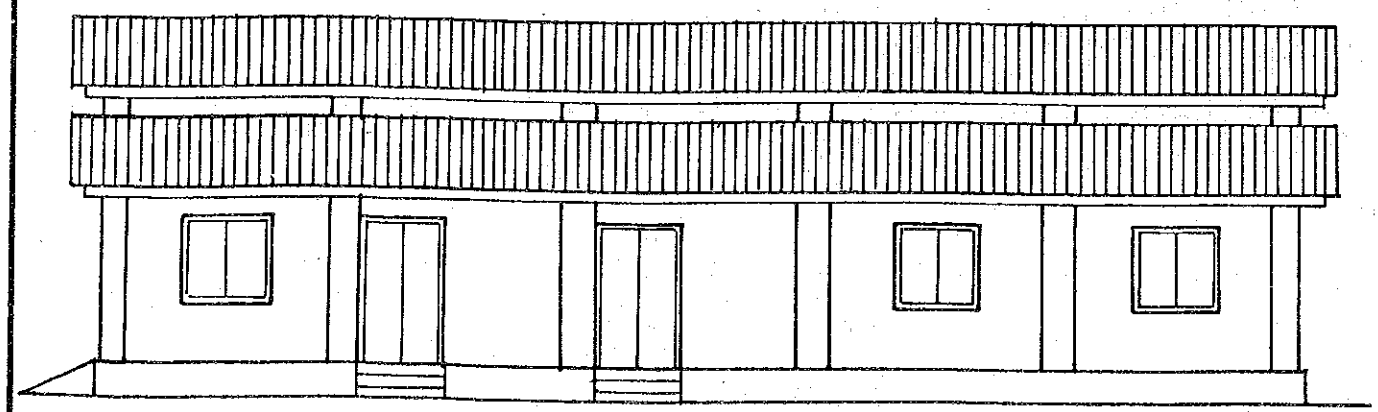
PLAN



SIDE ELEVATION



SECTION AT Y-Y



FRONT ELEVATION

DWG. 20 VDC FARMERS' COOPERATIVE OFFICE

RAJKUDWA IRRIGATION PROJECT KAPILVASTU, NEPAL	
COMMUNITY BUILDING	
JAPAN INTERNATIONAL COOPERATION AGENCY	
SCALE: 1: 100	DATE: March. 15, 1993

ATTACHMENTS

Summary of Farm Survey

1. Objectives of the Survey

The main objective of the farm survey was to assess the current socio-economic conditions of the rural people and their general attitude to the Rajkudwa Irrigation Project through the direct interview to the farmers in the study area. The survey also aimed at collecting and analysing the relevant data on general conditions of the study area.

2. Scope of the Survey Works

The JICA Study Team specified the scope of works and prepared the questionnaire for the farm survey. The questionnaire covers the following aspects :

- Household characteristics
- Land ownership
- Crop production and agricultural support services
- Animal husbandry, and
- General attitude

Initially, it was proposed by JICA Study Team that 100 farmers be selected as the samples for the direct interview and obtaining necessary information. Later it was suggested that ten (10) more farmers be interviewed in Patharkot and Birpur, as it was clarified that the headworks site of the project would be located at the Gudrung river lying north of the previously proposed headworks site at the Kondre river.

3. Methodology of the Study

The primary data were collected from 110 households by the local consultanting firm entrusted by the study team through the direct interview to the farmers, which was carried out in line with the questionnaire prepared by the study team. The following two-step random sampling method was employed to select the sample households for the interview:

- The survey area was firstly divided into three blocks: head, middle and tail. The area lying north of the East-West Highway (EWH) was defined as the head part, the area lying between EWH and the Gidahawa Village as the middle part and the area south of Gidahawa Village as the tail part of the study area.
- The following criteria were adopted for dividing the farmers into four different strata. Then, the numbers of sample farmer were proportional to the total numbers of farmer in each stratum, and selected randomly from each stratum to interview a total of 20 farmers at each site.

CRITERIA	LAND HOLDING
Landless	< 0.1 ha. (3 kattha)
Small Farmers	0.1 ha. to 2.37 ha. (3 kattha to 3.5 bigha)
Medium Farmers	2.37 ha. to 5.08 ha (3.5 bigha to 7.5 bigha)
Large Farmers	> 5.08 ha. (7.5 bigha)

- 100 farmers were selected as 40 farmers in the head block, 40 in the middle block and 20 in the tail block of the study area. These selected farmers were interviewed directly by the investigators and research officer of the local consulting firm visited to their houses or farms.

- Finally, 10 farmers were selected randomly from the Pattharkot and Birpur areas, and interviewed using the same method as mentioned above. Thus, the total number of the farmer's households interviewed was 110 as follows;

Farmer's Strata	No. of Sample FH
Small	67
Medium	33
Large	10
TOTAL	**110**

The data arrangement was carried out twice to check the quality of the collected data. The first arrengement was done by the research officer in the form of checking the questionnaires filled by investigators in the field every day. In the case of that there were inconsistency and/or error among the data, the investigator was requested to re-visit the farmers and correct the inconsistency or error. The second arrengement was made by an agro-economist of the local consultant before inputing the data into the computers to check the data.

The arrenged data were directly inputed into the IBM desk-top computers. The FOXBASE was used for inputing the data and also for further analysis. All the data inputed into the computers were printed and verified by the agro-economist, and the omissions and errors on outputs were corrected to re-input the correct ones into the computers. Then, the outputs were processed to the final forms for the report.

4. Implementation

The farm survey was carried out during the period of one month and a half. The finalization of the methodology and survey tools took about a week. The team of the professionals and investigators visited the field in the last week of July, 1992 and completed the field survey by the first week of August, 1992. The data analysis and report preparation were completed by the last week of August. The final report was prepared by the fourth week of September 1992.

5. Study on the Farm Survey

5.1 Household Characteristics

Of the total interviewee, 105 were male and the rest (five) female. More than 62 percent of them were aged between 21 to 45, about 31 percent more than 45 years and 6 percent between 16 to 20 years of age. The education level of the interviewee was not found very inspiring as about 32 percent of them were not educated at all. Some 16 percent of the interviewee were completed at least secondary level of education. Detaileds of interviewee is summalized as follows;

	FARM STRATA							
	SMALL		MEDIUM		LARGE		TOTAL	
	Male	Female	Male	Female	Male	Female	Male	Female
Age (Years)								
Less than 16	0	0	0	0	0	0	0	0
16 to 20	3	1	3	0	0	0	6	1
21 to 45	36	4	24	0	5	0	65	4
More than 45	23	0	6	0	5	0	34	0
Education Level								
None	18	2	13	0	2	0	33	2
Some Primary	19	2	8	0	2	0	29	2
Completed Primary	5	0	2	0	0	0	7	0
Some Secondary	14	0	4	0	1	0	19	0
Completed Secondary	1	0	5	0	2	0	8	0
College/University	2	0	0	0	2	0	4	0
Adult literacy class	3	1	11	0	1	0	5	1
TOTAL	65	5	33	0	10	0	105	5

There were 1,027 population in 110 sample households. The average family size was 9.34 which ranged from 8.03 among small farmers to 11.61 among medium farmers. The average family size among the large farmers was 10.60 persons. This figure is higher than the size of household reported by Central Bureau of Statistics (CBS) in its census survey result, 1991. The reason is that the local inhabitants (Terai people) have larger family size than those migrated from the hills.

Of the total population in sample households, about 41 percent were upto 15 years age, 9 percent were 16 to 20 years, 41 percent were 21 to 45 years and the rest (9 percent) more than 45 years of age. Female population out-numbered male population by 9 in total. Male : Female ration is estimated at 1 : 1.02. Details on population distribution by age, sex and farm strata are presented as below.

	FARM STRATA											
	SMALL			MEDIUM			LARGE			TOTAL		
	Male	Female	Both	Male	Female	Both	Male	Female	Both	Male	Female	Both
Less than 16 yrs.	116	107	223 (41)	79	81	160 (42)	21	14	35 (33)	216	202	418 (41)
16 to 20 years	32	19	51 (10)	20	8	28 (7)	9	6	15 (14)	61	33	94 (9)
21 to 45 years	103	114	217 (40)	72	90	162 (42)	19	23	42 (40)	194	227	421 (41)
More than 45 years	19	28	47 (9)	12	21	33 (9)	7	7	14 (13)	38	56	94 (9)
Total :	270	268	538 (100)	183	200	383 (100)	56	50	106 (100)	509	518	1027 (100)
Family Size :			8.03			11.61			10.6			9.34

One of the indicator of living standard is the percentage of total expenditure going for basic need commodities like food. The survey result shows that purchase of food items alone accounted for 32 percent in average. The other important item of expenses was social/religious ceremonies accounting for about 25 percent of total expenses. Cash expenditure in last one year is summarized as below.

	FARM STRATA							
	SMALL		MEDIUM		LARGE		ALL	
	Rs/HH	%	Rs/HH	%	Rs/HH	%	Rs/HH	%
Food Items	3,813	39	2,888	29	1,688	0	3,343	32
Hired Labour	489	5	776	8	4,900	28	976	9
Education	468	5	709	7	1,185	7	606	6
Fuel	378	4	492	5	628	4	35	4
Transport	914	9	608	6	900	5	821	8
Remittance	62	1	27	<1	62	<1	52	<1
Farm Input	575	6	1,031	10	852	5	736	7
Aid and Donation	83	1	53	<1	700	4	130	1
Ceremonies	2,172	22	2,811	28	4,790	28	2,601	25
Livestock Purchase	493	5	702	7	1,398	8	638	6
Others	250	3	0	0	250	1	175	2
TOTAL	9,697	100	10,097	100	17,353	100	10,513	100

Rice, wheat and maize are the staple food in the area, while the pulses are the next important crop. Households cultivate these crops for home consumption as well as for income generation through sales.

Use of major food grains in the household by the farm strate is summarized as below.

(kg/HH)

	FARM STRATA			
	SMALL	MEDIUM	LARGE	AVERAGE
Paddy				
(a) Production	2,600	6,627	14,057	4,851
(b) Purchase	29	0	0	18
(c) Sales	217	1,264	5,109	976
(d) Use in HH (a+b-c)	2,412	5,363	8,948	3,893
Rice				
(a) Purchase (Use in HH)	106	0	0	65
Maize				
(a) Production	33	29	28	32
(b) Purchase	17	3	0	11
(c) Sales	11	0	0	7
(d) Use in HH (a+b-c)	39	32	28	36
Wheat				
(a) Production	623	812	1,529	762
(b) Purchase	42	86	35	55
(c) Sales	4	44	260	39
(d) Use in HH (a+b-c)	661	854	1,304	778
Pulses				
(a) Production	176	390	590	277
(b) Purchase	8	7	8	7
(c) Sales	7	34	195	32
d) Use in HH (a+b-c)	177	363	403	252

Considering the average family size and food availability, about 423 kg food grains per capita, 570 kg food grain per capita and 1008 kg food grain per capita was available among the small medium and large farmers, respectively in gross form. These quatities are used for human consumption, livestock feed, hiring of labours and exchange of other commodities.

