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GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF IRRIGATION, WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD

DHAKA INTEGRATED FLOOD PROTECTION PROJECT
MID-TERM CONSULTANCY SERVICES
ADB LOAN - 1124-BAN (SF)

FINAL REPORT

VOLUME - III

ANNEXURE - III : STUDY ON PUMP STATION NO. 3 AT GORANCHATBARI

TECHNOCONSULT INTERNATIONAL LIMITED, BANGLADESH
in association with
ASSOCIATED CONSULTING ENGINEERS LIMITED, BANGLADESH
DESH UPODESH LIMITED, BANGLADESH
and
Individual Consultants from LOUIS BERGER INTERNATIONAL, INC., USA

MAY 1993

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1. Background

1.1 General

This report has been prepared to expand upon the feasibility study for the Dhaka Integrated Flood Protection Project (DIFPP) as related to Pump Station No.3 at Goranchatbari. This Pump Station is a segment of the implementation plan for the DIFPP, (FAP 8B) which was approved for ADB financing in Sept. 1991. This Pump Station is also proposed in the Master Plan for the Greater Dhaka Protection Project (GDPP) which was prepared by Japan International Corporation Agency (JICA) under the Flood Action Plan (FAP 8.A).

1.2 Related to Pump Station

Pump Station No. 3 at Goranchatbari has been proposed as a segment of the Master Plan with an ultimate capacity of 65.2 m^3/s. Under the Feasibility Study for FAP 8.B, the capacity of the Pump Station was reduced to a recommended initial discharge of 22.0 m^3/s, due to funding constraints for early implementation. It is expected that other donors may be found in the near future to allow completion of the full proposed capacity.

2. Purpose of Study

The purpose of this study is to (i) further investigate the effects of construction of the proposed partial capacity pump station of about one-third of the total proposed capacity as recommended by the Master Plan Study & Report, (ii) determine the type of pump and capacity of individual pump, (iii) prepare general layout plan for the pump station with provision for future expansion and (iv) assess the cost of the Pump Station.

Keeping in mind that the recommended ultimate capacity of 65.2 m^3/s is not firmly established, but is based upon providing protection against storms of 2 day duration and 5 year frequency; the possibility of changes in ultimate capacity of the pump station will depend upon the development within the area and the degree of protection desired. Therefore, it is desirable to first install the pump station with partial capacity and to monitor and further study the area with the pump station at partial capacity.

This study provides for an assessment of areas flooded for various combinations of storm duration, storm intensities and with controlled water levels within the drainage area, assuming that sluice gates for drainage from the area will be closed on May 1 of the year. The closure date may vary from year to year depending upon river water levels outside of the embanked area.

This study will also provide a preliminary evaluation of hydraulics and pumping combinations (type and size) required for the first stage with allowance for further expansion to the ultimate capacity.

3. Hydrology Studies - Flood routing

In order to find the flooded area for various combinations of storm duration, storm frequencies and controlled water level elevation at the start of flood routing; the following parameters were established:

- Storms of 2 days, 5 days, 30 days, 5 months and 6 months.
- Storms of 2, 5, 10, 50 and 100 year frequency of occurrence.
- Water levels at start of 5 and 6 month periods (May 1), were established at elevation 3.0 PWD. It was assumed that pumps would operate at full capacity until water levels return to starting level.

The drainage area boundary was reviewed and compared with values determined in the Master Plan study, and was found to be about 5 percent less. However, the boundary limits were not field checked and the higher values from the Master Plan of 57.2 sq. km. has been used in all calculations. For final design, better topographic maps will be needed and field checking of the drainage area will be necessary.

The area - capacity curve from Figure H.18 of the Master Plan report was utilized, but contour maps available for the area are not detailed enough to produce accurate information. For final design, topographic maps with 1/2 meter contour interval will be needed.

The storm rainfall from the Master Plan Report was used based upon the average annual values for 34 years of record.

A runoff factor of 0.8 was used for all computations.

Utilizing information from the Master Plan Report, including; (a) Drainage area 57.2 sq. km, (b) Area capacity Table 1, developed from Figure H.18 of the Master Plan and (c) Pump station discharges of Q=22 m^3/s and Q=65.2 m^3/s; storm routings were carried out for the following conditions:

- 5 yr - 2 day storm with starting water surface elevation at 3.0m.
- 2, 5, 10, 50 yr-5 day storms with starting water surfaces elevation at 3.0m.
- 2, 5, 10, 50 yr-30 day storms with starting water surface elevation at 3.0m.
- 2, 5, 10, 50 yr-5 month storms with starting water surface elevation at 3.0m.
- 2, 5, 10, 50 yr-6 month storms with starting water surface elevation at 3.0m.

Table 2 shows rainfall/runoff for the 30 day storm period at various storm frequencies. A summary of the storm routings for the above listed conditions is shown in Table-3. Figure 1 shows the results of some of the summary in graphic form for the 5 year - 5 day storm period and Figure 2 shows maximum pond elevation and area covered for the 5 month storm period. Table 4 shows the seasonal variation of rainfall/runoff.

From the information shown in Tables 3 & 4, the following main comparisons are made:

- For the 5 year - 2 day, 5 day, 30 day, 5 month and 6 month storms, the maximum pond elevation for pumping Q=22 m^3/s would be about 0.5 meter higher at 3.65 m than for pumping Q=65.2 m^3/s and would cover a ponded area of 15.5 sq. km compared to 8.6 sq. km. for pumping Q=65.2 m^3/s, a difference of 6.9 sq.km. or about 11 percent of the total drainage area.

- For the 10 year - 2 day, 5 day, 30 day, 5 month and 6 month storms, the maximum pond elevation for pumping Q=22 m^3/s would be about 0.47 meter higher at 3.75 m than for pumping Q=65.2 m^3/s and would cover a ponded area of 16.5 sq. km. compared to 10.5 sq. km. for pumping Q=65.2 m^3/s, a difference of 6.0 sq.km. or about 10 percent of the total project area.

- For the 50 year - 2 day, 5 day, 30 day, 5 month and 6 month storms, the maximum pond elevation for pumping Q=22 m^3/s would be about 0.37 meter higher at 3.90 m than for pumping Q=65.2 m^3/s and would cover a ponded area of 19.2 sq. km. compared to 13.8 sq. km. for pumping Q=65.2 m^3/s, a difference of 5.4 sq.km. or about 9 percent of the total drainage area.

- To pump out the 5 year - 5 day storm volume it would require 7.95 days while pumping Q=22 m^3/s compared to 1.95 days at pumping Q=65.2 m^3/s, a difference of six days.

- To pump out the 10 year - 5 day storm volume it would require 8.9 days while pumping Q=22 m^3/s compared to 2.50 days at pumping Q=65.2 m^3/s, a difference of 6.4 days.

- To pump out the 5 year - 5 month storm volume it would require pumping of Q=22 m^3/s for 54 days or 36% of the time compared to 18 days or 12% at pumping Q=65.2 m^3/s, a difference of 36 days.

o To pump out the 50 year - 5 month storm volume it would require pumping of Q=22 m^3/s for 77 days or 51% of the time compared to 26 days or 17% at pumping Q=65.2 m^3/s, a difference of 51 days.

o The 5 year 30 day storm volume without pumping would have a maximum pond elevation of 4.7 m and a maximum pond area of 27.5 sq. km. compared to maximum pond elevation of 3.65 m and maximum pond area of 15.5 sq. km. for pumping of Q=22 m^3/s and maximum pond elevation of 3.15 m and maximum pond area of 8.6 sq. km. for pumping of Q=65.2 m^3/s.

o The 5 year 5 month storm volume without pumping would have a maximum pond elevation of 6.6 m and a maximum pond area of 47.5 sq. km. compared to maximum pond elevation of 3.65 m and maximum pond area of 15.5 sq. km. for pumping of Q=22 m^3/s and maximum pond elevation of 3.15 m and maximum pond area of 8.6 sq. km. for pumping of Q=65.2 m^3/s.

o Changing the base control elevation at start of the control season from elevation 3.0 m to other lower or higher elevations does not significantly affect the relationship between the control levels and the depths of flooding, or the areas flooded. In other words, if the control elevation is set either higher or lower than elevation 3.0 m, the range above that set control is about the same.

o The 5 year 6 month storm volume without pumping would have a maximum pond elevation 6.8 m and a maximum pond area of 49.5 sq. km. compared to maximum pool elevation of 3.65 m and maximum pond area of 15.5 sq. km. for pumping of Q=22 m^3/s and maximum pond elevation of 3.15 and maximum pond area of 8.6 sq. km. for pumping of Q=65.2 m^3/s.

The 5 year frequency of occurrence for storms and storm periods have been used as the basis for design in the Master Plan Report, where the capacity for pumping of 65.2m^3/s was determined based upon the 2 day storm. In the above analysis, the results indicate that the first stage pumping at rate of Q=22 m^3/s will have significant impact upon reducing the flood levels within the protected area, during periods of outside river stages higher than elevation 3.0 meters, or whatever control base elevation is determined to be most suitable.

Based upon results of this study the following general conclusions and recommendation are presented:

Conclusions

(i) The installation of the pumping station at Goranchatbari, with approximately one-third of the final proposed capacity, will provide significant reduction in the area flooded and depth of flooding, during the five month period from May 1 through September when the drainage sluice gates will remain closed to protect the embanked area from higher outside river stages. The differences for conditions; (a) without pumping, (b) with pumping at rate of Q=22 m^3/s and (c) with pumping at rate of 65.2 m^3/s, can be seen on Figure 2 for the five month period beginning on May 1, for various storm frequencies of occurrence, and are summarized as follows :

Description	Storm Frequency	Without Pumping	Pumping Q=22 m^3/s	Pumping Q=65.2 m^3/s
Maximum water surface elevation	2 yr	6.25 m	3.45 m	0 m
	5 yr	6.60 m	3.65 m	3.15 m
	10 yr	6.90 m	3.75 m	3.28 m
	50 yr	7.45 m	3.90 m	3.53 m
Maximum pond area	2 yr	44.0 sq.km	13.0 sq.km	0
	5 yr	47.5 sq.km	15.5 sq.km	8.6 sq.km
	10 yr	51.0 sq.km	16.5 sq.km	10.5 sq.km
	50 yr	56.0 sq.km	19.2 sq.km	13.8 sq.km

(ii) The time required for pumping to remove the 5 month storm volume for various storm frequencies, as shown on Table 3, varies from 30% to 51% of the time for pumping at rate of 22 m^3/s and from 10% to 17% of the time for pumping at rate of 65.2 m^3/s, and is summarized as follows:

Description	Storm Frequency	Days of pumping during 5 month period	Percent of pumping during 5 month period
Days pumping @ Q=22 m^3/s	2 yr	45	30
	5 yr	54	36
	10 yr	61	41
	50 yr	77	51
Days pumping @ Q=65.2 m^3/s	2 yr	15	10
	5 yr	18	12
	10 yr	21	14
	50 yr	26	17

The pumping rate and period determined for the area will depend upon type and rate of development. By monitoring the area and studying the behavior after the one-third capacity pumping is installed, the determination can then be made as to how much additional capacity is required and the timing for such increases.

