Table I-3 COST ESTIMATE FOR ECONOMIC COMPARISON

	Unit	Reservoir Volume (million m3) 0	2	5	10	12	15	20
I. Pump								
1. Construction Cost for Pump and Well								
(1) Peak groundwater	(m3/sec)	5.78	5.53	5.20	4.66	4.43	4.10	3.55
(2) Additional groundwater by pump								
	(m3/sec)	1.67	1.43	1.10	0.56	0.33	0	0
	(million m3/month)	4.33	3.71	2.85	1.45	0.86	0	0
(3) Pump capacity	(1,000 m3/no.)	64.8	64.8	64.8	64.8	64.8	64.8	64.8
(4) Req. no. of pump	(nos.)	68	58	44	23	14	0	0
(5) Construction cost for pump and well								
	(1,000 US$)	4,284	3,654	2,772	1,449	882	0	0
2. O&M Cost								
(1) Annual groundwater	(million m3/year)	89.13	87.40	84.78	80.46	78.72	76.08	71.75
(2) Annual operation hour	(1,000 hr/year)	495.2	485.6	471.0	447.0	437.3	422.6	398.6
(3) Annual operation hour by additional pump								
	(1,000 hr/year)	72.6	63.0	48.4	24.4	14.7	0	-24.0
(4) Motor output	(kw)	18.5	18.5	18.5	18.5	18.5	18.5	18.5
(5) Annual kw hr	(1,000 kwhr)	1,342	1,164	895	450	272	0	-445
(6) Unit cost	(US$/kwhr)	0.073	0.073	0.073	0.073	0.073	0.073	0.073
(7) Operation cost	(1,000 US$)	98	85	65	33	20	0	-33
(8) Operator	(1,000 US$)	147	126	95	50	30	0	-47
(9) Maintenance cost	(1,000 US$)	43	37	28	15	9	0	-14
(10) Total	(1,000 US$)	288	248	188	98	59	0	-94
II. Reservoir								
1. Construction Cost for Reservoir								
	(1,000 US$)	0	1,144	2,600	5,148	6,240	7,780	13,580
2. O&M Cost	(1,000 US$)	0	1	3	5	6	8	14

Table I-4 CALCULATION OF NPV FOR ECONOMIC COMPARISON

V=0.0 NPV= 6,957

Year	Pump			Reservoir		Total
	Cost	Replace	O&M	Cost	O&M	
1	0	0	0	0	0	0
2	2,142	0	144	0	0	2,286
3	2,142	0	288	0	0	2,430
4	0	0	288	0	0	288
5	0	0	288	0	0	288
6	0	0	288	0	0	288
7	0	0	288	0	0	288
8	0	0	288	0	0	288
9	0	0	288	0	0	288
10	0	0	288	0	0	288
11	0	0	288	0	0	288
12	0	0	288	0	0	288
13	0	0	288	0	0	288
14	0	0	288	0	0	288
15	0	0	288	0	0	288
16	0	2,142	288	0	0	2,430
17	0	2,142	288	0	0	2,430
18	0	0	288	0	0	288
19	0	0	288	0	0	288
20	0	0	288	0	0	288
21	0	0	288	0	0	288
22	0	0	288	0	0	288
23	0	0	288	0	0	288
24	0	0	288	0	0	288
25	0	0	288	0	0	288
26	0	0	288	0	0	288
27	0	0	288	0	0	288
28	0	0	288	0	0	288
29	0	0	288	0	0	288
30	0	0	288	0	0	288
31	0	2,142	288	0	0	2,430
32	0	2,142	288	0	0	2,430
33	0	0	288	0	0	288
34	0	0	288	0	0	288
35	0	0	288	0	0	288
36	0	0	288	0	0	288
37	0	0	288	0	0	288
38	0	0	288	0	0	288
39	0	0	288	0	0	288
40	0	0	288	0	0	288
41	0	0	288	0	0	288
42	0	0	288	0	0	288
43	0	0	288	0	0	288
44	0	0	288	0	0	288
45	0	0	288	0	0	288
46	0	0	288	0	0	288
47	0	0	288	0	0	288
48	0	0	288	0	0	288
49	0	0	288	0	0	288
50	0	0	288	0	0	288

V=2.0 NPV= 6,825

Year	Pump			Reservoir		Total
	Cost	Replace	O&M	Cost	O&M	
1	0	0	0	347	0	347
2	1,827	0	124	347	0	2,298
3	1,827	0	248	347	1	2,423
4	0	0	248	0	1	249
5	0	0	248	0	1	249
6	0	0	248	0	1	249
7	0	0	248	0	1	249
8	0	0	248	0	1	249
9	0	0	248	0	1	249
10	0	0	248	0	1	249
11	0	0	248	0	1	249
12	0	0	248	0	1	249
13	0	0	248	0	1	249
14	0	0	248	0	1	249
15	0	0	248	0	1	249
16	0	1,827	248	0	1	2,076
17	0	1,827	248	0	1	2,076
18	0	0	248	0	1	249
19	0	0	248	0	1	249
20	0	0	248	0	1	249
21	0	0	248	0	1	249
22	0	0	248	0	1	249
23	0	0	248	0	1	249
24	0	0	248	0	1	249
25	0	0	248	0	1	249
26	0	0	248	0	1	249
27	0	0	248	0	1	249
28	0	0	248	0	1	249
29	0	0	248	0	1	249
30	0	0	248	0	1	249
31	0	1,827	248	0	1	2,076
32	0	1,827	248	0	1	2,076
33	0	0	248	0	1	249
34	0	0	248	0	1	249
35	0	0	248	0	1	249
36	0	0	248	0	1	249
37	0	0	248	0	1	249
38	0	0	248	0	1	249
39	0	0	248	0	1	249
40	0	0	248	0	1	249
41	0	0	248	0	1	249
42	0	0	248	0	1	249
43	0	0	248	0	1	249
44	0	0	248	0	1	249
45	0	0	248	0	1	249
46	0	0	248	0	1	249
47	0	0	248	0	1	249
48	0	0	248	0	1	249
49	0	0	248	0	1	249
50	0	0	248	0	1	249