The study area as a whole is food sufficient and food grains, oil seeds, pulses and livestock products are sold out from the area forming a major source of income.

5.2 Land Ownership

The average size and composition of operated land by farm size and land type is presented as below. The average size of land holding among small, medium and large was 1.22, 3.34, and 7.16 ha, respectively. A greater proportion of the operated land in the area was found to be lowland (93.1 percent), of the total lowland area 62.1 percent was reported to be under rainfed condition and 31.0 percent under some form of irrigation. Proportion of irrigated land was found higher among larger households than smaller households. About 1.6 percent of the total operated land was upland (Pakho), 2.0 percent squatted land and another 3.3 percent was under homestead which included kitchen garden.

	FARM STRATA			
	SMALL	MEDIUM	LARGE	TOTAL
Total Operational Area (ha)	81.74	110.22	71.6	269.5
Percentage Operational Area				
Low Land	91.0	94.4	98.2	93.1
Irrigated	22.1	34.7	38.1	31.0
Rainfed	68.9	59.9	60.1	62.1
Upland	2.5	1.2	0.4	1.6
Homestead	4.9	3.3	1.4	3.3
Squatted	1.6	0.9	0.0	2.0
Average Size of Holding (ha)	1.22	3.34	7.16	2.45

A greater proportion of households in the area were found to be exclusive land owner (48.2 percent). Among exclusive land owners, 52.2 percent households were in the small farmer group, 36.4 percent medium farmer and 60 percent in the large farmer group. The average proportion of owner cum rented-in land was 35.5 percent, owner cum rented-out 2.7 percent and owner-cum- squatted 8.2 percent. The owner cum rented-in land was found highest in medium households (42.4 %) followed by large (40 %) and small (31.3 %). From the survey it is noticed that some of the larger farmers also rented-in some land. Land tenurial pattern of the households in the survey area is presented as below.

TENURIAL STATUS	FARM STRATA			
	SMALL	MEDIUM	LARGE	TOTAL
Tenurial Status (%)				
Exclusive Owner	52.2	36.4	60	48.2
Owner cum Rented-in	31.3	42.4	40	35.5
Owner cum Rented-out	3.0	3.0	0	2.7
Owner Squatted +Rented out	1.5	0	0	0.9
Owner + Rented + Squatted	1.5	12.1	0	4.5
Owner cum Squatted	10.5	6.1	0	8.2

5.3 Crop Production

Paddy was the main rainy season crop of the study area. Share of paddy area to total cropped area in small, medium and large farm household groups was 56.5, 69.0 and 74.7 percent, respectively and for the study area it was 65.9 percent. Wheat was the important crop in the winter season in the surveyed area. Wheat crop contributed 17.6 percent in small, 11.2 percent in medium, 9.2 percent in the large and 13 percent in average household. The pulses was the next principle winter crop of the area. Proportion of total cropped area under pulses in small, medium, large and average households was 10.4, 11.1, 8.9 and 10.3 percent, respectively. The average share of oil crops in total cropped area was 6.9 percent, while potato and other crops collectively shared 2.3 percent. The sample households cultivated a total of 248 ha and their total cropped area accounted for about 368 ha.

(ha)

CROPS	FARM STRATA							
	SMALL		MEDIUM		LARGE		TOTAL	
		%	AREA	%	AREAAREA	%	AREA	%
Summer Crops								
Paddy	75.0	56.5	101.1	69.0	66.3	74.7	242.3	65.9
Maize	1.4	1.1	0.5	0.4	0.3	0.3	2.2	0.6
Pulses	2.8	2.0	0.9	0.6	0.0	0.0	3.7	1.0
Total	79.2	59.6	102.5	70.0	66.5	75	248.2	67.5
Winter Crops								
Wheat	23.4	17.6	16.3	11.2	8.2	9.2	48.0	13
Oilcrops	12.6	9.5	8.1	5.6	4.5	5.1	25.2	6.9
Pulses	13.9	10.4	16.3	11.1	7.9	8.9	38.1	10.3
Potato	2.9	2.2	2.5	1.7	1.4	1.5	6.7	1.8
Others	0.8	0.6	0.7	0.5	0.2	0.3	1.7	0.5
Total	53.6	40.3	43.9	30.0	22.2	25.0	119.7	32.5
Total Cropped area	132.9	100	146.4	100	88.7	100	368.0	100

The ownership of farm equipments by farm size is summarized as below.

DESCRIPTIONS	FARM STRATA											
	SMALL			MEDIUM			LARGE			ALL		
	HH	%	Avg. No.	HH	%	Avg. No.	HH	%	Avg. No.	HH	%	Avg. No.
Tractor	0	0	0	0	0	0	0	0	0	0	0	0
Water pump	0	0	0	1	3	2	2	20	1	3	3	1
Local plough	64	96	1.8	33	100	2.7	10	100	3.4	107	97	2.2
Improved Plough	2	3	1	2	6	2	1	10	1	5	5	1.4
Hoe	0	0	0	1	3	2	0	0	0	1	1	2
Sprayer	0	0	0	0	0	0	0	0	0	0	0	0
Thresher	0	0	0	0	0	0	0	0	0	0	0	0

Out of the total households, 44 percent reported irrigation facility in the study area. In average 43 percent household reported community irrigation facilities in their farms among them 43 percent small households, 45 percent medium and 30 percent large households. Only 1 percent of total respondent reported having their own irrigation facility. The number of households reporting (irrigation sources) by farm household is presented as below.

DESCRIPTIONS	FARM STRATA							
	SMALL		MEDIUM		LARGE		TOTAL	
	No.	%	No.	%	No.	%	No.	%
Number of Household reporting Irrigation Sources	30	45	15	45	3	30	48	44
Own	1	2	0	0	0	0	1	1
Community	29	43	15	45	3	30	47	43
Government	0	0	0	0	0	0	0	0
Others	0	0	0	0	0	0	0	0

Irrigation charges paid for diesel, irrigation fee and maintenance cost by farm size is shown as below. On an average Rs. 1000/ha was spent for diesel, Rs. 871/ha for maintenance and Rs. 270/ha for irrigation. In total Rs. 2,141/ha was spent for irrigation by the respondent.

	IRRIGATION CHARGE (RS./HA.)			
	SMALL	MEDIUM	LARGE	AVERAGE
Electricity	0	0	0	-
Diesel	0	1,000	1,000	1,000
Maintenance	533	1,039	0	871
Irrigation fee	40	500	0	270

A number of problems for irrigation were listed by the farm households. 35 percent among total household reported no irrigation facility, 29 percent household reported shortage of water and 21 percent households expressed intake of irrigation system was not good. The major problems faced by farm households for irrigation is presented as below.

	FARM STRATA							
	SMALL		MEDIUM		LARGE		TOTAL	
	No.	%	No.	%	No.	%	No.	%
Intake not good	14	21	7	21	2	20	23	21
Shortage of water	18	27	12	36	2	20	32	29
No irrigation in winter	3	5	1	3	1	10	5	5
No Equal Distribution	5	8	3	9	1	10	9	8
No irrigation facility	22	33	14	42	3	30	39	35
Drainage Problem	-	-	2	6	-	-	2	2
No WUG	7	10	1	3	-	-	8	7
Depend on Rain	4	6	-	-	2	20	6	6
Living Standard Low	3	5	-	-	2	20	5	5
Up Land	1	2	1	3	-	-	2	2
No	1	2	-	-	-	-	1	1
No Technology	2	3	-	-	-	-	2	2
Timely No Crop	-	-	1	3	-	-	1	1

The main reasons reported by farm households were shortage of water, late planting and poor knowledge about crop husbandry. Out of total households, 25 percent households expressed lower yield due to shortage of irrigation water, 16 percent household reported lower yield due to poor knowledge of farming, 15 percent households reported lower yield due to late planting and 10 percent household reported low yield due to diseases and insects incidence.

Reason for lower yield (HH)	FARM STRATA							
	SMALL		MEDIUM		LARGE		TOTAL	
	No.	%	No.	%	No.	%	No.	%
Late planting	18	27	6	18	2	20	16	15
Shortage of water	17	25	7	21	3	30	27	25
Wind	1	2	0	0	0	0	1	1
Animal/bird damage	1	2	2	6	2	20	5	5
Soil fertility	1	2	0	0	1	10	2	2
Salinity	-	-	-	-	-	-	-	-
Pest, disease	7	10	3	9	1	10	11	10
Poor husbandry	2	3	0	0	-	-	2	2
Seed quality	2	3	0	0	-	-	2	2
Poor knowledge on cultivation	10	15	6	18	2	20	18	16

An Agriculture Service Center and a Livestock Service Centre is located in Deuri village, Buddi village development committee. All the VDC of the project area are under the service area of Deuri Agriculture sub-center. Assistant Production Officer is the officer in-charge of the Agriculture Service Center. There are two cooperative society (Sajha) in the project area and they are located in Gorusinge and Dhankauli (now in Mahuwa). These societies are selling agricultural inputs in the project area. There is a sub-branch office of Nepal Bank Limited in Pattharkot, which deals with commercial as well as agricultural loan.

5.4 Animal Husbandry

The large farm households in the area were observed having a large number of livestock than the small households. The vital role of bullock for ploughing may be the reason why 83 percent of households owned bullock. 90 percent of large household had about 8.9 bullocks, 94 percent of medium households had 5.4 bullocks and 76 percent small households had 3 bullocks. Data on the total number of farm animals in the command area by VDC was also availed to the study team by livestock sector, is presented as below.