(iii) By installing the one-third capacity pumping station, the area will be protected from flooding above 3.9 meters for the 50 year storm events (2 day, 5 day, 30 day and up to 5 months). This will allow development of area above about elevation 4.5 m, which is approximately 65 percent of the drainage area. By installing the additional pumping capacity to 65.2 m^3/s the developable area would be increased by about 10 percent, to about 75 percent of the total drainage area, amounting to approximately 5.5 sq. km.

(iv) The water level at start of the assumed pumping period (May 1) may be varied either lower or higher, with about the same effect. In other words, if the starting base elevation is 2.0 m instead of 3.0 as assumed; the corresponding maximum flood levels will be approximately one-half meter higher and likewise if the starting base elevation is 4.0 m the corresponding maximum flood levels will be approximately one-half meter higher, for the 50 year storm frequency and pumping at rate of Q=22 m^3/s.

(v) The maximum water level for storm periods of shorter duration than 5 months will all be within the limit shown for the 5 month storm period, unless extreme storm events occur during an unusually short period of time.

(vi) This study of the hydrology for the pump station has shown that very significant benefits will be derived by pumping with initial one-third capacity and the installation in phases will be of further benefit since it will allow time to study the effect of pumping with partial capacity and to better determine the final design capacity of pump station.

Recommendations

- This hydrology study has confirmed the earlier feasibility study results, which indicate that construction of the pump station with initial capacity of about one-third capacity will have significant favourable impact upon the entire drainage area. It is, therefore, recommended that the investigation for site selection, foundation treatment and design of the pump station should proceed as fast as these activities can be initiated and carried out, along with other activities as part of the DIFPP.

- It is recommended that after completion of the first phase of the pump station (one-third capacity) the effects of pumping should be monitored and studied to determine the cost and timing of future expansion.

TABLE - 1

PUMP STATION NO. 3 GORANCHATBARI
AREA - CAPACITY

ELEV. in meter PWD	INTERVAL in meters	AREA SQ.KM	VOLUME-ABOVE ELEV. 2.0 M		VOLUME ABOVE ELEV. 3.0 M	
			Million m^3	Accumulated total	Million m^3	Accumulated total
2.0		0		0		
2.2	0.2	1.5	0.15	.15		
2.4	0.2	3.0	0.45	.60		
2.6	0.2	4.5	0.75	1.35		
2.8	0.2	6.0	1.05	2.45		
3.0	0.2	7.5	1.35	3.75	0	0
3.2	0.2	10.0	1.75	5.50	1.75	1.75
3.4	0.2	12.4	2.24	7.74	2.24	3.99
3.6	0.2	14.9	2.73	10.47	2.73	6.72
3.8	0.2	17.4	3.23	13.70	3.23	9.95
4.0	0.2	19.9	3.73	17.45	3.73	13.68
4.2	0.2	22.1	4.20	21.63	4.20	17.88
4.4	0.2	24.3	4.64	26.27	4.64	22.52
4.6	0.2	26.5	5.08	31.25	5.08	27.60
4.8	0.2	28.7	5.52	36.87	5.52	33.12
5.0	0.2	31.0	5.97	42.84	5.97	39.09
5.2	0.2	33.0	6.40	49.24	6.40	45.47
5.4	0.2	35.0	6.80	56.04	6.80	52.27
5.6	0.2	37.0	7.20	63.24	7.20	59.47
5.8	0.2	39.0	7.60	70.84	7.60	67.07
6.0	0.2	41.0	8.00	78.84	8.00	75.07
6.2	0.2	43.2	8.42	87.26	9.30	84.4
6.4	0.2	45.3	8.85	96.11	9.30	93.7
6.6	0.2	47.4	9.27	105.38	9.30	103.0
6.8	0.2	49.5	9.69	115.1	9.30	112.3
7.0	0.2	52.0	10.15	125.3	9.30	121.6
7.2	0.2	53.6	10.56	135.9	11.2	132.8
7.4	0.2	55.2	10.88	146.8	11.2	144.0
7.6	0.2	56.8	11.00	157.8	11.2	155.2
7.8	0.2	58.4	11.52	169.3	11.2	166.4
8.0	0.2	60.0	11.84	181.34	11.2	177.6
8.5	0.5	63.0	30.75	212.1	31.1	208.7
9.0	0.5	63.0	31.50	243.6	31.1	239.8
9.5	0.5	63.0	31.50	275.1	31.5	271.3
1.0	0.5	63.0	31.50	306.6	31.5	302.8

Note: Refer to Fig. H.18 Master Plan Report (see Appendix - B)

TABLE - 2

RAINFALL - RUNOFF CHART
COUNTRY SIDE

DAY	Ave. Annual		2 yr.		5 yr.		10 yr.		50 yr.		100 yr.	
	Rf.	Ro.	Rf.	Ro.	Rf.	Ro.	Rf.	Ro.	Rf.	Ro.	Rf.	Ro.
1			110	5.0 88	150	6.9 120	175	8.0 140	250	11.4 200	275	12.6 220
2			185	8.4 148	245	11.2 196	275	12.6 220	360	16.5 288	390	17.8 312
3				9.6		12.6		14.0		18.3		19.8
4				10.5		13.7		15.5		20.0		21.8
5			250	11.4 200	325	14.9 260	370	16.9 295	475	21.7 380	520	23.8 415
6				12.2		15.9		17.8		22.9		25.0
7				12.9		16.6		18.7		24.1		26.2
8				13.6		17.4		19.6		25.2		27.4
9				14.4		18.6		20.5		26.4		28.6
10			330	15.1 264	420	19.2 336	470	21.5 376	600	27.5 480	650	29.7 520
11				15.7		19.8		22.3		28.4		30.6
12				16.3		20.4		23.0		29.3		31.5
13				17.0		21.0		23.7		30.2		32.4
14				17.6		21.6		24.4		31.1		33.4
15			400	18.3 320	485	22.2 388	550	25.2 440	700	32.2 560	750	34.3 600
16				18.6		22.8		25.7		32.9		35.0
17				19.0		23.4		26.2		33.6		35.7
18				19.4		23.8		26.7		34.3		36.4
19				19.8		24.4		27.2		35.0		37.2
20			440	20.1 352	545	24.9 436	605	27.7 484	780	35.6 624	830	38.0 664
21				20.5		25.4		28.3		36.2		38.6
22				20.9		25.9		28.8		36.7		39.2
23				21.2		26.3		29.3		37.3		39.8
24				21.5		26.8		29.8		37.8		40.5
25			480	21.9 384	595	27.2 476	660	30.2 528	840	38.4 672	900	41.1 720
26				22.3		27.6		30.7		38.9		41.7
27				22.7		28.0		31.2		39.3		42.3
28				23.0		28.4		31.7		39.8		42.9
29				23.2		28.8		32.2		40.3		43.5
30	4320		515	23.5 410	640	29.2 510	720	32.8 575	890	40.7 712	970	44.0 770

Legend: Rainfall = Rf.
Runoff = Ro.

NOTES:

1. Refer to Fig. H.15 & H.16 Master Plan (see Appendix - B).
2. Volume of storm is shown in million m^3 for the drainage area of 57.2 Sq.Km.(Runoff only).
3. Rainfall and runoff values are shown for days:1,2,5,10,15,20,25,& 30 in millimeters.

TABLE 3

SUMMARY OF STORM ROUTING AT PUMP STATION

Storm duration	Frequency	Rainfall mm	Runoff million m^3	Pumping Time		Max. Pond Elev.		Max. Pond Area	
				Q22 m^3/s days/% *	Q66.2 m^3/s days/% *	Q22 m^3/s m	Q65.2 m^3/s m	Q22 m^3/s sq.km.	Q65.2 m^3/s Sq.Km.
2 Day	2 yr	185	8.4						
	5 yr	245	11.2	5.9	1.95	3.65	3.15	15.5	8.6
	10 yr	275	12.6						
	50 yr	360	16.5						
	100 yr	390	17.8						
5 Day	2 yr	250	11.4	6.0	0.90	3.45	3.0	13.0	0
	5 yr	325	14.9	7.85	1.95	3.65	3.15	15.5	8.6
	10	370	16.9	8.9	2.50	3.75	3.28	16.5	10.5
	50	475	21.7	11.4	3.55	3.90	3.53	19.2	13.8
	100	520	23.8						
30 Day	2 yr	515	23.5	6.2	0.9	3.45	3.0	13.0	0
	5 yr	640	29.2	9.95	2.0	3.65	3.15	15.5	8.6
	10 yr	720	32.8	12.5	2.5	3.75	3.28	16.5	10.5
	50 yr	890	40.7	17.0	3.25	3.90	3.53	19.2	13.8
	100 yr	970	44.0						
5 Months	2 yr	1878	85.9	45/30	15/10	3.45	3.0	13.0	0
	5 yr	2253	103.1	54/36	18/12	3.65	3.15	15.5	8.6
May	10 yr	2535	116.0	61/41	21/14	3.75	3.28	16.5	10.5
Sept.	50 yr	3192	146.1	77/51	26/17	3.90	3.53	19.2	13.8
	100 yr	3474	159.0	84/56	28/19				
6 Months	2 yr	2059	94.2	50/27	17/9	3.45	3.0	13.0	0
	5 yr	2470	113.0	60/33	20/11	3.65	3.15	15.5	8.6
May	10 yr	2780	127.1	67/37	22.5/12.5	3.75	3.28	16.5	10.5
Oct.	50 yr	3500	160.2	84/47	28.5/16	3.90	3.53	19.2	13.8
	100 yr	3810	174.3	92/51	31/17				

WITHOUT PUMPING	Runoff million m^3	MAX. POND ELEV.	MAX. POND AREA
2 day 5 yr	11.2	3.90 m	18.5 sq.km
2 day 50 yr	16.5	4.15 m	21.5 sq.km
5 day 5 yr	14.9	4.05 m	20.5 sq.km
5 day 50 yr	21.7	4.35 m	23.5 sq.km
30 day 5 yr	29.2	4.70 m	27.5 sq.km
30 day 50 yr	40.7	5.05 m	31.5 sq.km
5 mo. 5 yr.	103.1	6.60 m	47.5 sq.km
5 mo. 50 yr.	146.1	7.45 m	56.0 sq.km
6 mo. 5 yr.	113.0	6.80 m	49.5 sq.km
6 mo. 50.	160.2	7.70 m	57.5 sq.km

Note:

* Shows days of pumping and percent of 5 or 6 month periods.