V=5.0 NPV= 6,696

Year	Pump			Reservoir		Total
	Cost	Replace	O&M	Cost	O&M	
1	0	0	0	867	0	867
2	1,386	0	94	867	0	2,347
3	1,386	0	188	867	3	2,444
4	0	0	188	0	3	191
5	0	0	188	0	3	191
6	0	0	188	0	3	191
7	0	0	188	0	3	191
8	0	0	188	0	3	191
9	0	0	188	0	3	191
10	0	0	188	0	3	191
11	0	0	188	0	3	191
12	0	0	188	0	3	191
13	0	0	188	0	3	191
14	0	0	188	0	3	191
15	0	0	188	0	3	191
16	0	1,386	188	0	3	1,577
17	0	1,386	188	0	3	1,577
18	0	0	188	0	3	191
19	0	0	188	0	3	191
20	0	0	188	0	3	191
21	0	0	188	0	3	191
22	0	0	188	0	3	191
23	0	0	188	0	3	191
24	0	0	188	0	3	191
25	0	0	188	0	3	191
26	0	0	188	0	3	191
27	0	0	188	0	3	191
28	0	0	188	0	3	191
29	0	0	188	0	3	191
30	0	0	188	0	3	191
31	0	1,386	188	0	3	1,577
32	0	1,386	188	0	3	1,577
33	0	0	188	0	3	191
34	0	0	188	0	3	191
35	0	0	188	0	3	191
36	0	0	188	0	3	191
37	0	0	188	0	3	191
38	0	0	188	0	3	191
39	0	0	188	0	3	191
40	0	0	188	0	3	191
41	0	0	188	0	3	191
42	0	0	188	0	3	191
43	0	0	188	0	3	191
44	0	0	188	0	3	191
45	0	0	188	0	3	191
46	0	0	188	0	3	191
47	0	0	188	0	3	191
48	0	0	188	0	3	191
49	0	0	188	0	3	191
50	0	0	188	0	3	191

V=10.0 NPV= 6,667

Year	Pump			Reservoir		Total
	Cost	Replace	O&M	Cost	O&M	
1	0	0	0	1,716	0	1,716
2	725	0	49	1,716	0	2,490
3	725	0	98	1,716	5	2,544
4	0	0	98	0	5	103
5	0	0	98	0	5	103
6	0	0	98	0	5	103
7	0	0	98	0	5	103
8	0	0	98	0	5	103
9	0	0	98	0	5	103
10	0	0	98	0	5	103
11	0	0	98	0	5	103
12	0	0	98	0	5	103
13	0	0	98	0	5	103
14	0	0	98	0	5	103
15	0	0	98	0	5	103
16	0	725	98	0	5	828
17	0	725	98	0	5	828
18	0	0	98	0	5	103
19	0	0	98	0	5	103
20	0	0	98	0	5	103
21	0	0	98	0	5	103
22	0	0	98	0	5	103
23	0	0	98	0	5	103
24	0	0	98	0	5	103
25	0	0	98	0	5	103
26	0	0	98	0	5	103
27	0	0	98	0	5	103
28	0	0	98	0	5	103
29	0	0	98	0	5	103
30	0	0	98	0	5	103
31	0	725	98	0	5	828
32	0	725	98	0	5	828
33	0	0	98	0	5	103
34	0	0	98	0	5	103
35	0	0	98	0	5	103
36	0	0	98	0	5	103
37	0	0	98	0	5	103
38	0	0	98	0	5	103
39	0	0	98	0	5	103
40	0	0	98	0	5	103
41	0	0	98	0	5	103
42	0	0	98	0	5	103
43	0	0	98	0	5	103
44	0	0	98	0	5	103
45	0	0	98	0	5	103
46	0	0	98	0	5	103
47	0	0	98	0	5	103
48	0	0	98	0	5	103
49	0	0	98	0	5	103
50	0	0	98	0	5	103

V=12.0 NPV= 6,652

Year	Pump			Reservoir		Total
	Cost	Replace	O&M	Cost	O&M	
1	0	0	0	2,080	0	2,080
2	441	0	30	2,080	0	2,551
3	441	0	59	2,080	6	2,586
4	0	0	59	0	6	65
5	0	0	59	0	6	65
6	0	0	59	0	6	65
7	0	0	59	0	6	65
8	0	0	59	0	6	65
9	0	0	59	0	6	65
10	0	0	59	0	6	65
11	0	0	59	0	6	65
12	0	0	59	0	6	65
13	0	0	59	0	6	65
14	0	0	59	0	6	65
15	0	0	59	0	6	65
16	0	441	59	0	6	506
17	0	441	59	0	6	506
18	0	0	59	0	6	65
19	0	0	59	0	6	65
20	0	0	59	0	6	65
21	0	0	59	0	6	65
22	0	0	59	0	6	65
23	0	0	59	0	6	65
24	0	0	59	0	6	65
25	0	0	59	0	6	65
26	0	0	59	0	6	65
27	0	0	59	0	6	65
28	0	0	59	0	6	65
29	0	0	59	0	6	65
30	0	0	59	0	6	65
31	0	441	59	0	6	506
32	0	441	59	0	6	506
33	0	0	59	0	6	65
34	0	0	59	0	6	65
35	0	0	59	0	6	65
36	0	0	59	0	6	65
37	0	0	59	0	6	65
38	0	0	59	0	6	65
39	0	0	59	0	6	65
40	0	0	59	0	6	65
41	0	0	59	0	6	65
42	0	0	59	0	6	65
43	0	0	59	0	6	65
44	0	0	59	0	6	65
45	0	0	59	0	6	65
46	0	0	59	0	6	65
47	0	0	59	0	6	65
48	0	0	59	0	6	65
49	0	0	59	0	6	65
50	0	0	59	0	6	65

V=15.0 NPV= 6,515

Year	Pump			Reservoir		Total
	Cost	Replace	O&M	Cost	O&M	
1	0	0	0	2,593	0	2,593
2	0	0	0	2,593	0	2,593
3	0	0	0	2,593	8	2,601
4	0	0	0	0	8	8
5	0	0	0	0	8	8
6	0	0	0	0	8	8
7	0	0	0	0	8	8
8	0	0	0	0	8	8
9	0	0	0	0	8	8
10	0	0	0	0	8	8
11	0	0	0	0	8	8
12	0	0	0	0	8	8
13	0	0	0	0	8	8
14	0	0	0	0	8	8
15	0	0	0	0	8	8
16	0	0	0	0	8	8
17	0	0	0	0	8	8
18	0	0	0	0	8	8
19	0	0	0	0	8	8
20	0	0	0	0	8	8
21	0	0	0	0	8	8
22	0	0	0	0	8	8
23	0	0	0	0	8	8
24	0	0	0	0	8	8
25	0	0	0	0	8	8
26	0	0	0	0	8	8
27	0	0	0	0	8	8
28	0	0	0	0	8	8
29	0	0	0	0	8	8
30	0	0	0	0	8	8
31	0	0	0	0	8	8
32	0	0	0	0	8	8
33	0	0	0	0	8	8
34	0	0	0	0	8	8
35	0	0	0	0	8	8
36	0	0	0	0	8	8
37	0	0	0	0	8	8
38	0	0	0	0	8	8
39	0	0	0	0	8	8
40	0	0	0	0	8	8
41	0	0	0	0	8	8
42	0	0	0	0	8	8
43	0	0	0	0	8	8
44	0	0	0	0	8	8
45	0	0	0	0	8	8
46	0	0	0	0	8	8
47	0	0	0	0	8	8
48	0	0	0	0	8	8
49	0	0	0	0	8	8
50	0	0	0	0	8	8