ANIMALS	FARM STRATA							
	SMALL		MEDIUM		LARGE		ALL	
	% of HH Keeping	Ave. no of Animal	% of HH Keeping	Ave. no of Animal	% of HH Keeping	Ave. no of Animal	% of HH Keeping	Ave. no of Animal
Buffalo	51	2.4	36	1.8	40	4.3	46	2.4
Buffalo Bull	16	2.1	12	2.5	60	2.5	19	2.3
Cow	64	2.7	82	4.3	80	6.6	71	3.6
Bull/Steers	76	3	94	5.4	90	8.9	83	4.4
Pig	12	1	27	2.3	20	1	17	1.6
Sheep	5	5	15	4.6	-	-	7	4.8
Horse/Mule	-	-	-	-	-	-	-	-
Goat	39	2.6	46	5.1	50	3.6	42	4.7
Donkey	-	-	-	-	30	11.6	-	-
Chicken	30	6.6	49	6.7	-	4	37	7.2
Ducks	2	3	6	10	-	-	6	5.8
Others	-	-	-	-	-	-	-	-

5.5 General Attitude

The most serious problem constraining the development of agricultural production was the shortage of irrigation water which was pointed out by 93 percent of the farmers. The next one was the pest/disease in crops as pointed by 74 percent of the farmers. Poor road condition, and shortage of fertilizer and HYV seeds were the other constraints.

(percent)

CONSTRAINTS	FARM STRATA			
	SMALL	MEDIUM	LARGE	ALL
Irrigation Water	91	94	100	93
Excess Water	1	0	0	
Pests and Diseases	72	76	80	74
Labour Shortage	10	6	10	9
Shortage of HYV	28	24	30	27
Shortage of Fertilizer	25	39	30	30
Poor Road Condition	40	52	30	45
Other	1	0	0	1

Note : Percentage figures add-up to more than 100 because farmers had stated more than one constraints.

About 86 percent of the households were aware about Rajkudwa Irrigation Project. They were willing to help the project mainly by providing voluntary labour. However, people were very enthusiastic with the irrigation project in general. About 79 percent of them expected that production/productivity of crops will increase. Similarly 27 percent expected that production of fruits and vegetables will increase once the irrigation water will be available.

	FARM STRATA							
	SMALL		MEDIUM		LARGE		ALL	
	No.	%	No.	%	No.	%	No.	%
Even heard of the Project:								
- Yes	57	85	28	85	10	100	95	86
- No	10	15	5	15	0	0	15	14
Willing to contribute by *								
- Providing some cash	9	13	4	12	2	20	15	14
- Providing s-ome grain	1	1	3	9	2	20	6	5
- Providing Land	6	9	3	9	1	10	10	9
- Providing Voluntary Labour	57	85	29	88	8	80	94	85
Foresee any Hardship:								
- Yes	3	4	7	0	0	0	10	9
- No	64	96	26	0	10	100	100	91
If Yes, How								
- Project may take my land to construct canal/pond	3	4	7	21	0	0	10	9
Benefits Expected From the Project *								
- Increase in crop production	50	75	27	82	10	100	87	79
- Increase in Fruit & vegetable production	22	33	7	21	1	10	30	27
- Increase in Income	8	12	7	21	1	10	16	15
- Multiple cropping	10	15	2	6	1	10	13	12
- Timely cultivation	1	1	1	3	1	10	3	3
- Assured water supply with owen maintenance cost	1	1	1	3	1	10	3	3

* The totals add-up to more than hundred as farmers answers were more than one.

The general thinking of the people was that the project should start as soon as possible. It was suggested that the project should be directly helpful to as many farmers as possible, specially, in winter. Some of the farmers suggested that the Ranikudwa Irrigation Project should be rehabilitated and water available from Ranikudwa and Rajkudwa Project should combine together to irrigate largest possible area.

	FARM STRATA							
	SMALL		MEDIUM		LARGE		ALL	
	No.	%	No.	%	No.	%	No.	%
- Project is beneficial, should start soon	36	54	15	45	4	40	55	50
- Canal should use water from both Rajkudwa and Ranikudwa	6	9	1	3	1	10	8	7
- Should be directly helpful to farmers	8	12	11	33	2	20	21	19
- Should provide water during winter	8	12	3	9	1	10	12	11
- Seek peoples' participation	3	4	1	3	0	0	4	4
- Use existing ponds to increase discharge during dry season	1	1	1	3	0	0	2	2
- Provide compensation for land used by project	2	3	1	3	2	20	5	4
- Give priority to northern belt in distributing water	3	4	0	0	0	0	3	3

List of Farm Survey

No. of Farmer	Location	Family Size	Living Expediture	Cultivated Area
		Persons	NRs/year	ha
1	Dubiya VDC	14	18,180	1.50
2	Dubiya VDC	7	33,605	22.46
3	Dubiya VDC	10	12,620	16.42
4	Dubiya VDC	7	5,230	11.05
5	Dubiya VDC	7	3,025	1.50
6	Dubiya VDC	6	8,605	10.02
7	Dubiya VDC	13	8,774	2.58
8	Dubiya VDC	8	5,838	1.50
9	Dubiya VDC	19	13,928	9.68
10	Dubiya VDC	10	8,248	6.24
11	Dubiya VDC	6	1,380	2.10
12	Dubiya VDC	10	7,625	4.67
13	Dubiya VDC	15	15,974	4.68
14	Dubiya VDC	13	13,515	2.44
15	Dubiya VDC	12	4,280	6.91
16	Dubiya VDC	23	4,685	2.37
17	Dubiya VDC	8	6,154	2.44
18	Dubiya VDC	11	6,660	4.34
19	Dubiya VDC	16	14,260	7.92
20	Dubiya VDC	14	6,975	8.19
21	Jayanagar VDC	6	12,140	0.92
22	Jayanagar VDC	5	9,180	0.72
23	Jayanagar VDC	5	22,108	4.21
24	Jayanagar VDC	16	3,815	10.97
25	Jayanagar VDC	8	18,900	1.15
26	Jayanagar VDC	4	6,600	1.62
27	Jayanagar VDC	6	8,400	0.06
28	Jayanagar VDC	2	8,475	2.27
29	Jayanagar VDC	8	5,334	3.79
30	Jayanagar VDC	1	1,620	0.10
31	Jayanagar VDC	4	1,710	1.44
32	Jayanagar VDC	12	15,872	2.26
33	Jayanagar VDC	4	2,780	0.34
34	Jayanagar VDC	17	8,662	3.54
35	Jayanagar VDC	5	0	0.07
36	Jayanagar VDC	6	13,030	1.58
37	Jayanagar VDC	5	7,095	2.10
38	Jayanagar VDC	13	7,940	2.72
39	Jayanagar VDC	5	4,270	0.54
40	Jayanagar VDC	11	17,960	2.17
41	Buddi VDC	9	8,170	10.30
42	Buddi VDC	6	9,300	1.90
43	Buddi VDC	7	6,347	3.52
44	Buddi VDC	8	9,103	0.68
45	Buddi VDC	13	9,570	2.50
46	Buddi VDC	9	8,403	2.92
47	Buddi VDC	13	4,300	1.50
48	Buddi VDC	11	6,440	2.03
49	Buddi VDC	5	3,300	2.02
50	Buddi VDC	10	11,940	2.37
51	Buddi VDC	3	980	1.43
52	Buddi VDC	9	10,972	0.74
53	Buddi VDC	5	2,020	3.52
54	Buddi VDC	8	2,155	2.77
55	Buddi VDC	15	31,800	4.68
56	Buddi VDC	14	9,632	0.58
57	Buddi VDC	17	4,335	4.29
58	Buddi VDC	14	6,110	4.26
59	Buddi VDC	5	8,860	2.17
60	Buddi VDC	6	2,850	4.40
61	Dhankauli VDC	13	20,475	13.74
62	Dhankauli VDC	14	9,528	6.02
63	Dhankauli VDC	12	3,152	8.33
64	Dhankauli VDC	7	11,811	6.58
65	Dhankauli VDC	12	11,945	4.60
66	Dhankauli VDC	10	20,550	6.77
67	Dhankauli VDC	17	9,920	2.72
68	Dhankauli VDC	4	1,740	5.20
69	Dhankauli VDC	4	13,200	5.69
70	Dhankauli VDC	7	8,420	4.42
71	Dhankauli VDC	6	13,207	6.91
72	Dhankauli VDC	2	920	2.10
73	Dhankauli VDC	7	1,027	3.52
74	Dhankauli VDC	5	6,225	0.82
75	Dhankauli VDC	9	4,375	1.96
76	Dhankauli VDC	7	5,580	3.80
77	Dhankauli VDC	14	9,770	3.18
78	Dhankauli VDC	11	3,960	2.81
79	Dhankauli VDC	7	5,540	2.54
80	Dhankauli VDC	7	3,200	1.62
81	Buddi VDC	18	4,212	15.10
82	Buddi VDC	6	24,078	11.86
83	Buddi VDC	5	7,032	0.00
84	Buddi VDC	6	20,570	0.06
85	Buddi VDC	9	5,450	4.20
86	Buddi VDC	6	4,168	7.76
87	Buddi VDC	17	12,700	6.56
88	Buddi VDC	21	6,130	6.24
89	Buddi VDC	17	5,088	6.88
90	Buddi VDC	17	1,340	2.84
91	Buddi VDC	10	7,665	3.46
92	Buddi VDC	6	8,560	0.83
93	Buddi VDC	8	5,122	2.10
94	Buddi VDC	16	5,400	2.34
95	Buddi VDC	10	7,193	6.24
96	Buddi VDC	4	4,220	2.38
97	Buddi VDC	9	2,300	2.10
98	Buddi VDC	10	5,700	0.40
99	Buddi VDC	11	1,398	2.10
100	Buddi VDC	4	3,530	0.02
101	Mahendrakot VDC	7	5,210	0.54
102	Mahendrakot VDC	4	10,000	1.77
103	Mahendrakot VDC	8	32,660	0.48
104	Mahendrakot VDC	2	20,254	2.54
105	Mahendrakot VDC	5	18,560	1.56
106	Mahendrakot VDC	8	15,816	2.24
107	Mahendrakot VDC	16	22,982	4.68
108	Mahendrakot VDC	8	12,530	1.43
109	Mahendrakot VDC	7	16,305	3.45
110	Mahendrakot VDC	16	12,570	3.32