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TABLE- 4

SEASONAL VARIATION OF RAINFALL/RUNOFF

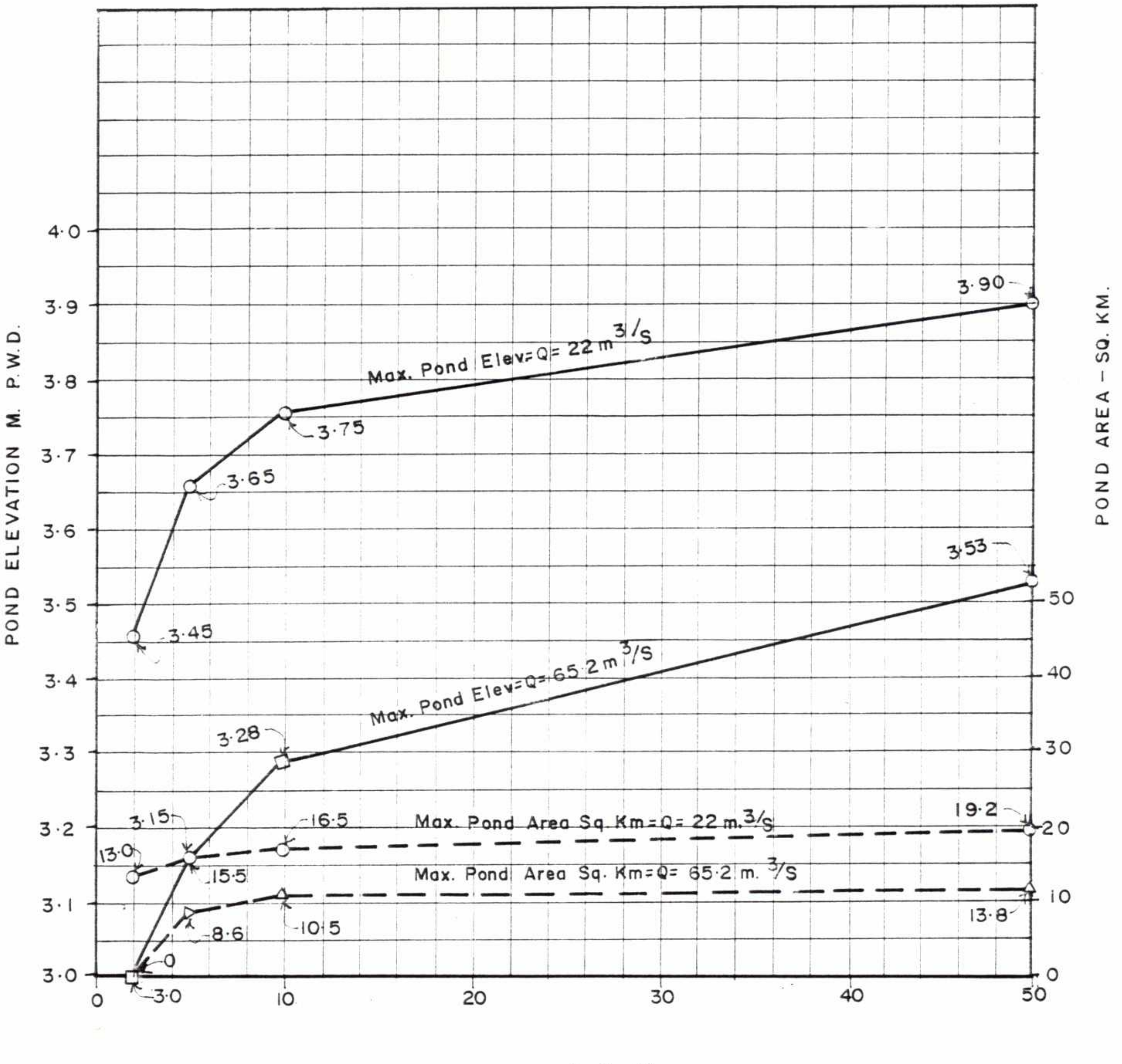
ASSUME RUNOFF COEFFICIENT = 0.80

Month	Ave. Annual Rainfall (mm) *	Ave. Annual Runoff (mm)	% of 5 months	% of 6 months	Runoff - million m^3		
					Average Annual	5 yr.	50 yr.
January	6.5	5.2			.3		
February	20.2	17.0			1.0		
March	52.3	41.8			2.4		
April	124.0	99.2			5.7		
May	283.0	226.4	17.0	15.5	13.0	17.6	24.9
June	398.6	318.8	24.0	21.8	18.2	24.6	34.9
July	391.4	313.0	23.5	21.4	17.9	24.2	34.3
August	328.0	262.4	19.7	18.0	15.0	20.2	28.8
September	264.0	211.2	15.9	14.5	12.1	16.4	23.2
October	160.0	128.0		8.8	7.3	9.9	14.1
November	25.3	20.2			1.1		
December	7.4	5.9			0.3		
May-Sept. (5 months)	1665 = 81%	1331 = 81%	100%		76.2 = 81% Max. WS elev. 6.0 m	103.1 = 81% Max. WS elev. 6.60 m	146.1 = 81% Max. WS elev. 7.45 m
May-Oct. (6 months)	1825 = 88.5%	1460 = 88.5%		100%	83.5=88.5% Max. WS elev. 6.15 m.	113.0=88.5% Max. WS elev. 6.80m.	160.2=88.5% Max. WS elev. 7.70m.
Total	2060 mm	1649 mm			94.3	127.6	181.0

Note : Rainfall data from BWDB (1953-1985) *

FIGURE. - 1

MAXIMUM POND ELEVATION AND AREA COVERED FOR 5 DAY STORM PERIOD

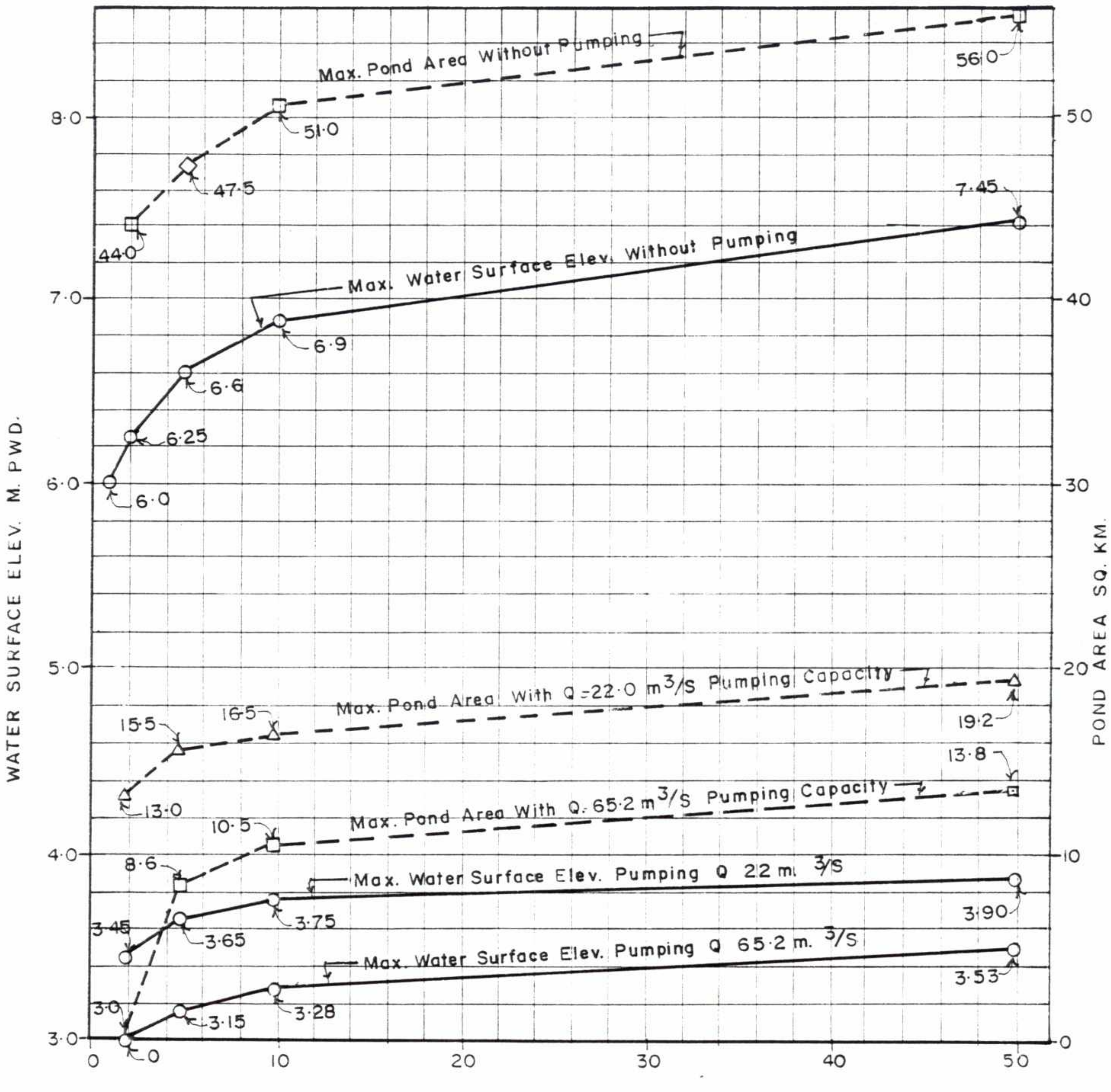


NOTES.

1. Assumed 5 day storm can occur at any time during the 5 or 6 month Period while sluice (drainage) Gates are closed, with assumed water Surface level of 3·0 meters.

FIGURE. - 2

MAXIMUM POND ELEVATION AND AREA COVERED FOR 5 MONTH STORM PERIOD



NOTES

1. Assumed storm period begins May 1 with assumed water surface elevation of 3.0 meter and closure of drainge sluice gates.