V=20.0 NPV= 10,564

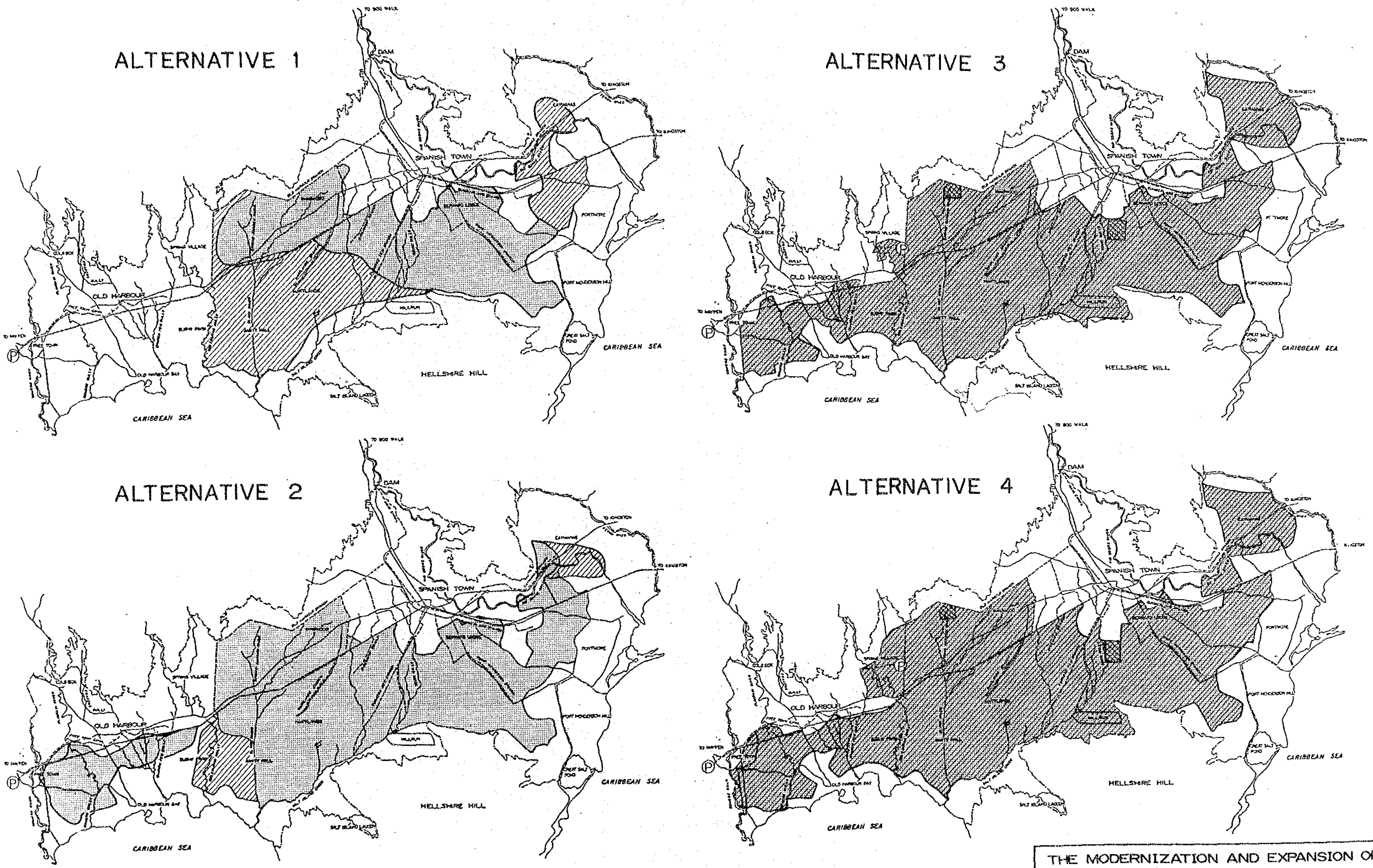
Year	Pump			Reservoir		Total
	Cost	Replace	O&M	Cost	O&M	
1	0	0	0	4,527	0	4,527
2	0	0	-47	4,527	0	4,480
3	0	0	-94	4,527	14	4,447
4	0	0	-94	0	14	-80
5	0	0	-94	0	14	-80
6	0	0	-94	0	14	-80
7	0	0	-94	0	14	-80
8	0	0	-94	0	14	-80
9	0	0	-94	0	14	-80
10	0	0	-94	0	14	-80
11	0	0	-94	0	14	-80
12	0	0	-94	0	14	-80
13	0	0	-94	0	14	-80
14	0	0	-94	0	14	-80
15	0	0	-94	0	14	-80
16	0	0	-94	0	14	-80
17	0	0	-94	0	14	-80
18	0	0	-94	0	14	-80
19	0	0	-94	0	14	-80
20	0	0	-94	0	14	-80
21	0	0	-94	0	14	-80
22	0	0	-94	0	14	-80
23	0	0	-94	0	14	-80
24	0	0	-94	0	14	-80
25	0	0	-94	0	14	-80
26	0	0	-94	0	14	-80
27	0	0	-94	0	14	-80
28	0	0	-94	0	14	-80
29	0	0	-94	0	14	-80
30	0	0	-94	0	14	-80
31	0	0	-94	0	14	-80
32	0	0	-94	0	14	-80
33	0	0	-94	0	14	-80
34	0	0	-94	0	14	-80
35	0	0	-94	0	14	-80
36	0	0	-94	0	14	-80
37	0	0	-94	0	14	-80
38	0	0	-94	0	14	-80
39	0	0	-94	0	14	-80
40	0	0	-94	0	14	-80
41	0	0	-94	0	14	-80
42	0	0	-94	0	14	-80
43	0	0	-94	0	14	-80
44	0	0	-94	0	14	-80
45	0	0	-94	0	14	-80
46	0	0	-94	0	14	-80
47	0	0	-94	0	14	-80
48	0	0	-94	0	14	-80
49	0	0	-94	0	14	-80
50	0	0	-94	0	14	-80

Reservoir Volume (million m3)	NPV (1,000 US$)
0.00	6,957
2.00	6,825
5.00	6,696
10.00	6,667
12.00	6,652
15.00	6,515
20.00	10,564

Table I-5 WATER DISTRIBUTION SCHEDULE

(Unit : lit/sec)