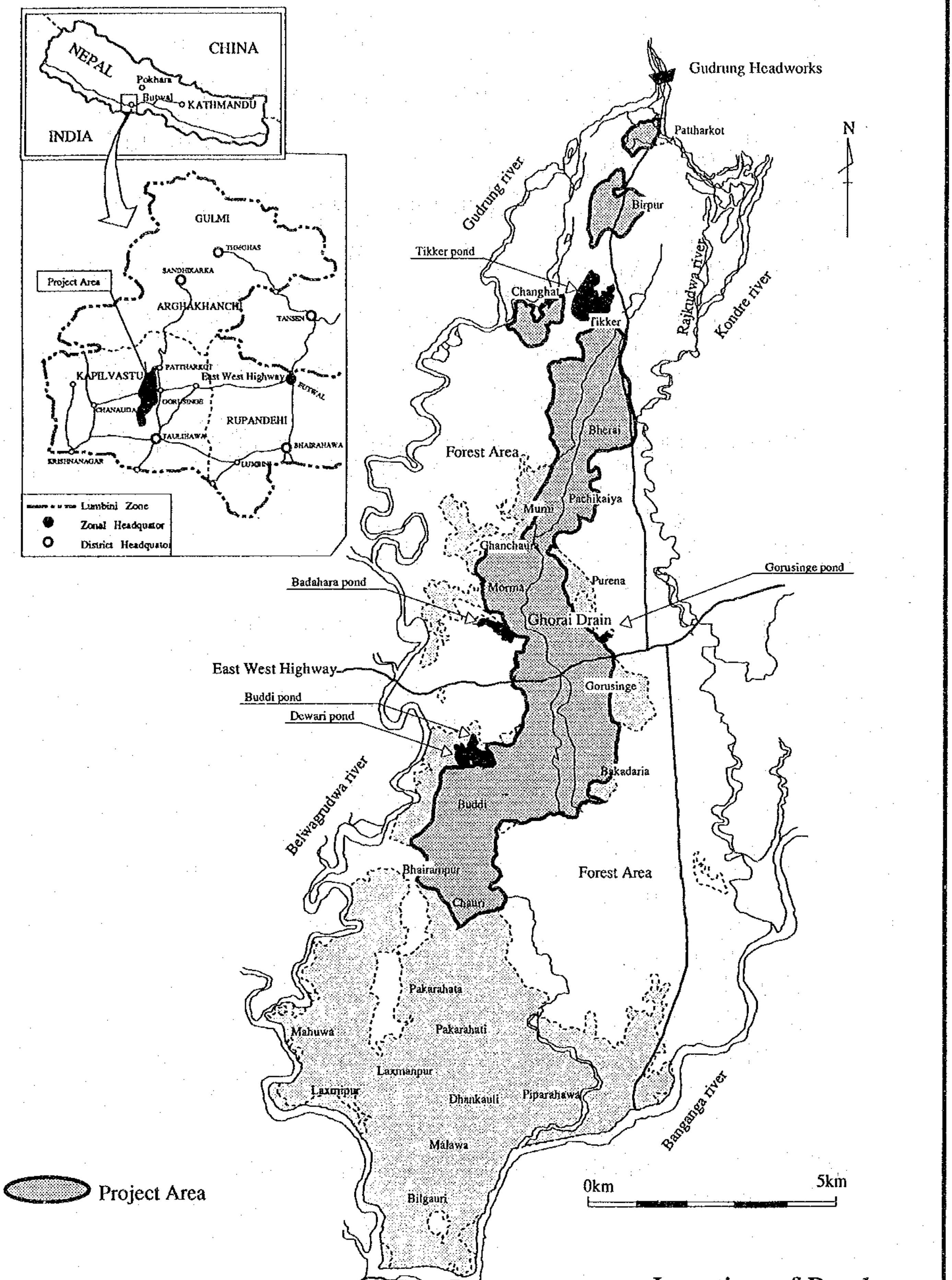
HIS MAJESTY'S GOVERNMENT OF NEPAL

RAJKUDWA IRRIGATION PROJECT

Results of Additional Geotechnical and Soil Mechanical Surveys and Seepage Loss of the Proposed Tikker Pond

November 1993

Japan International Cooperation Agency



Location of Ponds

Results of Additional Geotechnical and Soil Mechanical Surveys and Seepage Loss of the Proposed Tikker Pond

1. Background

The irrigation plan envisaged in the Interim Report on the Feasibility Study for the Rajkudwa Irrigation Project was a common irrigation plan which mainly uses the irrigation water taken from the Gudrung river and the Kondre river at the proposed headworks sites and supplementarily utilizes tha water stored in the proposed five ponds with excess flow of the two rivers, and thereby it was recognized that the scale and water depth of the ponds were not so large that the investigation on seepage loss of such ponds was required, and that the seepage loss from such ponds would not be so much since the surface and sub-surface strata were observed as terrace, talus and alluvial deposits of the Pleistocene thinly covered by Holocene, the Quaternary.

However, the hydrological analyses carried out in Japan clarified that the base flow of the two rivers were smaller than expected throughout the year. Therefore, the common irrigation plan envisaged in the Interim Report was abandoned, and the pond irrigation plan was formulated in the Draft Final Report on the Feasibility Study in order to efficiently use the discharge of the Gudrung river, particularly the floods in the rainy season.by storing the five ponds with the discharge of the river taken at the proposed headworks and distributing the ponds' water to the irrigable area. In this connection, the scale and water depth of the proposed ponds became much larger than those envisaged in the Interim Report, and thereby an additional geotechnical and soil mechanical surveys were needed to assess and evaluate the seepage loss of the proposed five ponds, particularly Tikker pond to be newly constructed.

In the light of such background as mentioned above, the Japan International Cooperation Agency (JICA) conducted the additional geotechnical and soil mechanical surveys for the proposed five ponds during the one month from 17 September to 16 October 1993 by dispatching an expert of the study team after getting a consent on it in the inter-ministerial discussion arranged by JICA.

This paper describes both the results of the additional geotechnical and soil mechanical surveys for the proposed Tikker pond out of the proposed five ponds and the overall seepage loss of the pond estimated by the seepage analysis based on the survey results, because the seepage losses of the other four existing ponds are estimated to be far smaller than that of the Tikker pond.

2. Additional Geotechnical and Soil Mechanical Surveys

2.1 Contents of the Survey

The following geotechnical and soil mechanical surveys were carried out in order to estimate the seepage loss from the proposed Tikker Pond.

A) Field Work and Laboratory Tests

1) core boring : 9 holes, a total of 72 m in length (6 to 10 m / hole).
2) standard penetration test (SPT) : 32 tests (2 to 3 m intervals in the boreholes)
3) borehole permeability test : 21 tests (3 m intervals).
4) field permeability test : 10 tests at 5 locations.
5) test pitting : 12 locations (1.5 to 4.0 m deep).
6) laboratory permeability test : 7 tests.
7) soil tests (grain size analysis, specific gravity test and moisture content test) : 39 samples (three tests for each sample).
8) compaction test on soil samples : 7 samples.
9) direct shear test : 7 samples.

B) Follow-up Work in Japan

1) an analysis of the field surveys.
2) an estimate of seepage loss by seepage analysis
3) preliminary design of seepage prevention works and cost estimate of the prevention works if the estimated seepage loss is very large.
4) a brief reporting on the above surveys, in order to utilize the results in the Final Report on the Feasibility Study.

2.2 Survey Results

2.2.1 Geomorphological and Geological Outlines of the Tikker Pond Site

In the left bank of the proposed Tikker Pond, remarkably monadnock-like topography is found. The topography might be correlative with the older fan (the Pleistocene) in the Pattharkot fan, which is located from 1.5 to 3.5 km north of the Tikker Pond. However, the topography could be geologically somewhat older than the older fan, because the elevation is a few meters higher than that of the older fan. The Tikker Pond and the right bank are located in the plane, which is correlative with the middle terrace (the Pleistocene) in the Pattharkot fan. The plane is newer than the monadnock-like topography in the left bank.

Almost all of the proposed Tikker Pond is covered with surface soil. The surface soil is underlaid by the Pleistocene unconsolidated deposits (gravel, sand, silt and clay) for more than 10 m in depth. The Pleistocene deposits are classified into three layers : the newest is Layer I which is correlative with the middle terrace deposits in the Pattharkot fan. Left bank monadnocks are composed of Layer II. Layer I and II are underlaid by Layer III.

2.2.2 Boring Results

Boring surveys, consisting of 9 holes with a total length of 72 m and test pitting of 12 holes with a total length of 31.5 m were conducted in and around the proposed Tikker Pond site. The location of the boring sites and test pits are shown in Fig. 2.1, and the boring results are shown in Table 2.1 and Figs. 2.2, 2.3 and 2.4. The Geology is summarized in order from the new layer as follows.

- Surface Soil
- Layer I : Layer I is classified into two or three layers; I-1 (sandy silt), I-2' (sand) and I-2 (sand and gravel). I-2' is found only around boreholes T-3, T-4 and T-5. The mean SPT N-values for I-1, I-2' and I-2 are 16, 22 and 39, respectively.
- Layer II : Layer II is classified into three or four layers; II-1 (sandy silt), II-2 (sand), II-2' (sand and gravel) and II-3 (sand and gravel). II-2' exists only around Q-3 and Q-11. The N-values are 15 for II-2 and 38 for II-3.
- Layer III : Layer III is classified into three layers: III-1 and III-2 (silty layer); and III-3 (sand). Because III-1 and III-2 are geologically similar, they could be regarded as a layer. The mean N-values for III-1, III-2 and III-3 are 22, 12 and 16, respectively.

In the layers described above the N-values of a part of I-2', many parts of I-2, and II-3 exceed 30 which is sufficient for structure foundations, while the N-values of a part of I-1, many parts of I-2', most parts of I-2, and II-3 exceed 20.

2.2.3 Hydrogeology

The hydrogeological formations in and around the proposed Tikker pond are classified into the following three layers :

- Phreatic aquifer :
  The phreatic aquifer is composed of layers I-1, I-2' and I-2 in the right bank of the Tikker Pond, and layers II-2, II-2' and II-3 in the left bank. Of these, I-2 and II-3 are the main aquifers which exist regionally in and around the pond. The average permeabilities are : 1 x 10^{-4} cm/s for I-1, 3 x 10^{-4} cm/s for I-2', 5 x 10^{-4} cm/s for I-2 (the maximum permeability is 1.2 x 10^{-3} cm/s, which exists in the northern most end of the pond.), and 1.5 x 10^{-4} cm/s for II-2. The permeability of II-3 would be nearly same as that of I-2. Since the layers I-1 and II-1 underlaid by the main aquifers I-2 and II-3 are somewhat impermeable, the amount of seepage from the pond would be slight. However, near the stream which runs in the eastern part of the pond, the seepage loss through the main aquifers and structural safety against piping in the aquifers, that is, the safety against the critical hydraulic gradient, etc. must be taken into consideration, because the impermeable layers I-1 and II-1 are eroded out.

- Impermeable basement :
  The layers III-1 and III-2 form the impermeable basement of the phreatic aquifer. The mean permeability of the basement is around 1 x 10^{-4} cm/s.

- Second aquifer :
  The layer III-3 forms the second aquifer. But, consideration of the seepage is not be required, because the permeability is not very high (2 x 10-4 cm/s), and the depth to the second aquifer is sufficient to prevent seepage.