4. Pump Station Preliminary Design

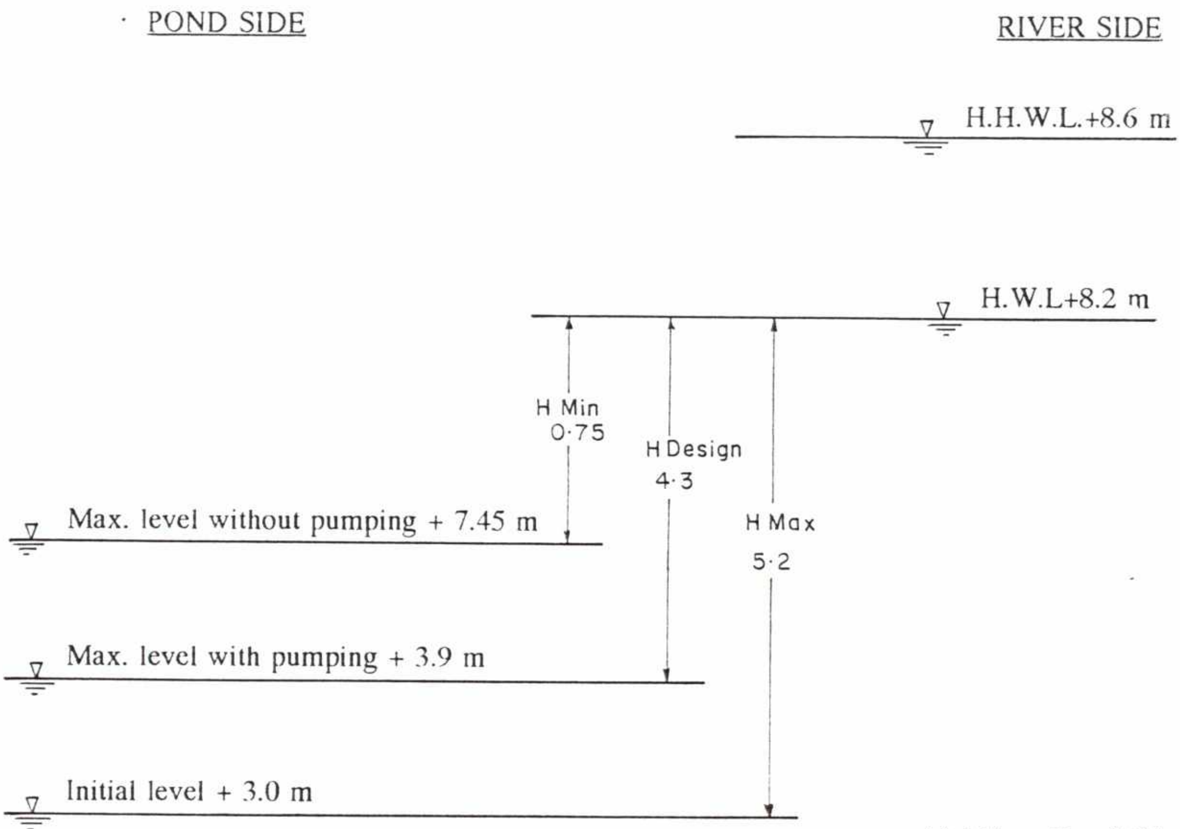
4.1 Pump Station Design Criteria

4.1.1. Pumping Capacity

As determined in the Feasibility Study Report, capacity of the first phase of the pump station will be 22 m^3/sec and the full capacity of the pump station on expansion in future, will be 65.20 m^3/sec. The hydrological study made by the consultants during the bridging period, has confirmed the feasibility study results. Since the pumps will be operated during the months of May to September/Oct., the repair and major maintenance can be done during the idle period. As such availability of the pump is considered 100 per cent and no extra capacity is proposed.

4.1.2 Pumping Head

A. Water levels at Pump Station:



(a) Min. H = 0.75

(b) Design H = 4.3

(c) Max. H = 5.2

B. Determination of Design Head of Pump

i) Pump Static Head

H Min. = River Side H.W.L (50 yr) - Pond Side H.W.L. without Pumping

= 8.2 - 7.45 = 0.75 m

H Max. = River Side H.W.L.(50 yrs) - Pond Side L.W.L. (initial level)

= 8.2 - 3.00 = 5.2 m

H Design = River Side H.W.L.(50 yr) - Maximum pond level with pumping ($Q=22m^3/sec$)

= 8.2 - 3.9 = 4.3 m

ii) Loss of Head for Pump Discharge

Head loss in Pump Station occures in the following area:

1) Friction Loss in Pipe
2) Head Loss in the pipe fittings
3) Loss in the Intake Screen
4) Loss in the Intake Structure

Since the diameter of pipe and fittings, the number of bends and valves, etc. are not finalized at this stage, actual head loss cannot be calculated accurately. However, the total losses is assumed to be 1.5 m.

iii) Total Design Head

Total Design Head = Design Static Head + Total Losses

= 4.3 m + 1.5 m = 5.8 m

C. Pumping period : May to September.

D. Ground elevation at pump station yard : To be decided after further study.

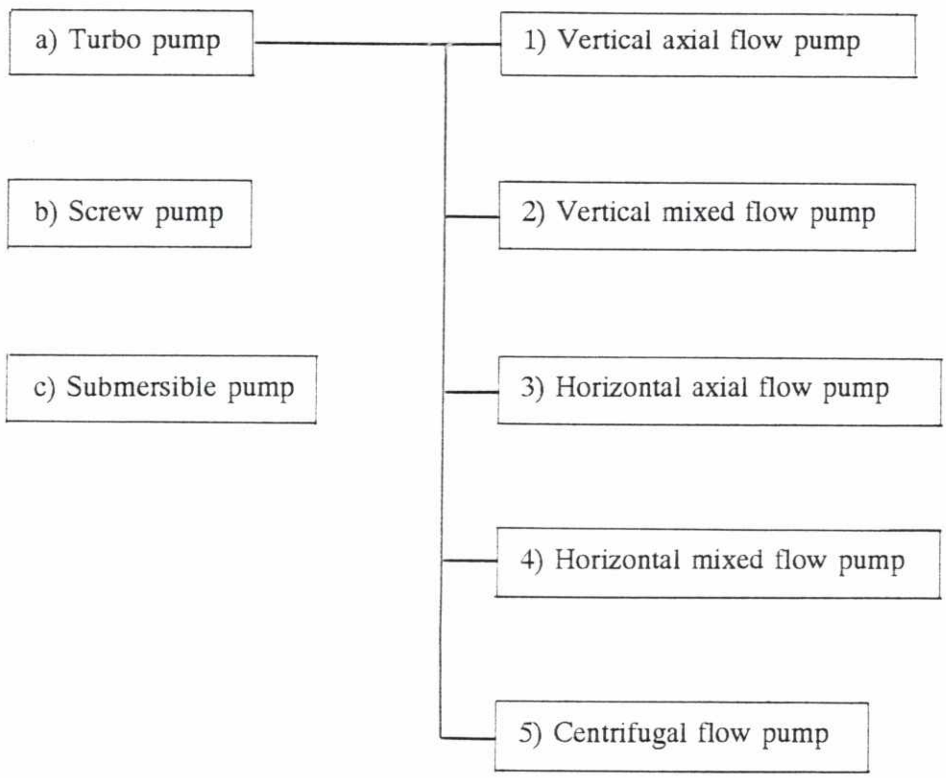
E. The pump facilities shall be principally designed for the required capacity under the static head of 4.30 m. The pumping facility design shall be such that it will be possible to discharge within the range of the static heads of 0.75 m and 5.6 m under the water level conditions as shown in the table below and given in section 4.1.2(A) without significant sacrifice in the pumping efficiency.

River Side Maximum Water Level in meter	Pond Side Water Level in meter			Pump Head in meter	
	Maximum		Minimum (starting level)	Max.	Min.
	Without Pumping	With Pumping			
8.6 (100 yr)	7.45	3.53 ($Q=65.2m^3/s$) 3.90 ($Q=22m^3/s$)	3.00	5.6 (100 yrs)	1.15 (100 yrs)
8.2 (50 yr)			3.00	5.2 (50 yrs)	0.75 (50 yrs)

4.1.3 Pump Type Selection

For Selection of pumps, the different type of pumps available and applicable range in total pump head and pump dia are given below:

PUMP TYPE



APPLICABLE RANGE IN TOTAL PUMP HEAD AND PUMP DIA

Pump Type		Applicable range in Total Pump Head	Available Pump Dia. (mm)
Axial flow	Horizontal	Less than 3 m	Less than 2,000$^{\varnothing}$
	Vertical	Less than 5 m	Less than 4,600$^{\varnothing}$
Mixed flow	Horizontal	Less than 7 m	Less than 2,200$^{\varnothing}$
	Vertical	Less than 9 m	Less than 4,600$^{\varnothing}$
Centrifugal flow pump	Horizontal	More than 10 m	Less than 1,600$^{\varnothing}$
	Vertical	More than 10 m	Less than 2,000$^{\varnothing}$
Screw pump		Less than 8 m	Less than 3,500$^{\varnothing}$
Submersible pump		Less than 20 m	Less than 1,800$^{\varnothing}$

Based on the criteria of the total pumping head of approximately 5.8 m and the capacity of two pumps of 11 m^3/sec, each the following three alternative pump types are considered:

Alternative 1: Vertical mixed flow pump

Alternative 2: Horizontal mixed flow pump

Alternative 3: Submersible pump

Other types of pump such as horizontal axial flow pump, centrifugal flow pump and screw pump, for pumping large flows over low heads are less suitable for the Goranchatbari pump station in consideration of their efficiency, operation and maintenance characteristic and construction cost. The pump type study is, therefore, limited to a comparison of above three pump types.

Alternative 1: Vertical mixed flow pump

Merits:

- It can be operated at high reliability over a wide range of flows with easy operation and maintenance

Demerits:

- Compared to the horizonal mixed flow type, this type saves 5 to 10 per cent in cost for civil works, but it requires additional cost for mechanical equipment. As a result, the total construction cost is higher.

Alternative 2: Horizonal mixed flow type

Merits:

- Dismantling of pump for inspection and repair is simple.
- Only a small vertical clearance is required inside the pump house for dismantling and removing pump.
- Total construction cost, including cost of equipment and civil works is less than that for vertical axial for type.

Demerits:

- Pre-operational procedures of pump is rather complicated and lengthy. The following steps are required to be taken when starting pump operation:

  a) Start the vacuum pump.

  b) Confirm that there is a full supply of water in the intake casing.

  c) Switch on the main pump.

  d) Start opening the discharge valve.

  e) Fully open the discharge valve.

  f) Stop vacuum pump operation

Due to the above-mentioned pre-operational steps, operational reliability of this type is lower then that of the vertical mixed flow type. Besides, a more detailed inspection of many pieces of auxiliary equipment is required in comparison to the vertical mixed flow type pump.

Alternative 3: Submersible motor pump

Merits:

- Total construction cost is approximately half of that for the other two types of pump.

Demerits:

a) Pump life is very short (5-7 yrs.), which is about one-third of the life of other two types of pumps.

b) Since motor is submersed more faults are experienced.

Through comparison of merits and demerits of each pump type, the vertical mixed flow pump is proposed as it can be operated under wide variation of head with little sacrifice of efficiency. This type of pump is more reliable and its operation and maintenance is easy. The available technical know-how for operation, repair and maintenance also warrants selection of this type of pump.