Name of Canal	Area (ha) Gross	Area (ha) Net	Month Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual (mean)
CAYMANAS B. CANAL	901	811	318	342	308	355	331	419	574	333	203	66	168	292	9.61
SURFACE WATER	*	*	118	92	0	0	0	0	134	0	203	66	168	92	2.26
GROUNDWATER	*	*	200	250	308	355	331	419	440	333	0	0	0	200	7.35
BALANCE			0	0	0	0	0	0	0	0	0	0	0	0	0
CUMBERLAND B. CANAL	1,238	1,114	500	452	310	402	499	705	898	383	213	125	304	480	13.66
SURFACE WATER	*	*	300	172	0	0	0	205	348	133	213	125	301	280	5.39
GROUNDWATER	*	*	200	280	310	402	499	500	550	250	0	0	0	200	8.27
BALANCE			0	0	0	0	0	0	0	0	0	0	0	0	0
PORT HENDERSON B. CANAL	2,105	1,890	870	720	402	570	851	1,319	1,712	701	364	252	570	870	23.85
SURFACE WATER	*	*	570	360	0	0	301	829	552	466	364	252	570	750	13.00
GROUNDWATER	*	*	300	360	360	400	400	400	400	235	0	0	0	120	7.71
RESERVOIR NO.1	*	*	0	0	42	170	150	90	760	0	0	0	0	0	3.14
BALANCE			0	0	0	0	0	0	0	0	0	0	0	0	0
TURNERS PEN B. CANAL	1,556	1,236	881	993	1,245	1,416	834	521	548	1,115	1,090	921	1,030	1,103	30.32
SURFACE WATER	*	*	723	794	520	349	336	269	293	973	981	829	927	953	20.60
GROUNDWATER	*	*	70	100	100	200	100	100	100	30	0	0	0	40	2.18
RETURN	*	*	88	99	125	142	83	52	55	112	109	92	103	110	3.03
RESERVOIR NO.1	*	*	0	0	500	725	315	100	100	0	0	0	0	0	4.51
BALANCE			0	0	1	0	0	0	0	1	0	0	0	0	0
BALANCE OF RESERV NO.1 (cubic m/sec)															
IN FLOW			0.87	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	1.00	0.50	9.75
OUT FLOW			0.00	0.00	0.54	0.90	0.47	0.19	0.86	0.00	0.00	0.00	0.00	0.00	7.65
LOSSES			0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.00	0.00	0.08	0.08	0.08	2.07
BALANCE			2.90	3.36	2.74	1.76	1.22	0.95	0.01	0.01	0.01	0.78	1.70	2.12	17.55
(million cubic m/month)			7.52	8.71	7.10	4.57	3.16	2.46	0.02	0.02	0.02	2.02	4.40	5.49	45.48
SUM OF GROUND WATER (cubic m/sec)			0.77	0.99	1.08	1.36	1.33	1.42	1.49	0.85	0.00	0.00	0.00	0.56	25.51
SUMMARY OF EAST MAIN CANAL (cubic m/sec)															
FLOW TO CANAL			1.71	1.42	0.52	0.35	0.64	1.30	1.33	1.57	1.76	1.27	1.97	2.08	41.25
FLOW TO RESERVOIR			0.87	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	1.00	0.50	9.75
FLOW TO OTHER			0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	11.51
SUB TOTAL			2.95	2.33	0.89	0.72	1.01	1.67	1.70	1.94	2.13	2.49	3.34	2.95	62.50
SYDENHAM BRANCH CANAL	663	597	434	503	551	587	389	373	549	612	526	338	382	477	14.83
SURFACE WATER	*	*	334	403	451	487	289	273	449	512	526	338	382	377	12.50
GROUND WATER	*	*	100	100	100	100	100	100	100	100	0	0	0	100	2.33
BALANCE			0	0	0	0	0	0	0	0	0	0	0	0	0
HART LAND BRANCH CANAL	2,871	2,484	1,321	1,452	2,286	2,772	2,003	1,713	1,685	2,123	2,002	1,584	1,823	2,011	59.03
SURFACE WATER	*	*	1,089	1,206	1,937	2,395	1,702	1,442	1,416	1,811	1,802	1,426	1,641	1,710	50.74
GROUNDWATER	*	*	100	100	100	100	100	100	100	100	0	0	0	100	2.33
RETURN	*	*	132	145	229	277	200	171	169	212	200	158	182	201	5.90
RESERVOIR NO.3	*	*	0	0	20	0	0	0	0	0	0	0	0	0	0.05
BALANCE			0	1	0	0	1	0	1	0	0	0	0	0	0
OLD HARBOUR B. CANAL	2,944	2,543	1,466	1,621	2,122	2,443	1,942	2,310	2,714	2,247	1,764	1,177	1,469	1,837	59.91
SURFACE WATER	*	*	819	909	1,310	164	898	1,229	753	1,172	1,588	1,059	1,322	953	31.56
GROUNDWATER	*	*	500	550	600	900	850	850	900	850	0	0	0	700	17.37
RETURN	*	*	147	162	212	244	194	231	271	225	176	118	147	184	5.99
RESERVOIR NO.2	*	*	0	0	0	855	0	0	790	0	0	0	0	0	4.26
RESERVOIR NO.3	*	*	0	0	0	280	0	0	0	0	0	0	0	0	0.73
BALANCE			0	0	0	0	0	0	0	0	0	0	0	0	0
EXTENSION CANAL	846	746	369	478	487	550	120	430	578	370	54	22	199	333	10.34
SURFACE WATER	*	*	269	378	342	360	20	330	478	270	54	22	199	333	7.92
GROUNDWATER	*	*	100	100	100	100	100	100	100	100	0	0	0	0	2.07
RESERVOIR NO.2	*	*	0	0	0	0	0	0	0	0	0	0	0	0	0.00
RESERVOIR NO.4	*	*	0	0	45	90	0	0	0	0	0	0	0	0	0.35
BALANCE			0	0	0	0	0	0	0	0	0	0	0	0	0
BALANCE OF RESERV NO.2 (cubic m/sec)															
IN FLOW			0.70	0.57	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.26	5.52
OUT FLOW			0.00	0.00	0.00	0.86	0.00	0.00	0.79	0.00	0.00	0.00	0.00	0.00	4.26
LOSSES			0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.00	0.00	0.00	0.00	0.06	1.24
BALANCE			0.84	1.35	1.29	0.38	0.92	0.86	0.00	0.00	0.00	0.00	0.00	0.21	5.86
(million cubic m/month)			2.18	3.50	3.34	0.97	2.37	2.22	0.01	0.01	0.01	0.01	0.01	0.53	15.18
BALANCE OF RESERV NO.3 (cubic m/sec)															
IN FLOW			0.40	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.61
OUT FLOW			0.00	0.00	0.02	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.78
LOSSES			0.08	0.08	0.08	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.83
BALANCE			0.32	0.46	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.14
(million cubic m/month)			0.83	1.19	0.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.95
BALANCE OF RESERV NO.4 (cubic m/sec)															
IN FLOW			0.10	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47
OUT FLOW			0.00	0.00	0.05	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35
LOSSES			0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
BALANCE			0.09	0.16	0.11	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	1.04
(million cubic m/month)			0.23	0.41	0.27	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	2.69
SUM OF GROUND WATER (cubic m/sec)			0.80	0.85	0.90	1.20	1.15	1.15	1.20	1.15	0.00	0.00	0.00	0.90	24.11
SUMMARY OF WEST MAIN CANAL (cubic m/sec)															
FLOW TO CANAL			2.51	2.90	4.04	3.41	2.91	3.27	3.10	3.77	3.97	2.85	3.54	3.37	102.72
FLOW TO RESERVOIR			1.20	0.87	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.26	7.59
FLOW TO G/W RECHARGE			0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.50	0.50	0.50	6.48
SUB TOTAL			4.21	3.77	4.04	3.41	3.51	3.27	3.10	3.77	4.47	3.35	4.04	4.13	116.79
BALANCE OF CANAL DISCHARGE (cubic m/sec)															
EAST MAIN CANAL			2.95	2.33	0.89	0.72	1.01	1.67	1.70	1.94	2.13	2.49	3.34	2.95	62.50
WEST MAIN CANAL			4.21	3.77	4.04	3.41	3.51	3.27	3.10	3.77	4.47	3.35	4.04	4.13	116.79
TOTAL (1)			7.16	6.09	4.93	4.13	4.52	4.95	4.79	5.71	6.60	5.84	7.38	7.08	179.29
INTAKE DISCHARGE			7.20	6.09	4.92	4.10	4.52	4.93	4.80	5.70	9.14	8.73	9.60	7.08	199.09
SUMMARY OF GROUND WATER (cubic m/sec)															
EAST MAIN CANAL			0.77	0.99	1.08	1.36	1.33	1.42	1.49	0.85	0.00	0.00	0.00	0.56	25.51
WEST MAIN CANAL			0.80	0.85	0.90	1.20	1.15	1.15	1.20	1.15	0.00	0.00	0.00	0.90	24.11
SUB TOTAL			1.57	1.84	1.98	2.56	2.48	2.57	2.69	2.00	0.00	0.00	0.00	1.46	49.62
ST.DOROTHY			0.87	1.07	1.05	1.10	0.45	0.95	1.40	1.03	0.54	0.32	0.59	0.85	26.49
TOTAL (2)			2.44	2.91	3.03	3.66	2.93	3.52	4.09	3.03	0.54	0.32	0.59	2.31	76.11
GRAND TOTAL (1)+(2)			9.60	9.00	7.96	7.78	7.45	8.47	8.88	8.74	7.14	6.16	7.97	9.39	255.40