- Groundwater table :
  The groundwater table during the wet season exist within 4 m from the ground level. The groundwater level during the dry season has not been adequately measured. However, at the stream running in the eastern part of the pond, the groundwater level is observed to be nearly same to the stream water level. Because impermeable I-1 layer doesn't exist along the stream, it is necessary to consider the seepage from the pond.
  The groundwater levels in boreholes T-3, T-4 and T-9 are lower than those in the vicinity. These holes are bored into the second aquifer. If the groundwater level in the second aquifer is lower than that in the phreatic aquifer, it is possible that the groundwater level in the boreholes T-3, T-4 and T-9 indicates that fact.

2.2.4 Laboratory Tests

The soil samples were collected from the seven test pits (TPI to TP7) in order to investigate the usefulness for the embankment material.of the pond's dike. The permeability coefficient ranged from 1.11 to 3.47 x 10^{-6} cm/s in the case of samples with a density of 95% of the maximum dry density sample. The shear strength and the angle of shear resistance ranged from 0.78 to 1.63 kg/cm^2 and from 13.5° to 28.5°, respectively. The true specific gravity of the specimens sampled from the boreholes T1 to T8 and the test pits was in the range of 2.66 to 2.71 g/cm^3. These results show that the Layers I-1 and I-2' can be used as the embankment materials for the dike of the Tikker Pond.

3. Seepage Analysis

3.1 Method of Analysis

For the purpose of estimating the seepage loss from the reservoir or pond and sounding the distribution of the groundwater potential, there are three seepage analysis methods: the first one is to use a vertical 2 dimensional model; the second is to utilize a horizontal 2 dimensional model; and the third is to employ a 3 dimensional model. The most popular one is the vertical 2 dimensional model. The horizontal 2 dimensional model is mostly used to estimate the loop seepage in the bank supported by dam abutments and in the similar cases, and the 3 dimensional model is usually employed for estimating the seepage from minor parts of the dam and its reservoir banks.

Since the proposed Tikker pond has a water surface area of 52 ha and a max. water depth of 9.0 m, it was supposed that the seepage would mostly appear around the dike and banks of the pond. Accordingly, it seemed that the unit seepage loss of the pond could be estimated using a vertical 2 dimensional model for the pond's dike and banks and the surroundings, and the total seepage loss would be computed by multiplying the unit loss and the total length of the dike and banks. Thus, two sections of the pond were taken as the typical profile for the vertical 2 dimensional model: one is an east-west section of which hydraulic gradient is larger than that of other sections and hydraulic conductivity (permeability) is also higher, and another is a north-west section crossing the east-west section at right angle.

For the seepage analysis there are two kinds of the finite element method as follows:

1) Method for a saturated domain
   The analysis is limited to saturated domain, however its domain can be transformed according to changes of groundwater level.

2) Method for a saturated-unsaturated domain
The analysis is extended to both the saturated domain and the unsaturated one. The seepage in the saturated and unsaturated domains can simultaneously be computed as the value of positive potential and that of negative potential, respectively.

Since it is said that the analysis for a saturated-unsaturated domain should be applied in the case that the groundwater table of the domain is complicated, the seepage loss of the Tikker pond was analyzed by using the method for a saturated-unsaturated domain.

3.2 Estimated Seepage Loss

The following two tables show the unit seepage loss of the east-west section and north-south section computed by using the respective vertical 2 dimensional models, of which the boundary conditions and thickness of the strata are shown in Fig.-3.1 and the permeability coefficient of each stratum is set in line with the results of the additional geotechnical and soil mechanical surveys:

Table-1 Unit Seepage Loss of the East-West Section

GWL of Boundary EL. (m)		Permeability Coefficient x 10^{-4} (cm/sec)									Seepage Loss <per m of dike> (m^3/day)		
h1	h2	k1	k2	k3	k4	k5	k6	k7	k8	k9	East	West	Total
127.0	125.0	1.5	13.0	5.0	3.9	0.88	0.57	3.4	1.2	0.5	0.267	0.317	0.584

Table-2 Unit Seepage Loss of the North-South Section

GWL of Boundary EL. (m)	Permeability Coefficient x 10^{-4} (cm/sec)						Seepage Loss <per m of dike> (m^3/day)		
h0	k3	k4	k5	k6	k8	k9	North	South	Total
133.0	5.0	3.9	0.88	0.57	1.2	0.5	0.0	0.238	0.238

The overall seepage loss of the Tikker pond is estimated to be 770 m^3 a day, which has been computed as a total of the seepage losses calculated from the unit seepage loss shown in the above tables and the respective command lengths of the dike and the banks, and it can be converted into a percolation or infiltration rate of 1.5 mm/day by dividing the overall seepage loss by the pond area.

For reference, an earth blanket was studied as a practical seepage protection works for the Tikker pond. The earth blanket envisaged was a thickness of 1.0 m constructed by the excavated, harrowed and compacted existing soils at the site, since the permeability coefficient of the existing soils will be increased from $k_1 \times 10^{-4}$ in natural condition to $k_2 \times 10^{-5}$ by such earthworks, which was implied by the compaction and permeability tests of the existing soil samples carried out in Kathmandu. However, the seepage analysis clarified that the earth blanket would be not effective, because the seepage losses reduced by the blankets extended up to 50 m, 100 m and 150 m in length from the dike or the banks to the inside of pond were only 3 - 4 % of the overall seepage loss of the unblanketed pond in all the case.

4. Conclusion

The Tikker pond proposed in the Draft Final Report has an effective storage of 2.07 million tons, a water surface area of 52 ha and total dike length of 2,100 m, and the overall seepage loss computed by the seepage analysis based on the results of the additional geotechnical and soil mechanical surveys is 1.5 mm/day on an average.

The computed seepage loss of the Tikker pond almost satisfies the following criteria on the allowable seepage for the ponds in Japan:

1) Daily seepage loss is to be less than 0.05% of the storage capacity of the pond (0.04%);
2) Seepage loss per 100 m of the pond's dike is to be less than 1.0 l/s (0.4 l/s); and
3) Seepage loss is to be less than 1.0% of the in-flow to the pond (1.4%).

Note: Bracketed figures show the values of the Tikker pond.

Therefore, no protection work is proposed for the Tikker pond so far as the seepage loss is concerned.

The overall seepage loss of the Tikker pond: 3.0 mm/day estimated in the Draft Final Report on the Feasibility Study is twice larger than 1.5 mm/day computed this time. However, the seepage loss of 3.0 mm/day is rather appropriate, taking into consideration such indefinite factors as boundary line of strata, boundary condition of seepage analysis model such as depth of impermeable layer, groundwater table, distance from inlet to outlet of seepage, etc., seepage analysis to two sections of the pond; an east-west section and a north-south section, etc.

Therefore, the pond irrigation plan formulated in the Draft Final Report, which aims at irrigating about 1,800 ha of arable lands by the canal systems mostly branching from the proposed five irrigation ponds, is technically feasible, because the plan is based on the water balance of the five irrigation ponds computed with an overall seepage loss of 3.0 mm/day.

Table 2.1 Geological Formations

Geological Age		Geological Formation	Constiuents	Thickness (m)	Coefficient of Permeability ([ ] shows the average*)		Hydrogeology	N-Value ([ ] shows the average**)	Remarks
QUATERNARY	HOLOCENE	Al	Top Soil	0 ~ 1	-		-	-	
	PLEISTOCENE	I-1	Sandy Silt Clayey Silt	0 ~ 4	$8.7 \times 10^{-5} \sim 1.2 \times 10^{-4}$ $[1.0 \times 10^{-4}]$		Phreatic Aquifer (Low Permeable)	11 ~ 25 [16]	Layer I is correlative with the middle terrace deposits in the Pattharkot fan. It is distributed in the right bank and the central area of Tikker Pond.
		I-2'	Silty Sand Silty Sand with Gravel	0 ~ 2	$2.7 \sim 3.4 \times 10^{-4}$ $[3.0 \times 10^{-4}]$		Phreatic Aquifer	8 ~ 42 [22]	
		I-2	Sand and Gravel, Silty Sand with Gravel, Silty Sand, (A Little Clayey Silt)	0 ~ 3.5+	$1.7 \times 10^{-4} \sim 1.2 \times 10^{-3}$ $[5.0 \times 10^{-4}]$		Phreatic Aquifer (Main Aquifer)	15 ~ 50/20 [39]	
		II-1	Sandy Silt	0 ~ 2	-		-	-	Layer II might be correlative with the older fan deposits in the Pattharkot fan, or the former is somewhat older than the latter. Layer II forms monadnoks in the right bank of the Tikker Pond.
		II-2	Silty Sand	0 ~ 2	1.5×10^{-4}		Phreatic Aquifer	15	
		II-2'	Sand and Gravel (Disributed Q-3 and Q-11 Only)	-	-		Phreatic Aquifer	-	
		II-3	Sand and Gravel	0 ~ 2	-		Phreatic Aquifer (Main Aquifer)	38	
		III-1	Silty Clay Clayey Silt Silty Sand	1 ~ 3+	$1.1 \sim 3.9 \times 10^{-4}$ $[2.1 \times 10^{-4}]$	$[1.2 \times 10^{-4}]$	Impermeable Basement of the Phreatic Aquifer	13 ~ 32 [22]	It is inferred that Layer III is extensively distributed in the Tikker Pond site.
		III-2	Sandy Silt Silty Clay	1 ~ 4	$4.9 \sim 8.8 \times 10^{-5}$ $[6.5 \times 10^{-5}]$			10 ~ 15 [12]	
		III-3	Silty Sand with Gravel Silty Sand Sandy Silt	-	$5.9 \times 10^{-5} \sim 5.7 \times 10^{-4}$ $[2.0 \times 10^{-4}]$		Second Aquifer	11 ~ 24 [16]	