4.1.4 Number of pump units

Construction cost of pump station with fewer pump units of higher capacity is less than that of pump station with larger number of pump units of lower capacity. But operational risk with pump of higher capacity is higher than that with pump of lower capacity. If two pump unit are provided in the first phase of the pump station , the operational risk will be 50 per cent in case one pump goes out of order. If three pump units are provided, the operational risk wall be 33 per cent in case one pump goes out of order. On installation of the full capacity pump station, non-functioning of one pump will reduce the capacity of pump station by 16.6 per cent in case of six pumps and 11.1 per cent in case of nine pumps. Increase in the operational risk with pumps of higher capacity is not significant. In view of the lower construction cost of pump station and the lower capital cost of pump of higher capacity, two pump units of capacity 11 m^3/sec each is proposed for the first phase of the proposed pump station.

It may be mentioned here that pumps will be running for about 5 (five) months in a year. As such all the pumps will be available for annual maintenance and repair during the remaining 7 (seven) month, which will minimize the operational risk to a great extent and the availability of pumps during the operating season is expected to be 100 per cent.

4.1.5 Power source of pump operation

As alternatives for the power source, the electrical motor driven type and diesel engine type have been studied. Of the two types, the electrical motor driven type is proposed, taking into consideration the ease of its operation and maintenance, and availability of electricity in Dhaka. A backup electric power source will have to be provided to face emergency arising from power failure.

4.2 Pump Station location

Location of the proposed pump station will depend on the sub-soil condition and other factors which will influence the selection of location. Sub-soil boring has been made at some locations in the area near the prosperative sites of the pump station. The location of the boring points and the depth below which the SPT values greater than 5, are shown in figure 3. The sub-soil information on the said area have been reviewed. It appears form the review of sub-soil information that the area near (i) ch. 13+100 (located about 1.2 km north of the anticipated location near the old channel crossing of the embankment, (ii) ch. 14+300 (near the old channel crossing of the embankment and (iii) ch. 14+750 (near the Botanical Garden area), will offer the suitable site for the pump station. But further sub-soil investigation and study are needed to select the most suitable site.

A plane-table survey of the area near ch. 14+750 was made under the Bridging Service Contract, but time and funds did not permit survey of the other two area.Plane-table survey of the other two areas might be necessary.

4.3 Pump Station Building

The pump station building is to be planned and designed for the initial capacity of 22m3/sec with provision of expansion for full capacity in future. All common facilities such as electric panel room, repairing space, overhead crane, etc should be included in the first phase of the pump station. The super structure of the pump station will have to provide spaces for the following:

(i) Pump and motor equipment room
(ii) Electric panel room
(iii) Control room
(iv) Repair workshop
(v) Store room for spares and tools
(vi) Staff resting room
(vii) Meeting room
(viii) Toilet

The floor area at first phase of pump station building, including the electric panel room and repairing space will be about 460 m^2 and that of the full capacity pump station will be about 750 m^2. A layout plan of pump station building is shown in fig. 4 and a typical sectional elevation of the building is shown in figure 5.

The inlet and discharge basin of the pump station will be sized in accordance with the hydraulic requirements.

4.4 Pump station foundation

From study of existing bore-logs of the sub-soils in the areas where the pump station might be constructed, it is apparent that treatment of the foundation soil will be required for its improvement. The possible alternative sub-grade improvement measures are (i) RCC piling (pre-cast/cast-in-situ) (ii) stabilized earth pier/grouted columns (iii) installation of vertical wick drains with pre-loading and (iv) sand piling.

On selection of the site of the pump station,it will be necessary to make detailed investigation of the foundation soil for determining the most suitable measure for foundation treatment.

Depending on the type of foundation treatment found to be most suitable, it may be advantageous to provide treatment to the entire ultimate pump station area during construction of the first phase of the pump station. This is especially significant if foundation treatment by vertical wick drains and pre-loading are found to be most suitable. Since additional borrow earth for embankment construction will be needed in the area near the pump station and since there will be ponding area at the pump station site, where right of way will have to be acquired for permanent use, it might be advantageous to combine these efforts to utilize the borrow earth for pre-loading and then utilize the same for embankment construction after the pre-loading function is completed. This option would require careful scheduling and advance planning to ensure that excavation and work progress as smoothly as per schedule.

4.5 Power Supply

Power requirement for each pump with 20% reserve is estimated at 900 KW at this stage. So for six pumps the requirement is 5.4 MW. Considering 10% for the allied equipments, total power requirement for the pump station will be 6 MW. As per BPDB rules, supply of power will be through high voltage line of 33 KV (from 5 MW to 15 MW). So a 33/3.3 KV Substation of 7.5 MVA capacity is needed for the pumping station. Detail design of the sub-station will be needed after finalization of Pump and Motor specifications.

5. Cost of pump station

The cost of the first phase of was estimated during the feasibility study, based on the information available at that time. The costs shown in the feasibility study report are as follows:

Total cost including duties and taxes	= Tk. 400 million
- Cost of civil work	= Tk. 120 million
- Cost of materials and equipment	= Tk. 280 million

During the Bridging Period of the consultancy services, preliminary study was made on the pump station and some additional relevant information was collected. Cost of the pump station has been estimated at Tk. 458 million on the basis of study made and information collected during the bridging period. The break-up of the cost is as follows:

(i)	Civil work	= Tk. 104 million
(ii)	Pump	= Tk. 146 million
(iii)	Motor and gear box	= Tk. 76 million
(iv)	Pipe and valve	= Tk. 28 million
(v)	Electrical facilities	= Tk. 62 million
(vi)	Crane and allied equipments	= Tk. 16 million
(vii)	Pump installation carriage and storing	= Tk. 21 million
(viii)	Misc.	= Tk. 5 million
	Total	= Tk. 458 million

6. Design and Construction Schedule of Pump Station

Implementation the project has two major divisions. One is construction of pump station building (civil works) and the other is procurement of pumps and associated equipment and installation of these equipment.

1) Construction of pump station building has the following components:

   a) Detail Design, finalisation of specifications and preparation of Tender Document (eight months).

   b) Tendering, evaluation and award of contract for works (four months).

   c) Construction of pump house including mobilization and demobilization (twelve months).

2) Procurement and Installation of Pumps and Associated equipments has the following components:

   a) Finalization of specifications and Preparation of Tender Document (three months).

   b) Tendering, evaluation and award of contract (four months).

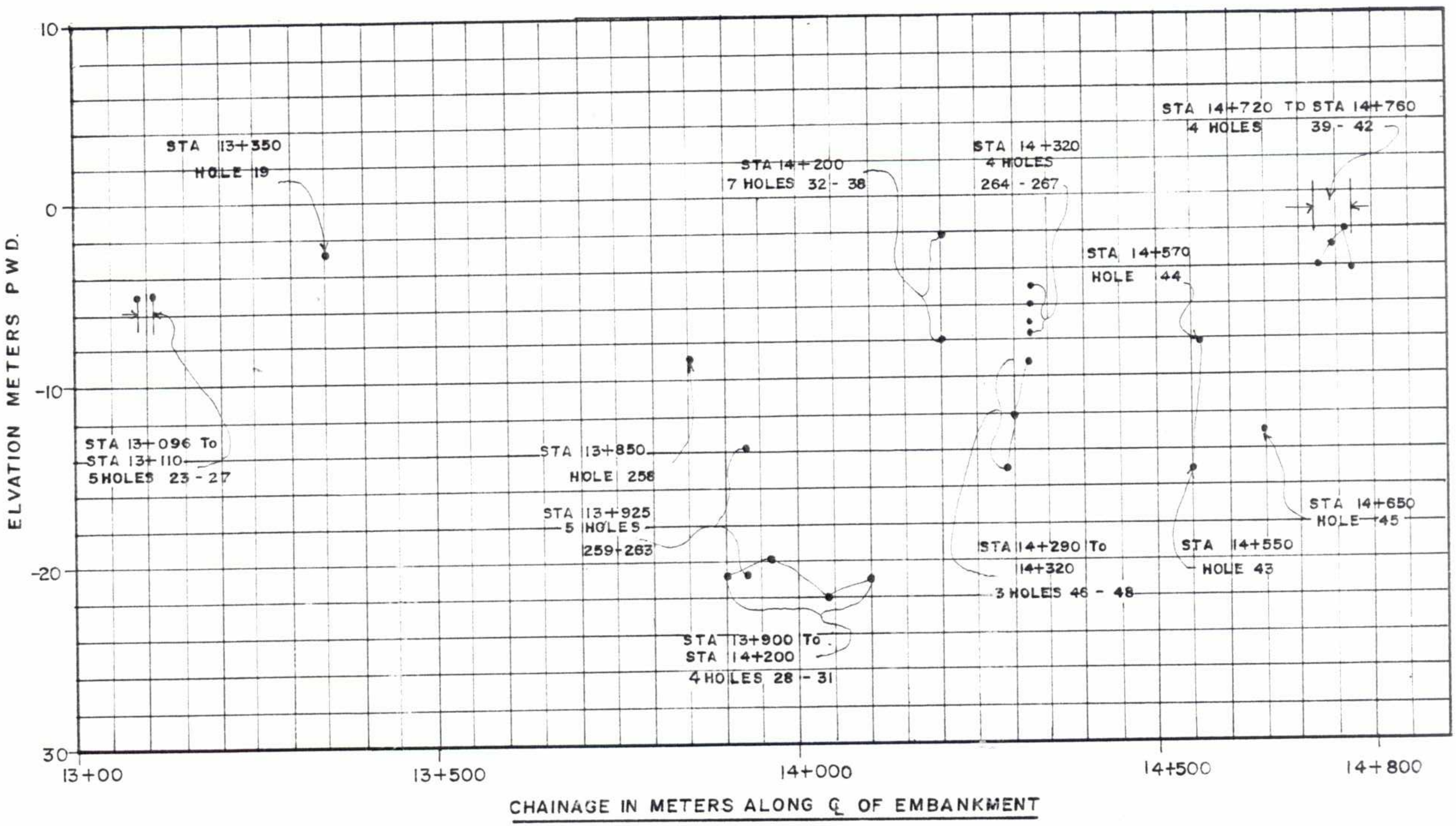
   c) Manufacturing and shipment of pumps and equipment (ten months).

   d) Clearing and carriage of the pumps and equipment to site (three months).

   e) Installation and Commissioning (four months).

The total period for design and construction of pump station building, procurement of pumps and equipment and installation of pumps is 28 months. The design and construction schedule is shown in fig. 6.