LEGEND

: Area to be irrigated in Dry Season

: Area to be irrigated in Wet Season

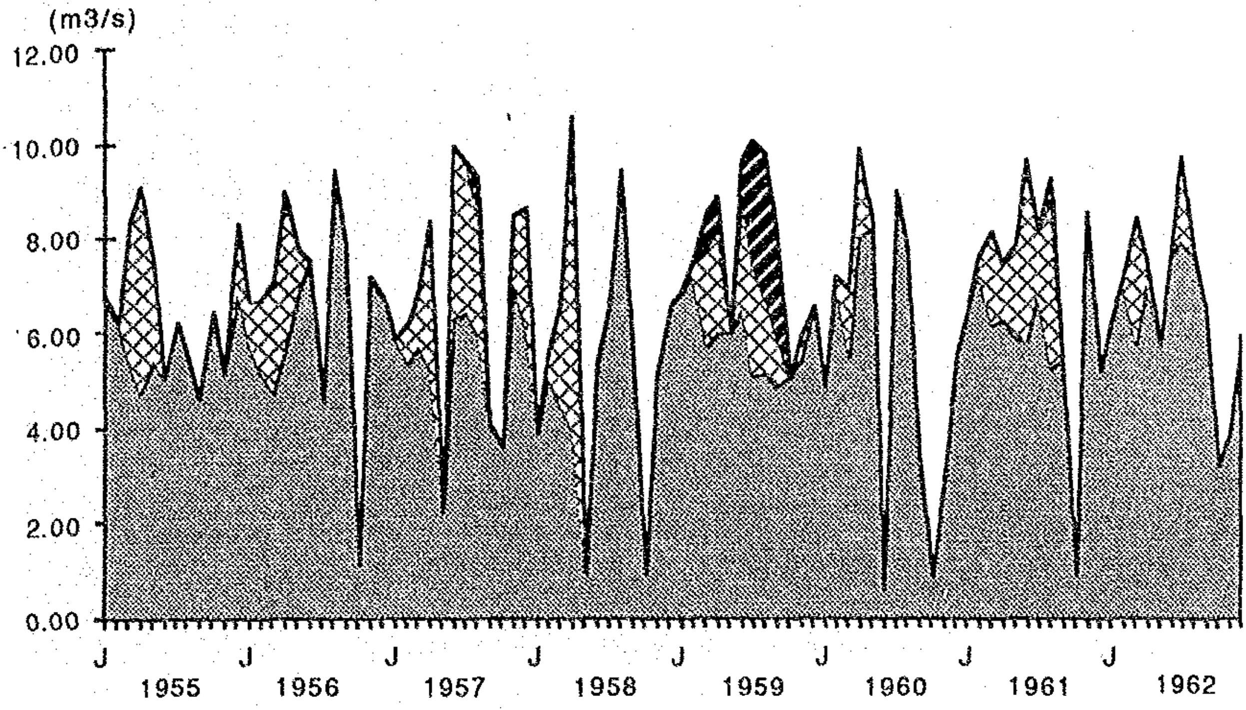
SCALE

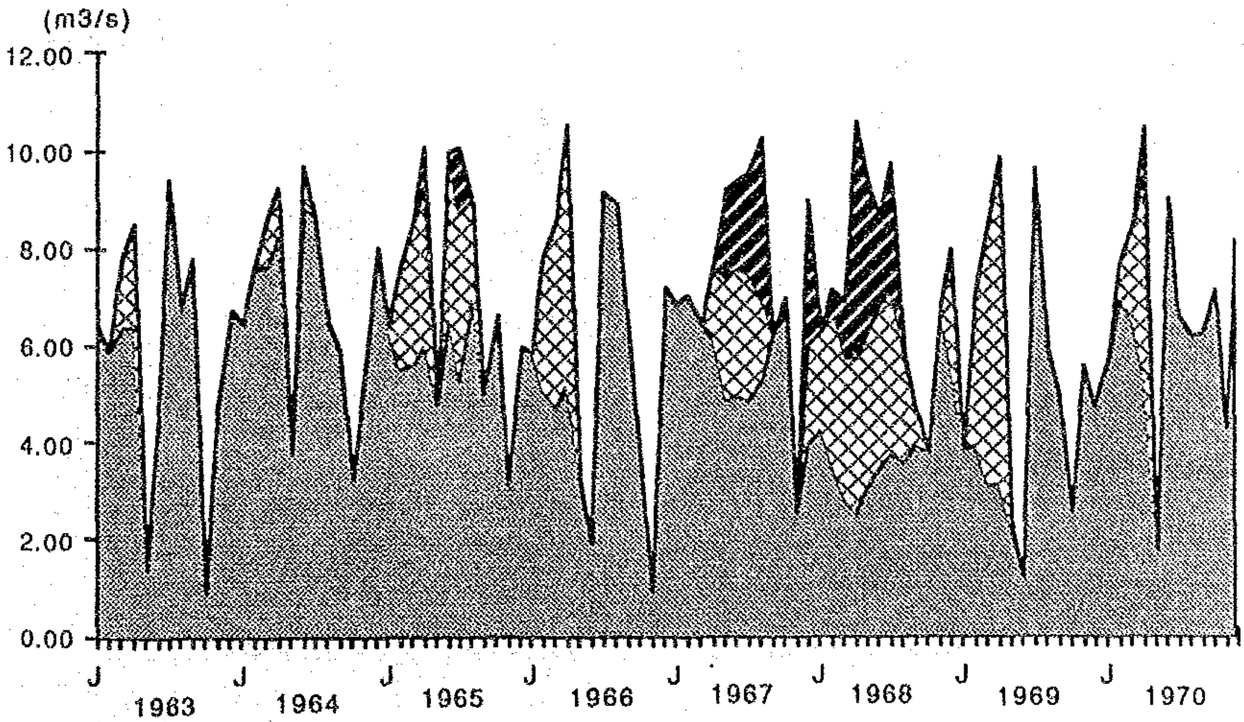
0 1 2 3 4 5KM

THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

Fig. I-1 ALTERNATIVE PLAN

JAPAN INTERNATIONAL COOPERATION AGENCY