*) a geometric mean **) an arithmetic mean

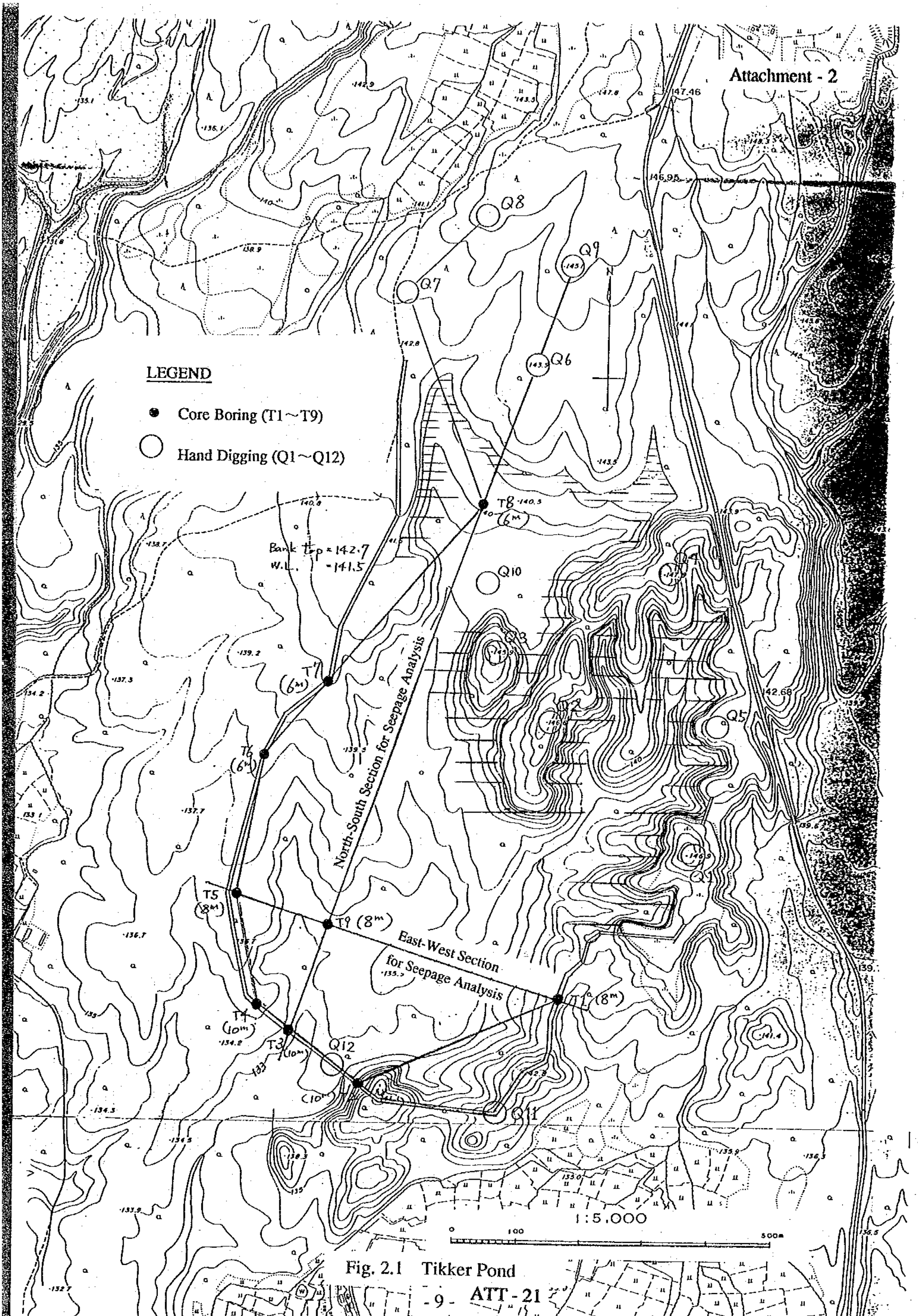
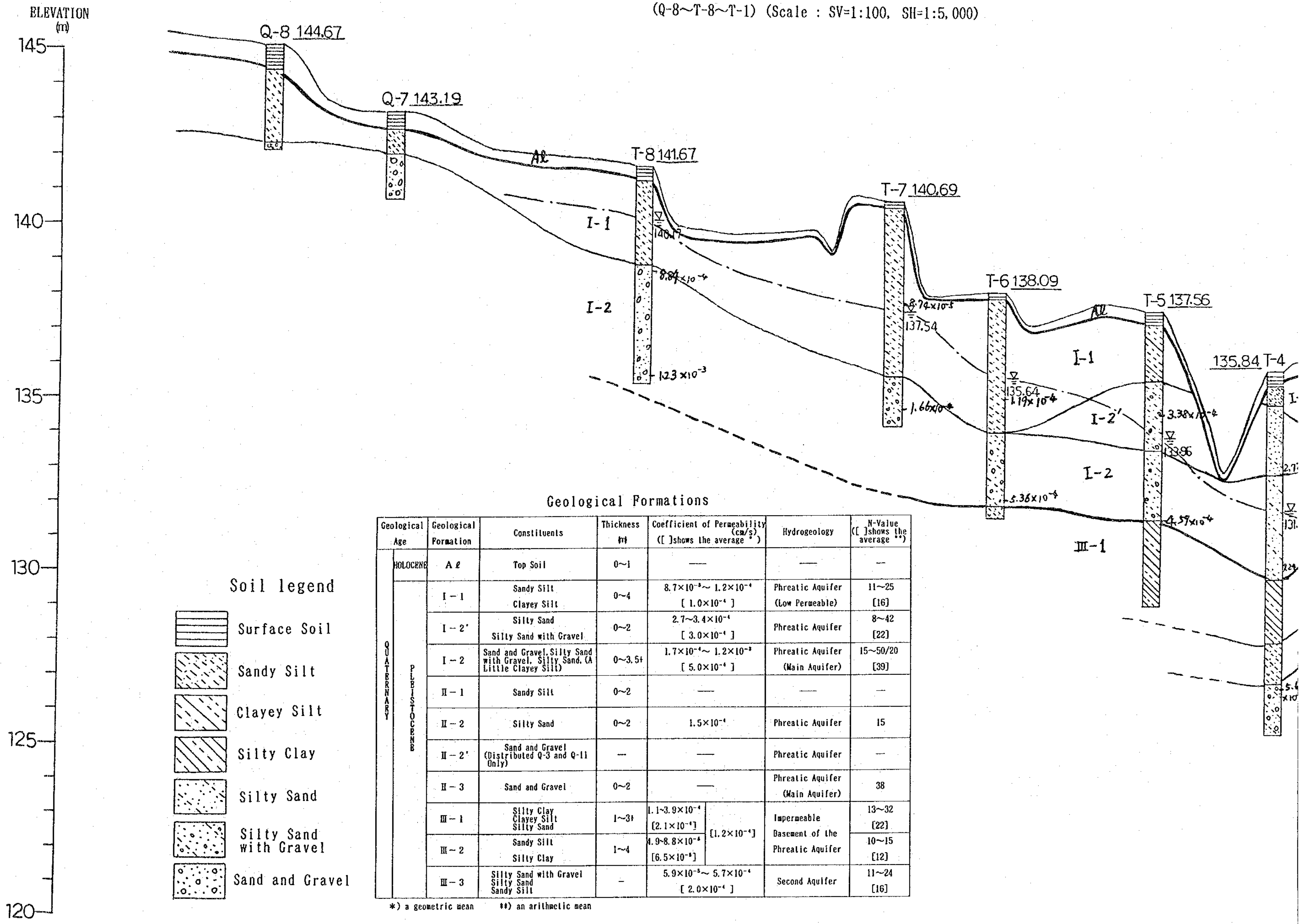


Fig. 2.1 Tikker Pond

Fig. 2. 2. Geological Profile at the Tikker Pond Site

(Q-8～T-8～T-1) (Scale : SV=1:100, SH=1:5,000)