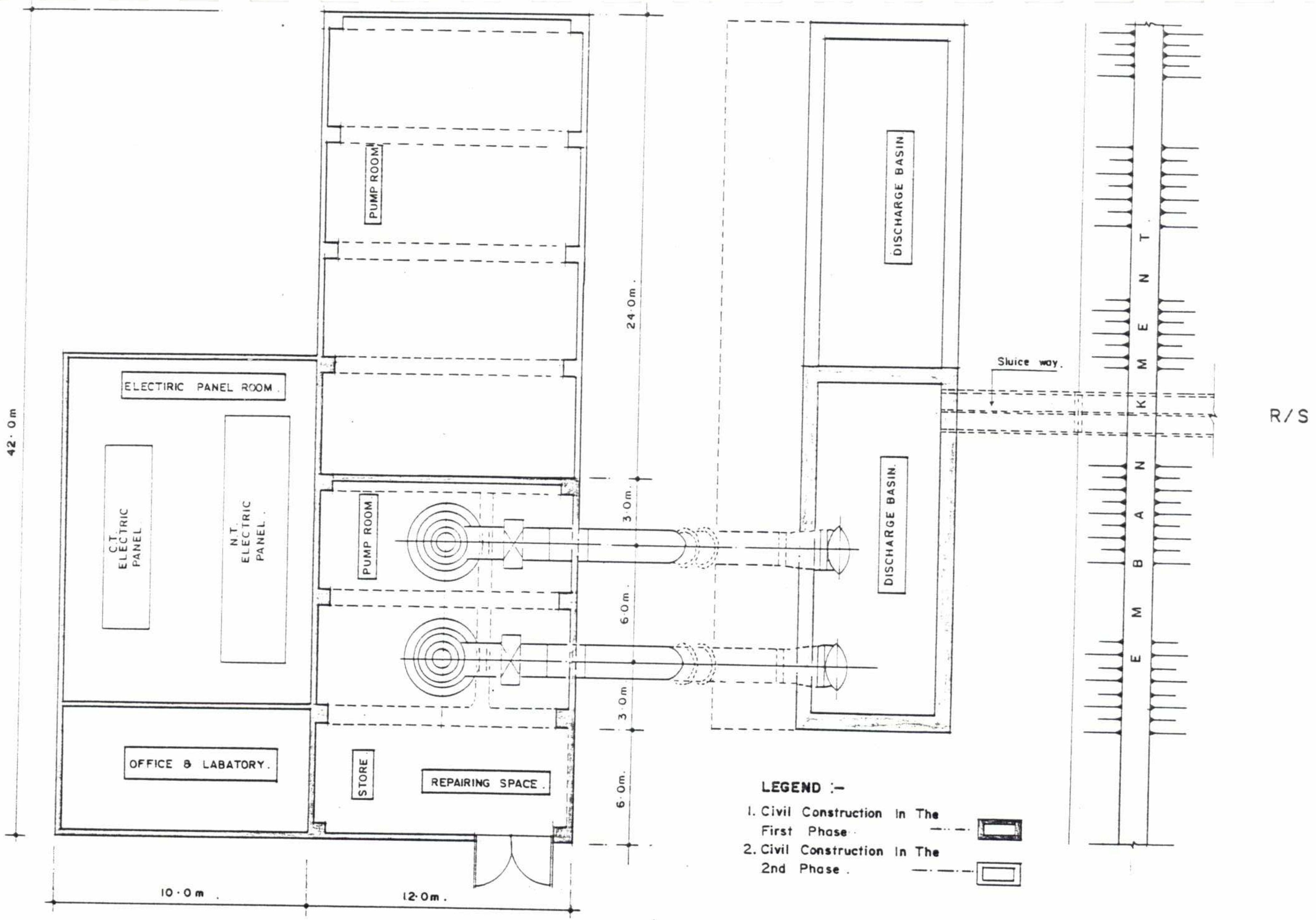
LOCATIONS OF SUB-SOIL BORINGS AND INFORMATION ABOUT S.P.T. VALUES (SOFT SUBSOILS) IN PUMP STATION AREA



NOTES.

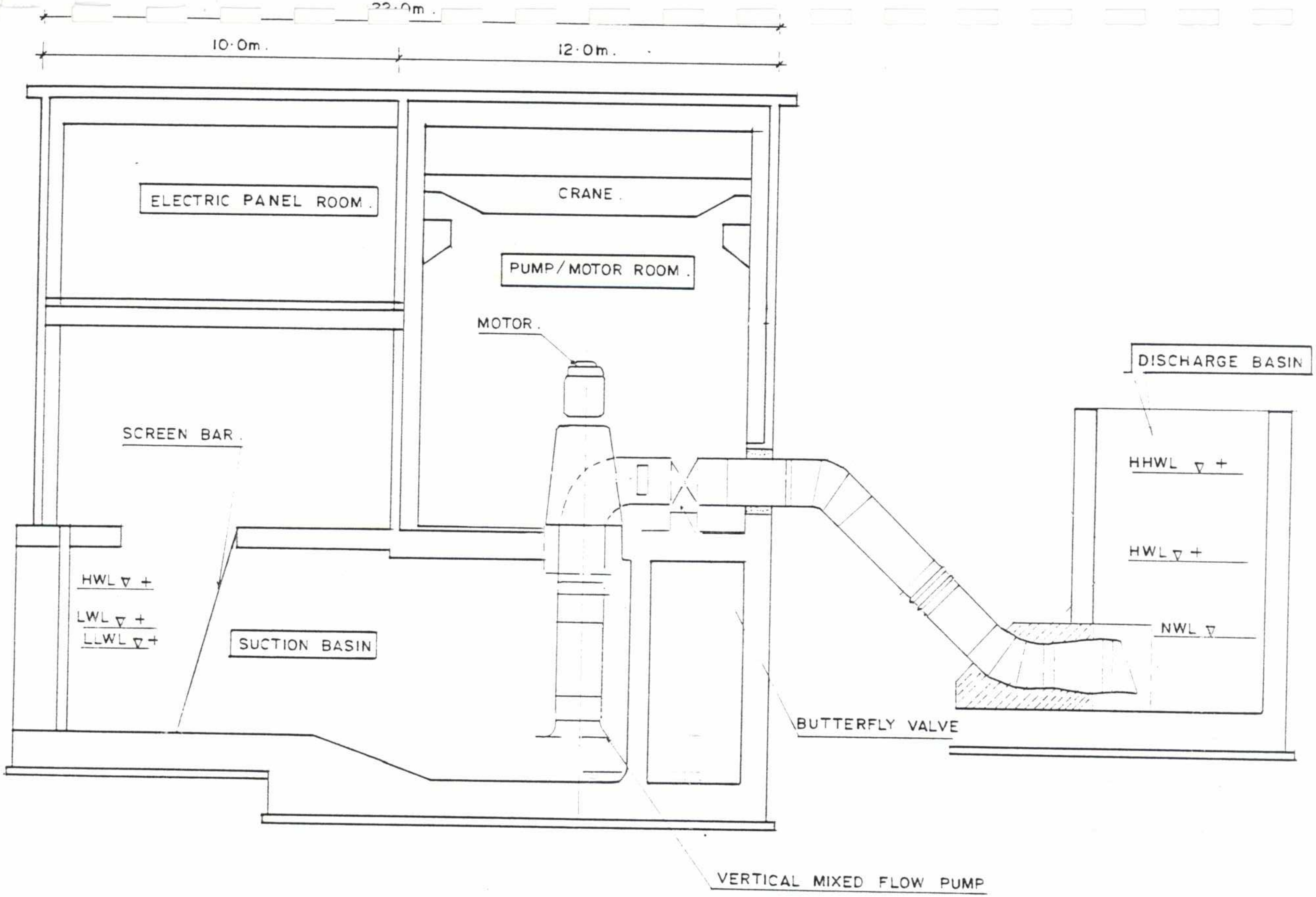
1. Plotted Points indicates depths below which S.P.T. values are greater than 5
2. Prospective Pump station locations are : (a) STA. 13+100 (b) STA. 14+300 & (c) STA. 14+750

FIGURE - 3



TYPICAL LAY-OUT PLAN OF PUMPING PLANT No. 3 AT GORANCHATBARI

FIGURE - 4



TYPICAL SECTIONAL ELEVATION OF PUMPING PLANT FOR VERTICAL MIXED FLOW PUMP.