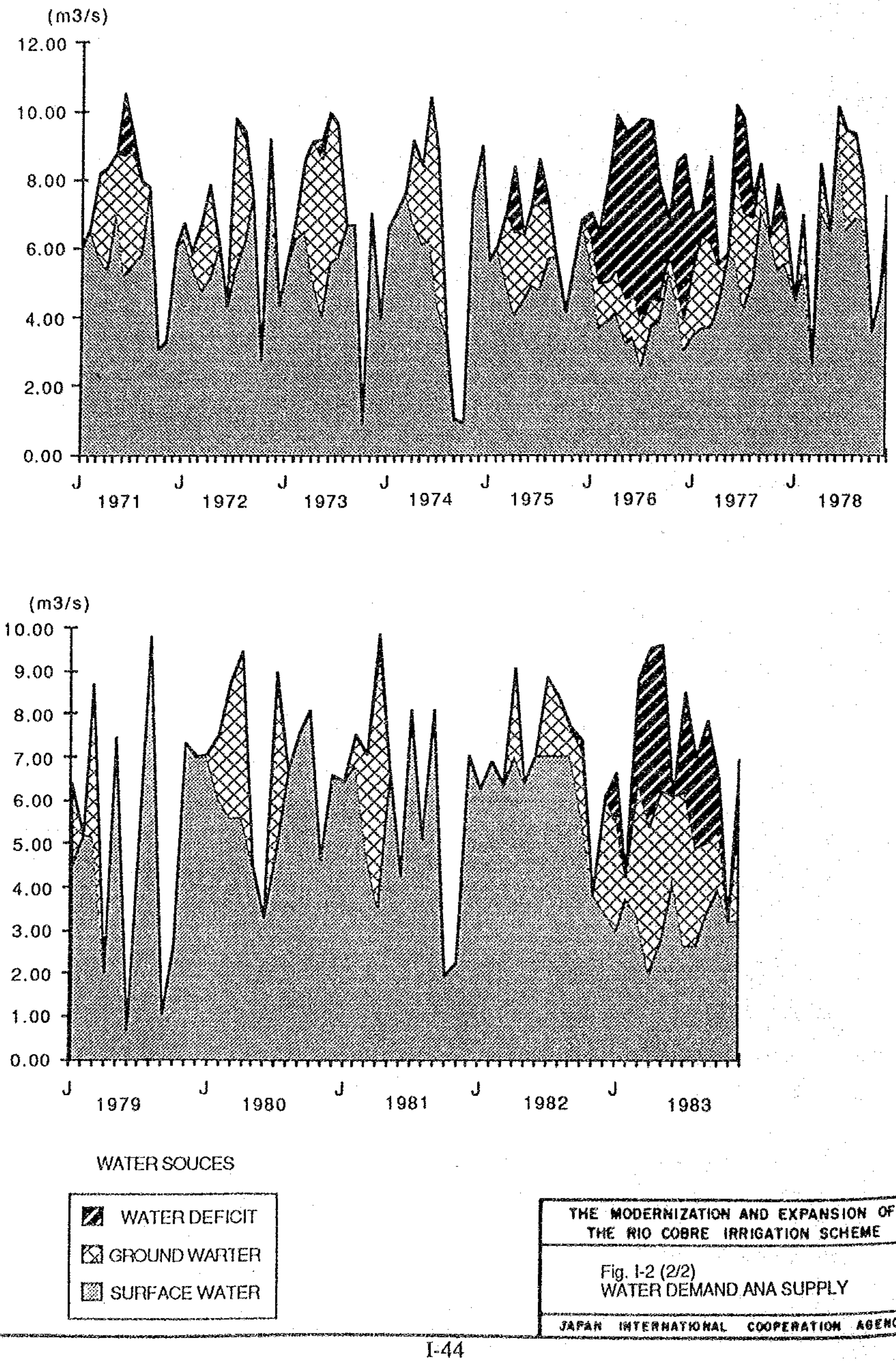
WATER SOUCES

WATER DEFICIT
GROUND WARTER
SURFACE WATER

THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

Fig. I-2 (1/2)
WATER DEMAND ANA SUPPLY

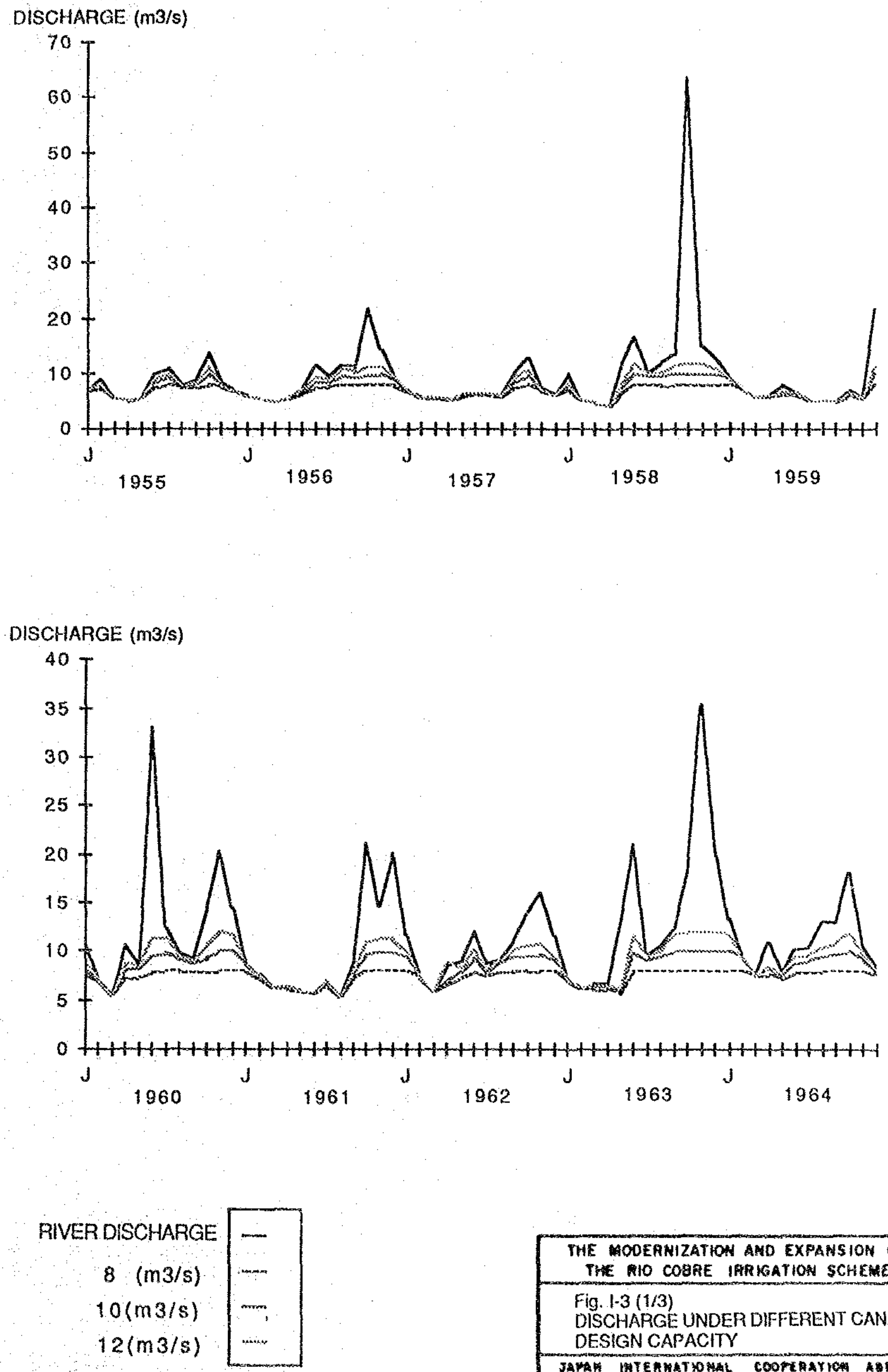
JAPAN INTERNATIONAL COOPERATION AGENCY



THE MODERNIZATION AND EXPANSION OF