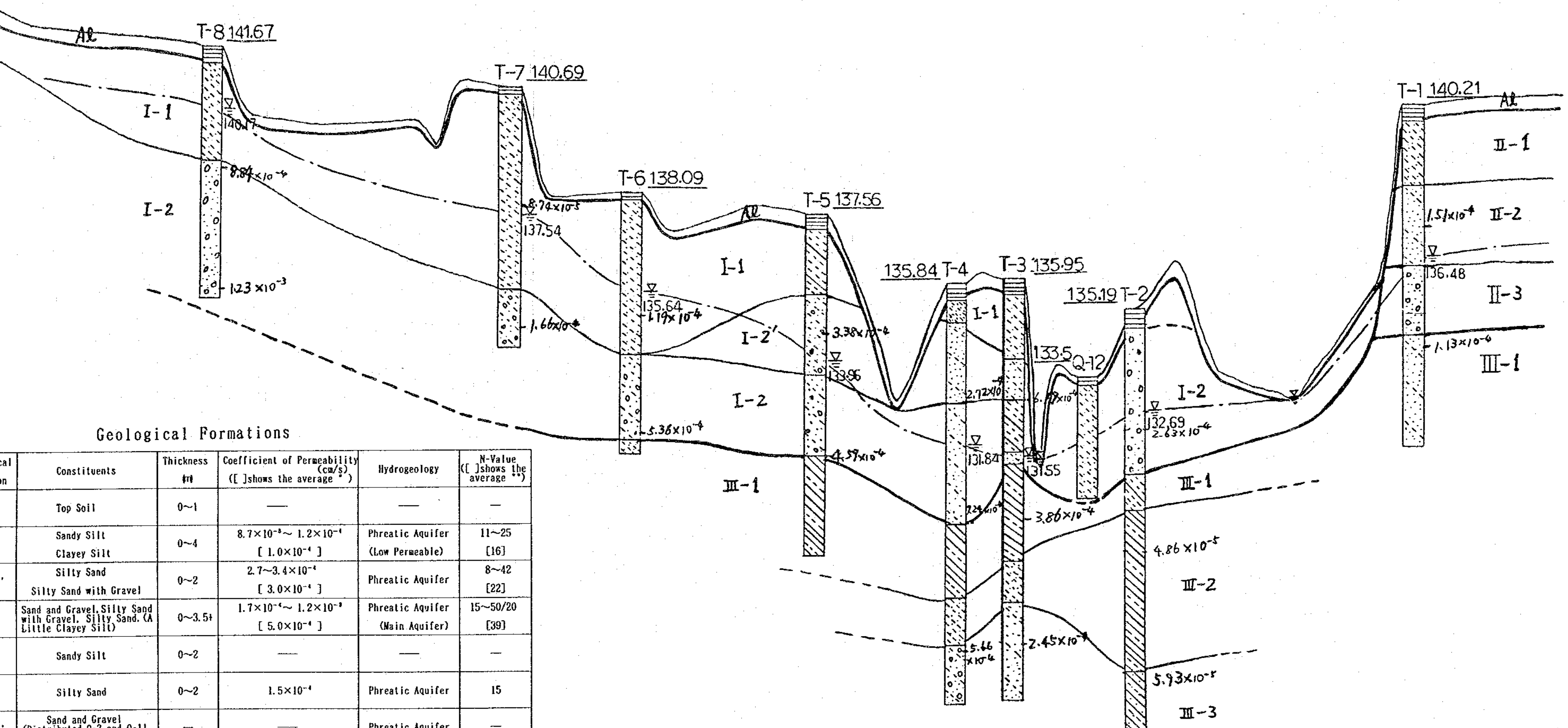
Geological Formations

Geological Age		Geological Formation	Constituents	Thickness (m)	Coefficient of Permeability (cm/s) ([ ]shows the average *)		Hydrogeology	N-Value ([ ]shows the average **)
QUATERNARY	HOLOCENE	A ℓ	Top Soil	0～1	—		—	—
	PLEISTOCENE	I－1	Sandy Silt Clayey Silt	0～4	8.7×10^{-5}～ 1.2×10^{-4} [1.0×10^{-4}]		Phreatic Aquifer (Low Permeable)	11～25 [16]
		I－2'	Silty Sand Silty Sand with Gravel	0～2	2.7～3.4×10^{-4} [3.0×10^{-4}]		Phreatic Aquifer	8～42 [22]
		I－2	Sand and Gravel, Silty Sand with Gravel, Silty Sand, (A Little Clayey Silt)	0～3.5+	1.7×10^{-4}～ 1.2×10^{-3} [5.0×10^{-4}]		Phreatic Aquifer (Main Aquifer)	15～50/20 [39]
		II－1	Sandy Silt	0～2	—		—	—
		II－2	Silty Sand	0～2	1.5×10^{-4}		Phreatic Aquifer	15
		II－2'	Sand and Gravel (Distributed Q-3 and Q-11 Only)	—	—		Phreatic Aquifer	—
		II－3	Sand and Gravel	0～2	—		Phreatic Aquifer (Main Aquifer)	38
		III－1	Silty Clay Clayey Silt Silty Sand	1～3+	1.1~3.9×10^{-4} [2.1×10^{-4}]	[1.2×10^{-4}]	Impermeable Basement of the Phreatic Aquifer	13～32 [22]
		III－2	Sandy Silt Silty Clay	1～4	4.9~8.8×10^{-5} [6.5×10^{-5}]			10～15 [12]
		III－3	Silty Sand with Gravel Silty Sand Sandy Silt	–	5.9×10^{-5}～ 5.7×10^{-4} [2.0×10^{-4}]		Second Aquifer	11～24 [16]

*) a geometric mean　　**) an arithmetic mean

Fig. 2. 2. Geological Profile at the Tikker Pond Site

(Q-8~T-8~T-1) (Scale : SV=1:100, SH=1:5,000)



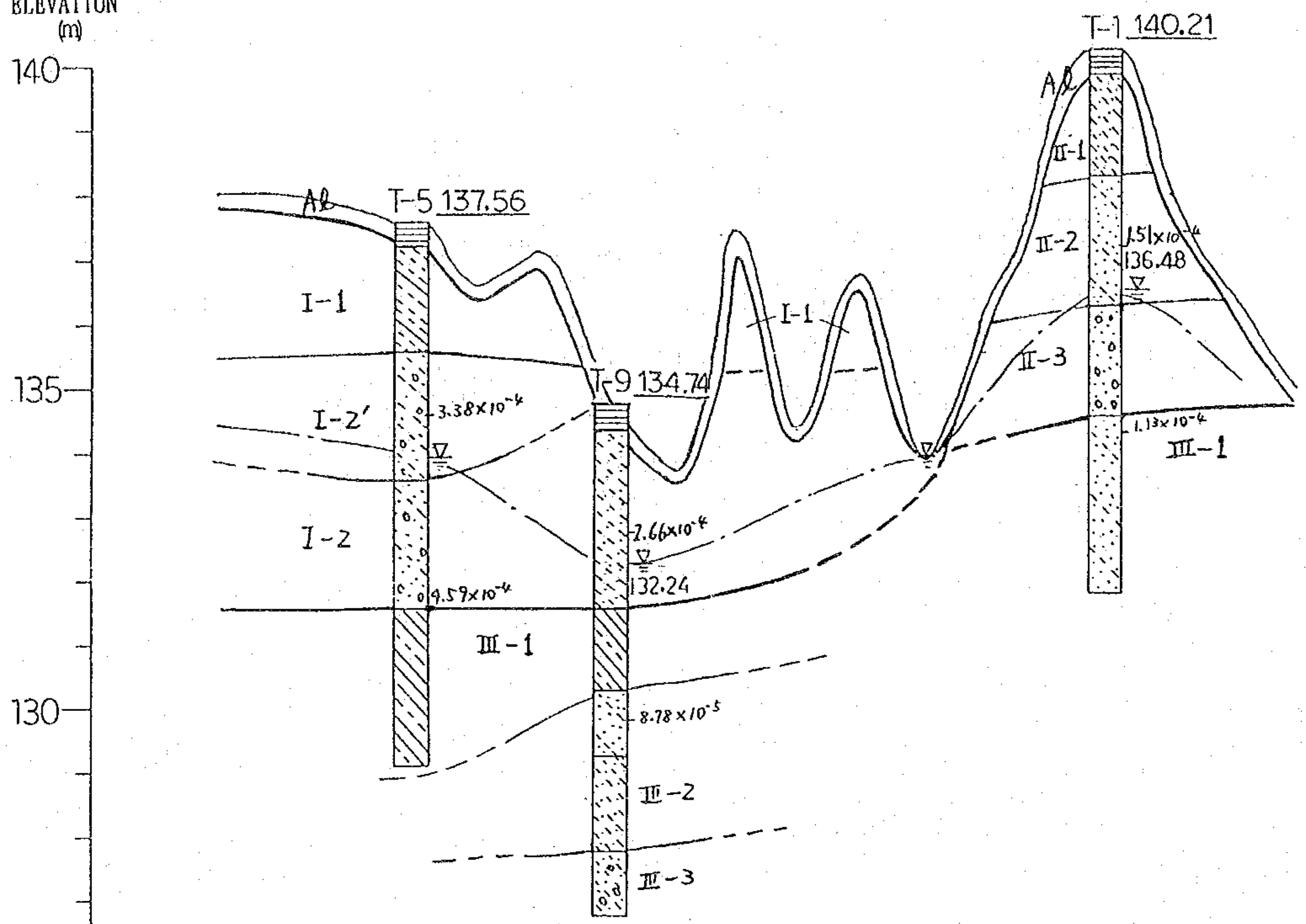
Geological Formations

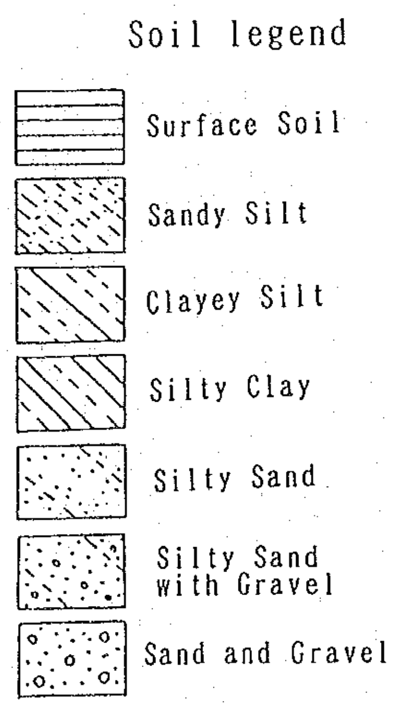
…cal …n	Constituents	Thickness (m)	Coefficient of Permeability (cm/s) ([ ]shows the average *)		Hydrogeology	N-Value ([ ]shows the average **)
	Top Soil	0~1	—		—	—
	Sandy Silt Clayey Silt	0~4	8.7×10^{-5} ~ 1.2×10^{-4} [1.0×10^{-4}]		Phreatic Aquifer (Low Permeable)	11~25 [16]
	Silty Sand Silty Sand with Gravel	0~2	2.7~3.4×10^{-4} [3.0×10^{-4}]		Phreatic Aquifer	8~42 [22]
	Sand and Gravel, Silty Sand with Gravel, Silty Sand. (A Little Clayey Silt)	0~3.5†	1.7×10^{-4} ~ 1.2×10^{-3} [5.0×10^{-4}]		Phreatic Aquifer (Main Aquifer)	15~50/20 [39]
	Sandy Silt	0~2	—		—	—
	Silty Sand	0~2	1.5×10^{-4}		Phreatic Aquifer	15
	Sand and Gravel (Distributed Q-3 and Q-11 Only)	—	—		Phreatic Aquifer	—
	Sand and Gravel	0~2	—		Phreatic Aquifer (Main Aquifer)	38
	Silty Clay Clayey Silt Silty Sand	1~3†	1.1~3.9×10^{-4} [2.1×10^{-4}]	[1.2×10^{-4}]	Impermeable Basement of the Phreatic Aquifer	13~32 [22]
	Sandy Silt Silty Clay	1~4	4.9~8.8×10^{-5} [6.5×10^{-5}]			10~15 [12]
	Silty Sand with Gravel Silty Sand Sandy Silt	–	5.9×10^{-5} ~ 5.7×10^{-4} [2.0×10^{-4}]		Second Aquifer	11~24 [16]

…ean **) an arithmetic mean

Fig. 2.3 Geological Profile at the Tikker Pond Site

(T-5～T-9～T-1) (Scale : SV=1:100, SH=1:5,000)