FIGURE - 5

62

DESIGN AND CONSTRUCTION SCHEDULE OF PUMPING STATION

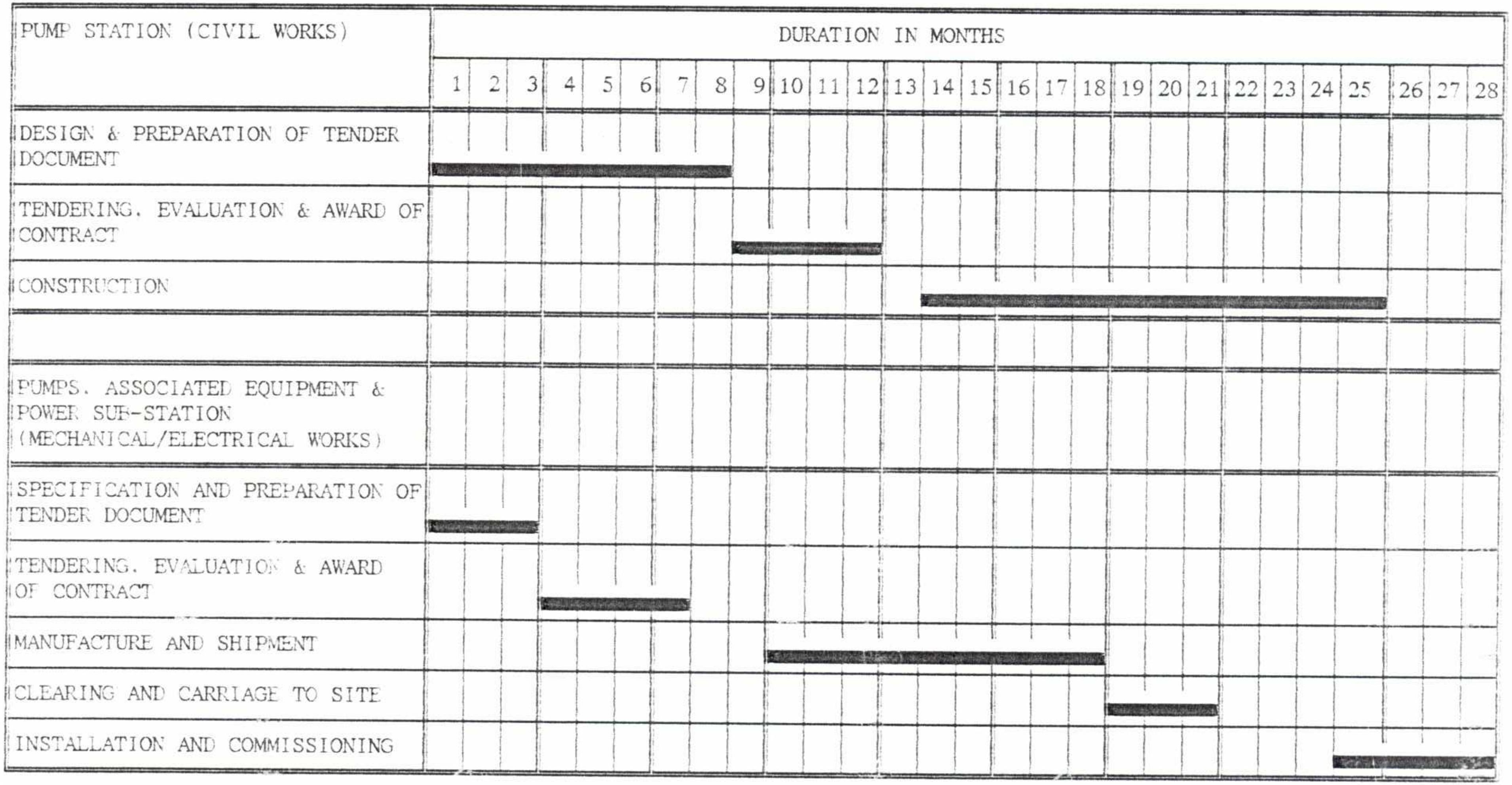


FIGURE - 6

APPENDIX-A

APPENDIX-A

HYDROLOGY-FLOOD ROUTING

5 Yr **Frequency**   **2 Day** **Duration**

Day	Runoff		Pumping				Volume in Excess of Pumping				Q22		Q65.2	
	Million m^3		Q22		Q65.2		Q22		Q65.2		Max.WS Elev. m	Max. Pond Area. sq. km	Max.WS Elev. m	Max.Pond Area. sq. km
	Daily	Accum	million m^3		million m^3		million m^3		million m^3					
			Daily	Accum	Daily	Accum	Daily	Accum	Daily	Accum				
1	6.9	6.9	1.9	1.9	5.63	5.63	5.0	5.0	1.27	1.27			3.15	8.6
2	4.3	11.2	1.9	3.8	5.63	11.26	2.4	7.4	-1.33	-.06 ←	3.65	15.5		
3			1.9	5.7	5.63		-1.9	5.5						
4			1.9	7.6	5.63		-1.9	3.6						
5			1.9	9.5	5.63		-1.9	1.7						
6			**1.9**	10.4			-1.9	-0.2 ←						
7														
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Summary

Q22 pumping for 5.9 days   11.2÷1.9 = 5.9 days
Q65.2 pumping for 1.95 days
Q22 max. pond elev. 3.65m, max. pond area 15.5 sq.km
Q69.2 max. pond elev. 3.15m, max. pond area 8.6 sq.km
← shows day when pond water level returns to elev 3.0m and pumping stops.

APPENDIX-A

HYDROLOGY-FLOOD ROUTING

2 Yr **Frequency** **5 Day** **Duration**

Day	Runoff		Pumping				Volume in Excess of Pumping				Q22		Q65.2	
	Million m^3		Q22 million m^3		Q65.2 million m^3		Q22 million m^3		Q65.2 million m^3		Max.WS Elev. m	Max. Pond Area. sq. km	Max.WS Elev. m	Max.Pond Area. sq. km
	Daily	Accum	Daily	Accum	Daily	Accum	Daily	Accum	Daily	Accum				
1	5.6	5.0	1.9	1.9	5.63	5.63	3.1	3.1	-0.63	None			3.0	0
2	3.4	8.4	1.9	3.8	5.63	11.26	1.5	4.6			3.45	13.0		
3	1.2	9.6	1.9	5.7	5.63	16.89	-0.7	3.9						
4	0.9	10.5	1.9	7.6	5.63	22.52	-1.0	2.9						
5	0.9	11.4	1.9	9.5	5.63	28.15	-1.0	1.9						
6			1.9	11.4			1.9	0←						
7			1.9	13.3										
8			1.9	15.2										
9			1.9	17.1										
10			1.9	19.0										
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Summary

Q22 pumping for 6.0 days 11.4÷1.9 = 6 days
Q65.2 pumping for 0.9 days
Q22 max. pond elev. 3.45m, max. pond area 13.0 sq.km
Q65.2 max. pond elev. 3.0m, max. pond area 0

← shows day when pond water level returns to elev 3.0 and pumping stops.

HYDROLOGY-FLOOD ROUTING

5 Yr
Frequency

5 Day
Duration

Day	Runoff		Pumping				Volume in Excess of Pumping				Q22		Q65.2	
	Million m^3		Q22		Q65.2		Q22		Q65.2		Max.WS Elev. m	Max. Pond Area. sq. km	Max.WS Elev. m	Max.Pond Area. sq. km
	Daily	Accum	million m^3		million m^3		million m^3		million m^3					
			Daily	Accum	Daily	Accum	Daily	Accum	Daily	Accum				
1	6.9	6.9	1.9	1.9	5.63	5.63	5.0	5.0	1.27	1.27			3.15	8.6
2	4.3	11.2	1.9	3.8	5.63	11.26	2.4	7.4	-1.33	-.06 ←	3.65	15.5		
3	1.4	12.6	1.9	5.7	5.63	16.89	-0.5	6.9						
4	1.1	13.7	1.9	7.6	5.63	22.52	-0.8	6.1						
5	1.2	14.9	1.9	9.5	5.63	28.15	-0.7	5.4						
6			1.9	11.4			-1.9	3.5						
7			1.9	13.3			-1.9	1.6						
8			1.9	15.2			-1.9	-0.3 ←						
9			1.9	17.1			-1.9							
10			1.9	19.0			-1.9							
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Summary

Q22 pumping for 7.85 days 14.9÷1.9 = 7.85 days
Q65.2 pumping for 1.95 days
Q22 max. pond elev. 3.65m, max. pond area 15.5 sq.km
Q65.2 max. pond elev. 3.15m, max. pond area 8.6 sq.km
← shows day when pond water level returns to elev 3.0 and pumping stops.

APPENDIX-A

HYDROLOGY-FLOOD ROUTING

10 Yr
Frequency

5 Day
Duration

Day	Runoff		Pumping				Volume in Excess of Pumping				Q22		Q65.2	
	Million m³		Q22		Q65.2		Q22		Q65.2		Max.WS Elev. m	Max. Pond Area. sq. km	Max.WS Elev. m	Max.Pond Area. sq. km
	Daily	Accum	million m³		million m³		million m³		million m³					
			Daily	Accum	Daily	Accum	Daily	Accum	Daily	Accum				
1	8.0	8.0	1.9	1.9	5.63	5.63	6.1	6.1	2.37	2.37			3.28	10.5
2	4.6	12.6	1.9	3.8	5.63	11.26	2.7	8.8	-1.03	1.34 ←	3.75	16.5		
3	1.4	14.0	1.9	5.7	5.63	16.89	-.5	8.3	-4.23	-2.89				
4	1.5	15.5	1.9	7.6	5.63	22.52	-.4	7.9						
5	1.4	16.9	1.9	9.5	5.63	28.15	-.5	7.4						
6			1.9	11.4			-1.9	5.5						
7			1.9	13.3			-1.9	3.6						
8			1.9	15.2			-1.9	1.7						
9			1.9	17.1			-1.9	-.2 ←						
10			1.9	19.0			-1.9							
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Summary

Q22 pumping for 8.9 days 16.9÷1.9 = 8.9 days
Q65.2 pumping for 2.5 days
Q22 max. pond elev. 3.75m, max. pond area 16.5 sq.km
Q65.2 ma6x. pond elev. 3.28m, max. pond area 10.5 sq.km

← shows day when pond water level returns to elev 3.0 and pumping stops.

HYDROLOGY-FLOOD ROUTING

<u>50 Yr</u>
Frequency

<u>5 Day</u>
Duration

Day	Runoff		Pumping				Volume in Excess of Pumping				Q22		Q65.2	
	Million m^3		Q22		Q65.2		Q22		Q65.2		Max.WS Elev. m	Max. Pond Area. sq. km	Max.WS Elev. m	Max.Pond Area. sq. km
	Daily	Accum	million m^3		million m^3		million m^3		million m^3					
			Daily	Accum	Daily	Accum	Daily	Accum	Daily	Accum				
1	11.4	11.4	1.9	1.9	5.63	5.63	9.5	9.5	5.77	5.77			3.53	13.8
2	5.1	16.5	1.9	3.8	5.63	11.26	3.2	12.7	-.53	5.24	3.90	19.2		
3	1.8	18.3	1.9	5.7	5.63	16.89	-0.1	12.6	-3.83	+1.41				
4	1.7	20.0	1.9	7.6	5.63	22.52	-0.2	12.4	-3.93	-2.52←				
5	1.7	21.7	1.9	9.5	5.63	28.15	-0.2	12.2						
6			1.9	11.4			-1.9	10.3						
7			1.9	13.3			-1.9	8.4						
8			1.9	15.2			-1.9	6.5						
9			1.9	17.1			-1.9	4.6						
10			1.9	19.0			-1.9	2.7						
11			1.9	20.9			-1.9	0.8						
12			1.9	22.8			-1.9	-1.1←						
13			1.9	24.7										
14			1.9	26.6										
15			1.9	28.5										
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Summary

Q22 pumping for 11.4 days 21.7÷1.9 = 11.4 days
Q65.2 pumping for 3.55 days
Q22 max. pond elev. 3.90m, max. pond area 19.2 sq.km
Q65.2 max. pond elev. 3.53m, max. pond area 13.8 sq.km

← shows day when pond water level returns to elev 3.0 and pumping stops.

HYDROLOGY-FLOOD ROUTING

2 Yr **Frequency** — **30 Day** **Duration**

Day	Runoff		Pumping				Volume in Excess of Pumping				Q22		Q65.2	
	Million m³		Q22 million m³		Q65.2 million m³		Q22 million m³		Q65.2 million m³		Max.WS Elev. m	Max. Pond Area. sq. km	Max.WS Elev. m	Max.Pond Area. sq. km
	Daily	Accum	Daily	Accum	Daily	Accum	Daily	Accum	Daily	Accum				
1	5.0	5.0	1.9	1.9	5.63	5.63	3.1	3.1	-.63	None			3.0	0
2	3.4	8.4	1.9	3.8	5.63	11.26	1.5	4.6			3.45	13.0		
3	1.2	9.6	1.9	5.7	5.63	16.89	-0.7	3.9						
4	0.9	10.5	1.9	7.6	5.63	22.52	-1.0	2.9						
5	0.9	11.4	1.9	9.5	5.63	28.15	-1.0	1.9						
6	0.8	12.2	1.9	11.4	5.63	33.78	-1.1	0.8 ←						
7	0.7	12.9	1.9	13.3	5.63	39.41	-1.2	-0.4						
8	0.7	13.6	1.9	15.2	5.63	45.04	-1.2							
9	0.8	14.4	1.9	17.1	5.63	50.67	-1.1							
10	0.7	15.1	1.9	19.0	5.63	56.30	-1.2							
11	0.6	15.7	1.9	20.9	5.63									
12	0.6	16.3	1.9	22.8	5.63									
13	0.7	17.0	1.9	24.9	5.63									
14	0.6	17.6	1.9	26.6	5.63									
15	0.7	18.3	1.9	28.5	5.63	84.45								
16	0.3	18.6	1.9		5.63									
17	0.4	19.0	1.9		5.63									
18	0.4	19.4	1.9		5.63									
19	0.4	19.8	1.9		5.63									
20	0.3	20.1	1.9	38.0	5.63	112.6								
21	0.4	20.5	1.9		5.63									
22	0.4	20.9	1.9		5.63									
23	0.3	21.2	1.9		5.63									
24	0.3	21.5	1.9		5.63									
25	0.4	21.9	1.9	42.5	5.63	140.7								
26	0.4	22.3	1.9		5.63									
27	0.4	22.7	1.9		5.63									
28	0.3	23.0	1.9		5.63									
29	0.2	23.2	1.9		5.63									
30	0.3	23.5	1.9	57.0	5.63	168.9								

Summary

Q22 pumping for 6.2 days — 23.5÷1.9 = 12.4 days

Q65.2 pumping for 0.9 days

Q22 max. pond elev. 3.45m, max. pond area 13.0 sq.km

Q65.2 max. pond elev. 3.0m, max. pond area 0

← shows day when pond water level returns to elev 3.0 and pumping stops.