THE RIO COBRE IRRIGATION SCHEME

Fig. I-2 (2/2)
WATER DEMAND ANA SUPPLY

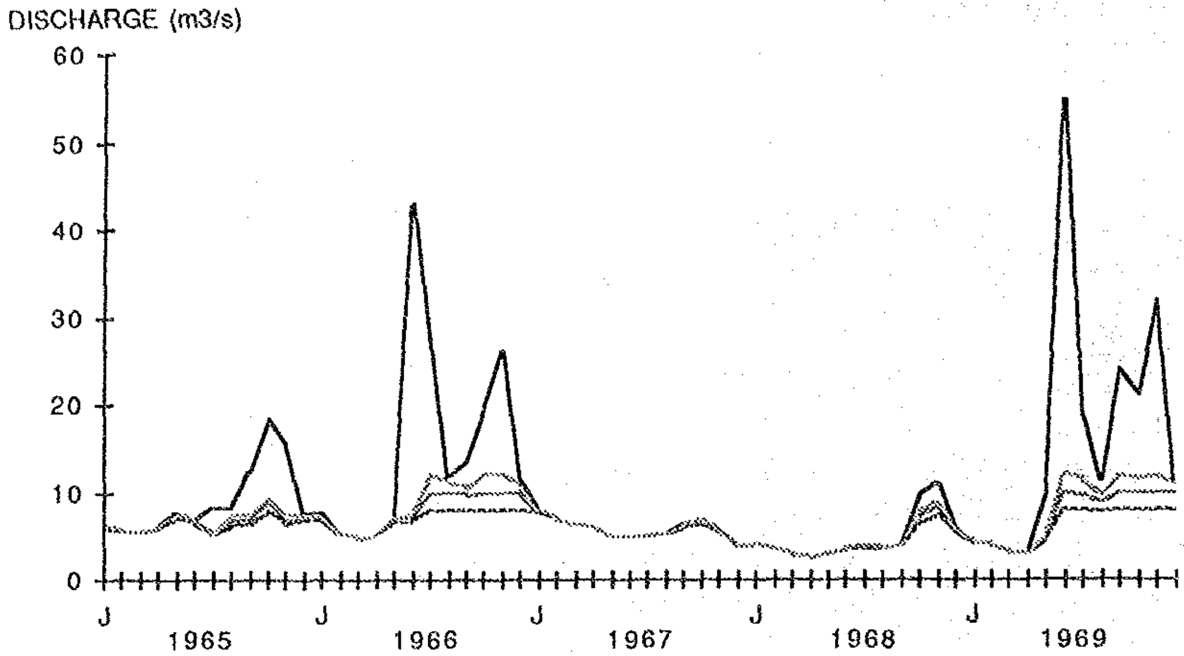
JAPAN INTERNATIONAL COOPERATION AGENCY

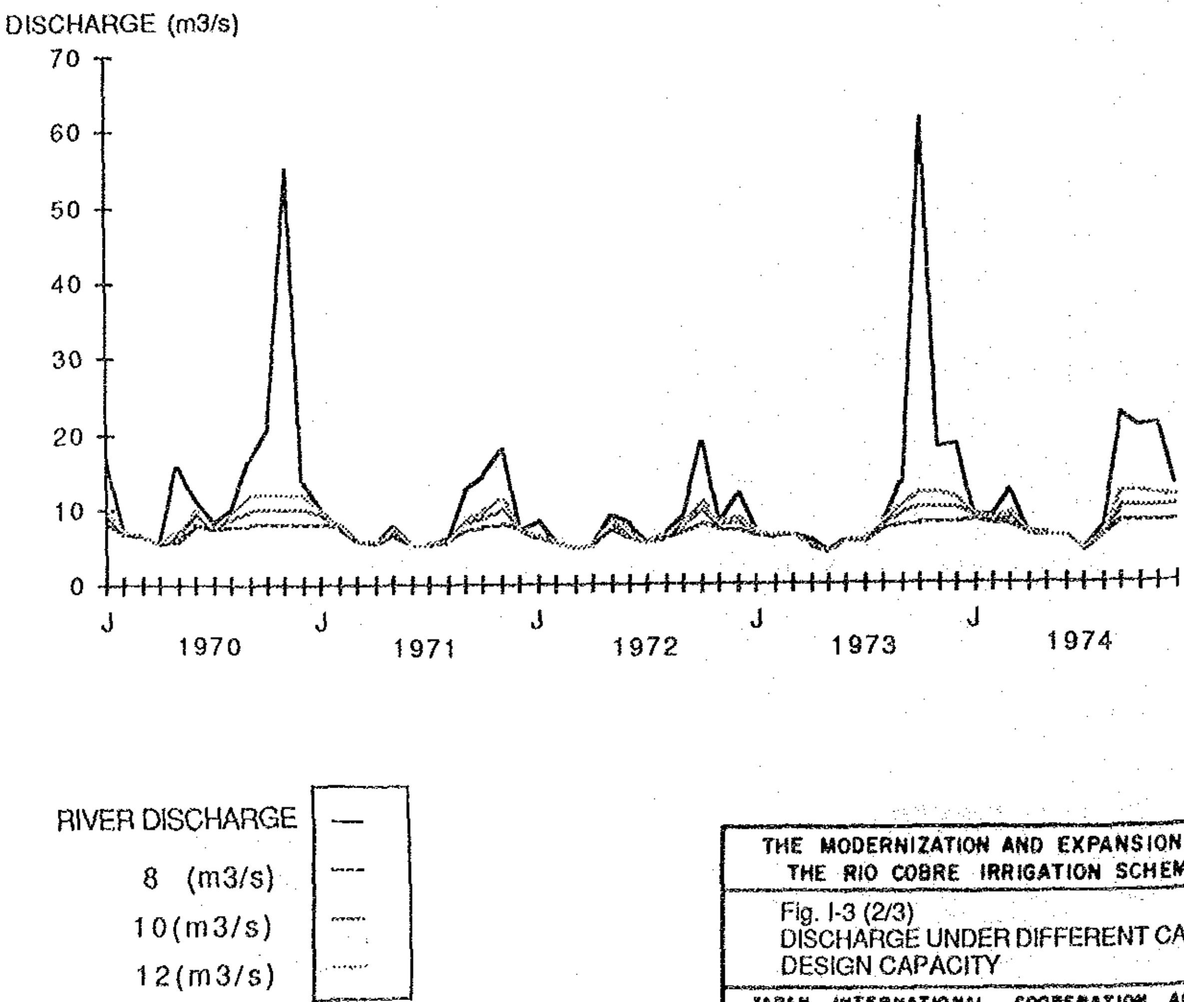


THE MODERNIZATION AND EXPANSION OF
THE RIO COBRE IRRIGATION SCHEME

Fig. I-3 (1/3)
DISCHARGE UNDER DIFFERENT CANAL DESIGN CAPACITY