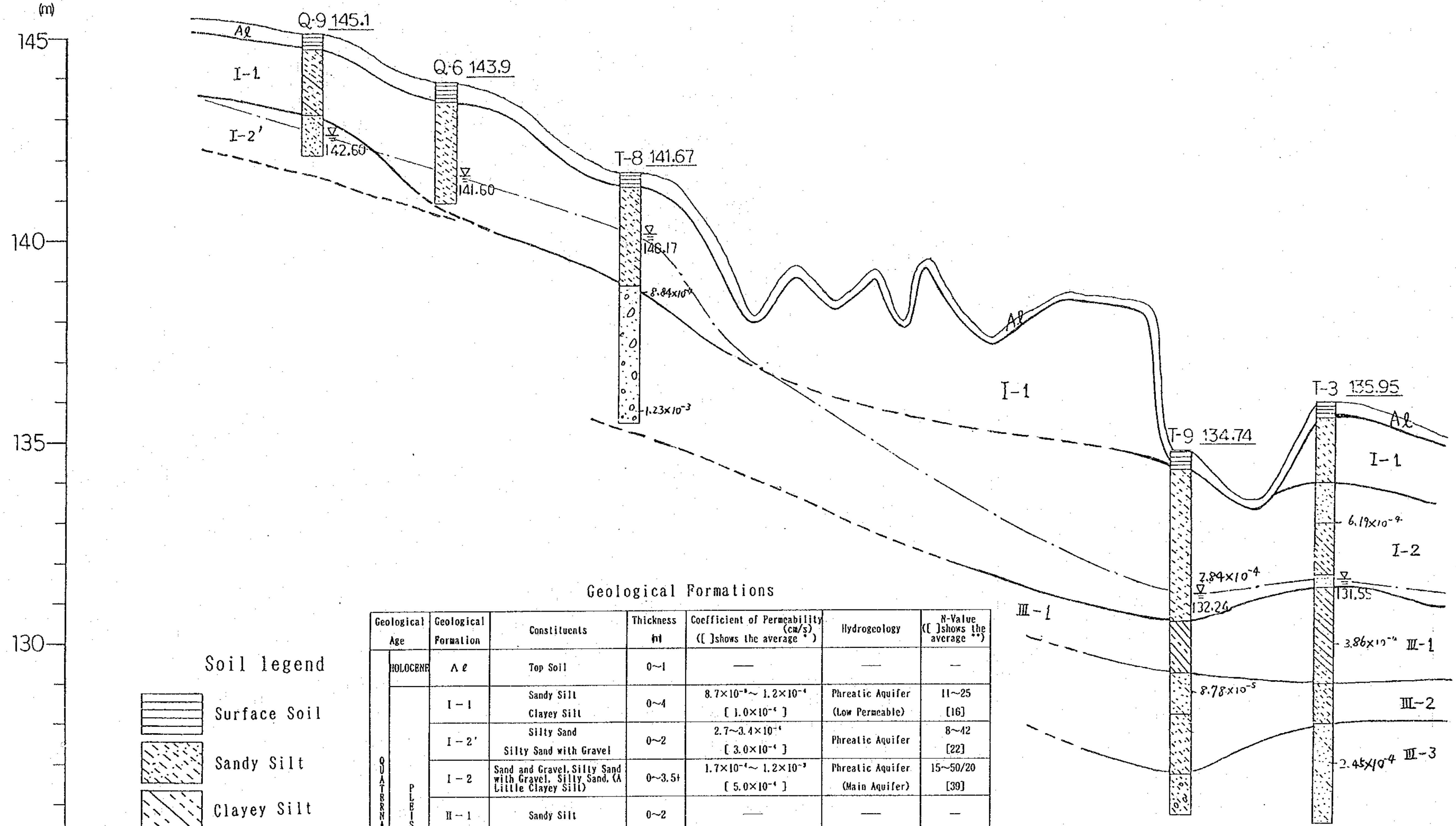
Geological Formations

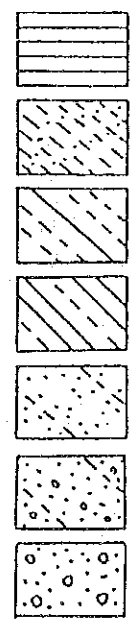
Geological Age		Geological Formation	Constituents	Thickness (m)	Coefficient of Permeability (cm/s) ([ ]shows the average *)		Hydrogeology	N-Value ([ ]shows the average **)
QUATERNARY	HOLOCENE	Aℓ	Top Soil	0～1	—		—	—
	PLEISTOCENE	I－1	Sandy Silt Clayey Silt	0～4	8.7×10^{-5}～ 1.2×10^{-4} [1.0×10^{-4}]		Phreatic Aquifer (Low Permeable)	11～25 [16]
		I－2'	Silty Sand Silty Sand with Gravel	0～2	2.7～3.4×10^{-4} [3.0×10^{-4}]		Phreatic Aquifer	8～42 [22]
		I－2	Sand and Gravel, Silty Sand with Gravel, Silty Sand, (A Little Clayey Silt)	0～3.5+	1.7×10^{-4}～ 1.2×10^{-3} [5.0×10^{-4}]		Phreatic Aquifer (Main Aquifer)	15～50/20 [39]
		II－1	Sandy Silt	0～2	—		—	—
		II－2	Silty Sand	0～2	1.5×10^{-4}		Phreatic Aquifer	15
		II－2'	Sand and Gravel (Distributed Q-3 and Q-11 Only)	—	—		Phreatic Aquifer	—
		II－3	Sand and Gravel	0～2	—		Phreatic Aquifer (Main Aquifer)	38
		III－1	Silty Clay Clayey Silt Silty Sand	1～3+	1.1~3.9×10^{-4} [2.1×10^{-4}]	[1.2×10^{-4}]	Impermeable Basement of the Phreatic Aquifer	13～32 [22]
		III－2	Sandy Silt Silty Clay	1～4	4.9~8.8×10^{-5} [6.5×10^{-5}]			10～15 [12]
		III－3	Silty Sand with Gravel Silty Sand Sandy Silt	—	5.9×10^{-5}～ 5.7×10^{-4} [2.0×10^{-4}]		Second Aquifer	11～24 [16]

*) a geometric mean **) an arithmetic mean

Fig. 2.4 Geological Profile at the Tikker Pond Site

(Q-9～T-8～T-3) (Scale : SV=1:100, SH=1:5,000)





Geological Formations

Geological Age		Geological Formation	Constituents	Thickness (m)	Coefficient of Permeability (cm/s) ([ ]shows the average *)		Hydrogeology	N-Value ([ ]shows the average **)
QUATERNARY	HOLOCENE	Aℓ	Top Soil	0～1	—		—	—
	PLEISTOCENE	I - 1	Sandy Silt Clayey Silt	0～4	8.7×10^{-5}～1.2×10^{-4} [1.0×10^{-4}]		Phreatic Aquifer (Low Permeable)	11～25 [16]
		I - 2'	Silty Sand Silty Sand with Gravel	0～2	2.7～3.4×10^{-4} [3.0×10^{-4}]		Phreatic Aquifer	8～42 [22]
		I - 2	Sand and Gravel, Silty Sand with Gravel, Silty Sand, (A Little Clayey Silt)	0～3.5+	1.7×10^{-4}～1.2×10^{-3} [5.0×10^{-4}]		Phreatic Aquifer (Main Aquifer)	15～50/20 [39]
		II - 1	Sandy Silt	0～2	—		—	—
		II - 2	Silty Sand	0～2	1.5×10^{-4}		Phreatic Aquifer	15
		II - 2'	Sand and Gravel (Distributed Q-3 and Q-11 Only)	—	—		Phreatic Aquifer	—
		II - 3	Sand and Gravel	0～2	—		Phreatic Aquifer (Main Aquifer)	38
		III - 1	Silty Clay Clayey Silt Silty Sand	1～3+	1.1～3.9×10^{-4} [2.1×10^{-4}]	[1.2×10^{-4}]	Impermeable Basement of the Phreatic Aquifer	13～32 [22]
		III - 2	Sandy Silt Silty Clay	1～4	1.9～8.8×10^{-5} [6.5×10^{-5}]			10～15 [12]
		III - 3	Silty Sand with Gravel Silty Sand Sandy Silt	—	5.9×10^{-5}～5.7×10^{-4} [2.0×10^{-4}]		Second Aquifer	11～24 [16]

*) a geometric mean **) an arithmetic mean

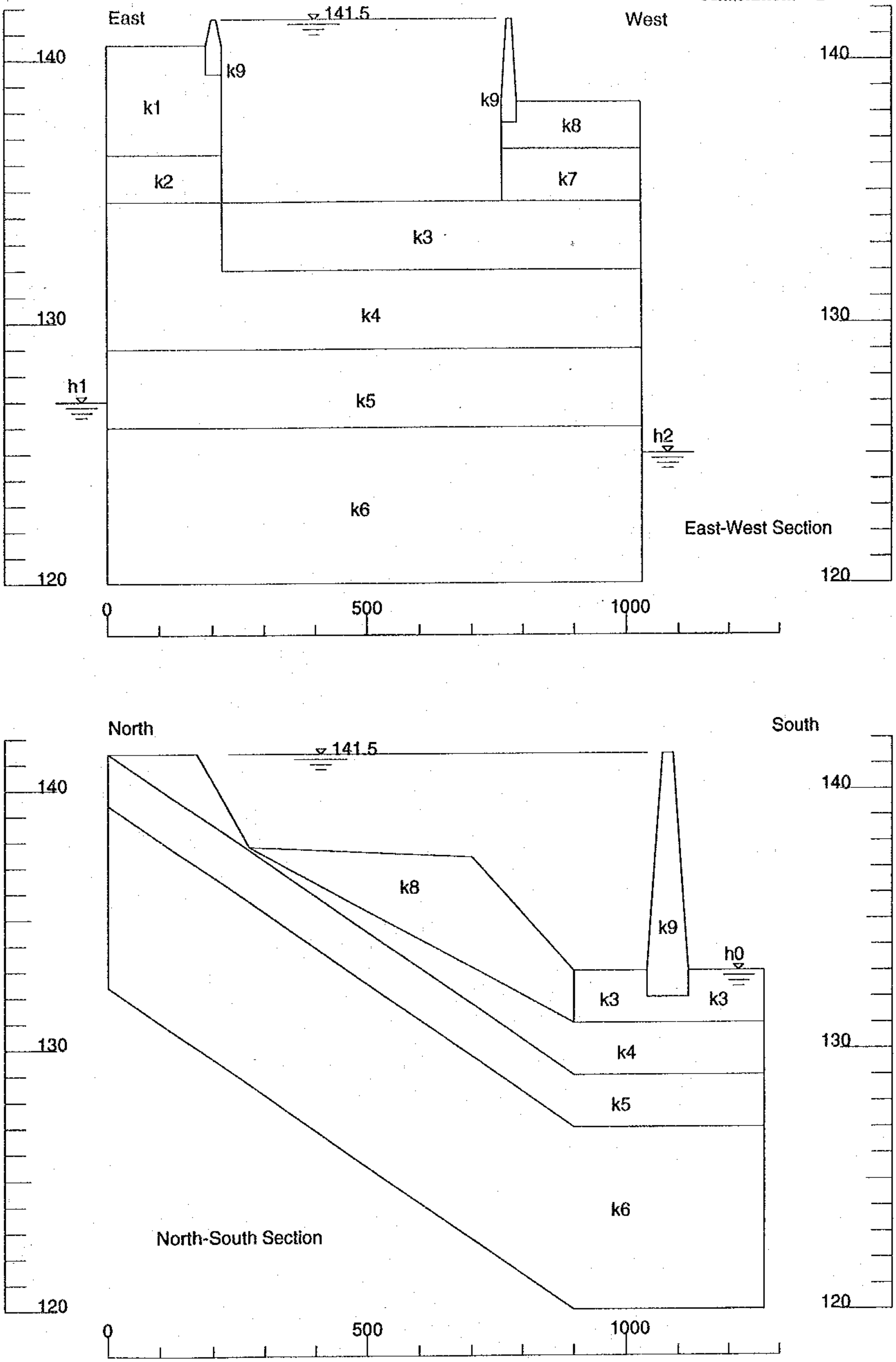


Fig 3.1 Model for Seepage Analysis