HYDROLOGY-FLOOD ROUTING

5 Yr **Frequency**   **30 Day** **Duration**

Day	Runoff		Pumping				Volume in Excess of Pumping				Q22		Q65.2	
	Million m^3		Q22		Q65.2		Q22		Q65.2		Max.WS Elev. m	Max.Pond Area. sq. km	Max.WS Elev. m	Max.Pond Area. sq. km
	Daily	Accum	million m^3		million m^3		million m^3		million m^3					
			Daily	Accum	Daily	Accum	Daily	Accum	Daily	Accum				
1	6.9	6.9	1.9	1.9	5.63	5.63	5.0	5.0	1.27	1.27			3.15	8.6
2	4.3	11.2	1.9	3.8	5.63	11.26	2.4	7.4	-1.33	-0.06←	3.65	15.5		
3	1.4	12.6	1.9	5.7	5.63	16.89	-.5	6.9						
4	1.1	13.7	1.9	7.6	5.63	22.52	-.8	6.1						
5	1.2	14.9	1.9	9.5	5.63	28.15	-.7	5.4						
6	1.0	15.9	1.9	11.4	5.63	33.78	-.9	4.5						
7	0.7	16.6	1.9	13.3	5.63	39.41	-1.2	3.3						
8	0.8	17.4	1.9	15.2	5.63	45.04	-1.1	2.2						
9	0.9	18.3	1.9	17.1	5.63	50.67	-1.0	1.2						
10	0.9	19.2	1.9	19.0	5.63	56.30	-1.0	-0.2←						
11	0.6	19.8	1.9	20.9	5.63									
12	0.6	20.4	1.9	22.8	5.63									
13	0.6	21.0	1.9	24.7	5.63									
14	0.6	21.6	1.9	26.6	5.63									
15	0.6	22.2	1.9	28.5	5.63	84.45								
16	0.6	22.8	1.9	30.4	5.63									
17	0.6	23.4	1.9	32.3	5.63									
18	0.4	23.8	1.9	34.2	5.63									
19	0.6	24.4	1.9	36.1	5.63									
20	0.5	24.9	1.9	38.0	5.63	112.6								
21	0.5	25.4	1.9	39.9	5.63									
22	0.5	25.9	1.9	41.8	5.63									
23	0.4	26.3	1.9	43.7	5.63									
24	0.5	26.8	1.9	45.6	5.63									
25	0.4	27.2	1.9	47.5	5.63	140.7								
26	0.4	27.6	1.9	49.4	5.63									
27	0.4	28.0	1.9	51.3	5.63									
28	0.4	28.4	1.9	53.2	5.63									
29	0.4	28.8	1.9	55.1	5.63									
30	0.4	29.2	1.9	52.0	5.63	168.9								

Summary

Q22 pumping for 9.95 days   29.2÷1.9 = 15.4 days

Q65.2 pumping for 2.0 days

Q22 max. pond elev. 3.65m, max. pond area 15.5 sq.km

Q65.2 max. pond elev. 3.15m, max. pond area 8.6 sq.km

← shows day when pond water level returns to elev 3.0 and pumping stops.

HYDROLOGY-FLOOD ROUTING

10 Yr Frequency   **30 Day Duration**

Day	Runoff		Pumping				Volume in Excess of Pumping				Q22		Q65.2	
	Million m^3		Q22 million m^3		Q65.2 million m^3		Q22 million m^3		Q65.2 million m^3		Max.WS Elev. m	Max.Pond Area. sq. km	Max.WS Elev. m	Max.Pond Area. sq. km
	Daily	Accum	Daily	Accum	Daily	Accum	Daily	Accum	Daily	Accum				
1	8.0	8.0	1.9	1.9	5.63	5.63	6.1	6.1	2.37	2.37			3.28	10.5
2	4.6	12.6	1.9	3.8	5.63	11.26	2.7	8.8	-1.03	1.34 ←	3.75	16.5		
3	1.4	14.0	1.9	5.7	5.63	16.89	-.5	8.3	-4.23	-2.89				
4	1.5	15.5	1.9	7.6	5.63	22.52	-.4	7.9						
5	1.4	16.9	1.9	9.5	5.63	28.20	-.5	7.4						
6	0.9	17.8	1.9	11.4	5.63	33.78	-1.0	6.4						
7	0.9	18.7	1.9	13.3	5.63	39.41	-1.0	5.4						
8	0.9	19.6	1.9	15.2	5.63	45.04	-1.0	4.4						
9	0.9	20.5	1.9	17.1	5.63	50.67	-1.0	3.4						
10	1.0	21.5	1.9	19.0	5.63	56.30	-0.9	2.5						
11	0.8	22.3	1.9	20.9	5.63		-1.1	1.4						
12	0.7	23.0	1.9	22.8	5.63		-1.2	0.2 ←						
13	0.7	23.7	1.9	24.7	5.63		-1.2	-1.0						
14	0.7	24.4	1.9	26.6	5.63		-1.1							
15	0.8	25.2	1.9	28.5	5.63	84.45	-1.2							
16	0.5	25.7	1.9		5.63									
17	0.5	26.2	1.9		5.63									
18	0.5	26.7	1.9		5.63									
19	0.5	27.2	1.9		5.63									
20	0.5	27.7	1.9	38.0	5.63	112.6								
21	0.6	28.3	1.9		5.63									
22	0.5	28.8	1.9		5.63									
23	0.5	29.3	1.9		5.63									
24	0.5	29.8	1.9		5.63									
25	0.4	30.2	1.9	47.5	5.63	140.7								
26	0.5	30.7	1.9		5.63									
27	0.5	31.2	1.9		5.63									
28	0.5	31.7	1.9		5.63									
29	0.5	32.2	1.9		5.63									
30	0.6	32.8	1.9	57.0	5.63	168.9								

Summary

Q22 pumping for 12.5 days   32.8÷1.9 = 17.3 days
Q65.2 pumping for 2.5 days
Q22 max. pond elev. 3.75m, max. pond area 16.5 sq.km
Q65.2 max. pond elev. 3.28m, max. pond area 10.5 sq.km

← shows day when pond water level returns to elev 3.0 and pumping stops.

APPENDIX-A

HYDROLOGY-FLOOD ROUTING

50 Yr **Frequency**   **30 Day** **Duration**

Day	Runoff		Pumping				Volume in Excess of Pumping				Q22		Q65.2	
	Million m³		Q22		Q65.2		Q22		Q65.2		Max.WS Elev. m	Max.Pond Area. sq. km	Max.WS Elev. m	Max.Pond Area. sq. km
	Daily	Accum	million m³		million m³		million m³		million m³					
			Daily	Accum	Daily	Accum	Daily	Accum	Daily	Accum				
1	11.4	11.4	1.9	1.9	5.63	5.63	9.5	9.5	5.77	5.77			3.53	13.8
2	5.1	16.5	1.9	3.8	5.63	11.26	3.2	12.7	-.53	5.24	3.9	19.2		
3	1.8	18.3	1.9	5.7	5.63	16.87	-.1	12.6	-4.33	1.41				
4	1.7	20.0	1.9	7.6	5.63	22.52	-0.2	12.4	-3.63	-2.52←				
5	1.7	21.7	1.9	9.5	5.63	28.15	-.2	12.2						
6	1.2	22.9	1.9	11.4	5.63	33.78	-.7	11.5						
7	1.1	24.1	1.9	13.3	5.63	39.41	-.8	10.7						
8	1.2	25.2	1.9	15.2	5.63	45.04	-.7	10.0						
9	1.2	26.4	1.9	17.1	5.63	50.67	- .7	9.3						
10	1.1	27.5	1.9	19.0	5.63	56.30	- .8	8.5						
11	1.0	28.5	1.9	20.9	5.63	61.93	-.9	7.6						
12	0.9	29.4	1.9	22.8	5.63	67.56	-1.0	6.6						
13	0.9	30.2	1.9	24.7	5.63	73.19	-1.0	5.6						
14	0.9	31.1	1.9	26.6	5.63	78.82	-1.0	4.6						
15	1.0	32.2	1.9	28.5	5.63	84.45	-.9	3.7						
16	0.7	32.9	1.9	30.4	5.63		-1.2	2.5						
17	0.7	33.6	1.9	32.3	5.63		-1.2	1.3						
18	0.6	34.3	1.9	34.2	5.63		-1.3	0←						
19	0.7	35.0	1.9	36.1	5.63		-1.2							
20	0.7	35.6	1.9	38.0	5.63	112.6								
21	0.6	36.2	1.9	39.9	5.63									
22	0.5	36.7	1.9	41.8	5.63									
23	0.6	37.3	1.9	43.7	5.63									
24	0.5	37.8	1.9	45.6	5.63									
25	0.6	38.4	1.9	47.5	5.63	140.7								
26	0.5	38.9	1.9	49.4	5.63									
27	0.4	39.3	1.9	51.3	5.63									
28	0.5	39.8	1.9	53.2	5.63									
29	0.4	40.3	1.9	55.1	5.63									
30	0.5	40.7	1.9	57.0	5.63	168.9								

Summary

Q22 pumping for 17.0 days   40.7÷1.9 = 21.4 days
Q65.2 pumping for 3.25 days
Q22 max. pond elev. 3.90m, max. pond area 19.2 sq.km
Q65.2 max. pond elev. 3.53m, max. pond area 13.6 sq.km
← shows day when pond water level returns to elev 3.0 and pumping stops.