JAPAN INTERNATIONAL COOPERATION AGENCY

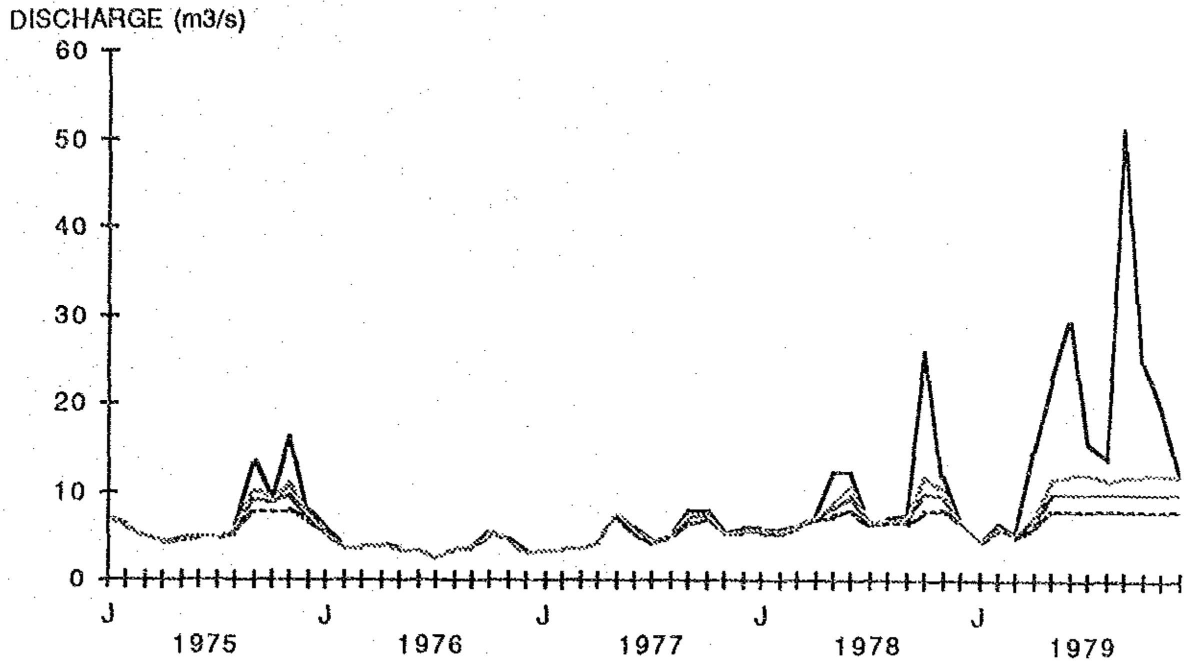


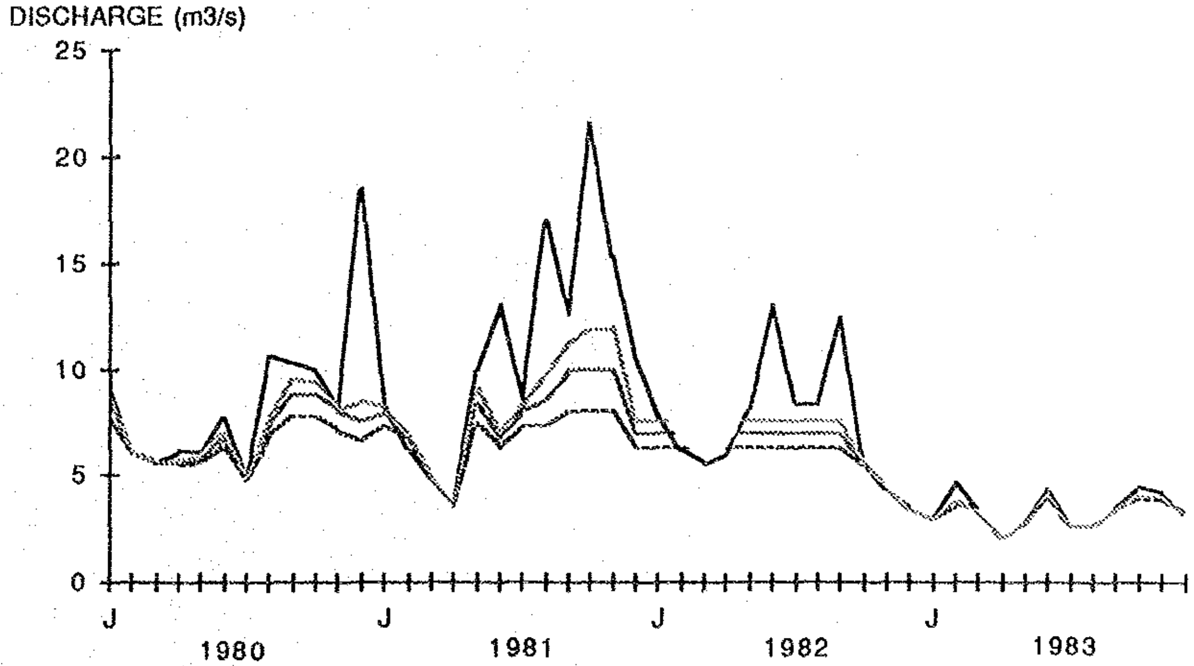


THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

Fig. I-3 (2/3)
DISCHARGE UNDER DIFFERENT CANAL DESIGN CAPACITY

JAPAN INTERNATIONAL COOPERATION AGENCY



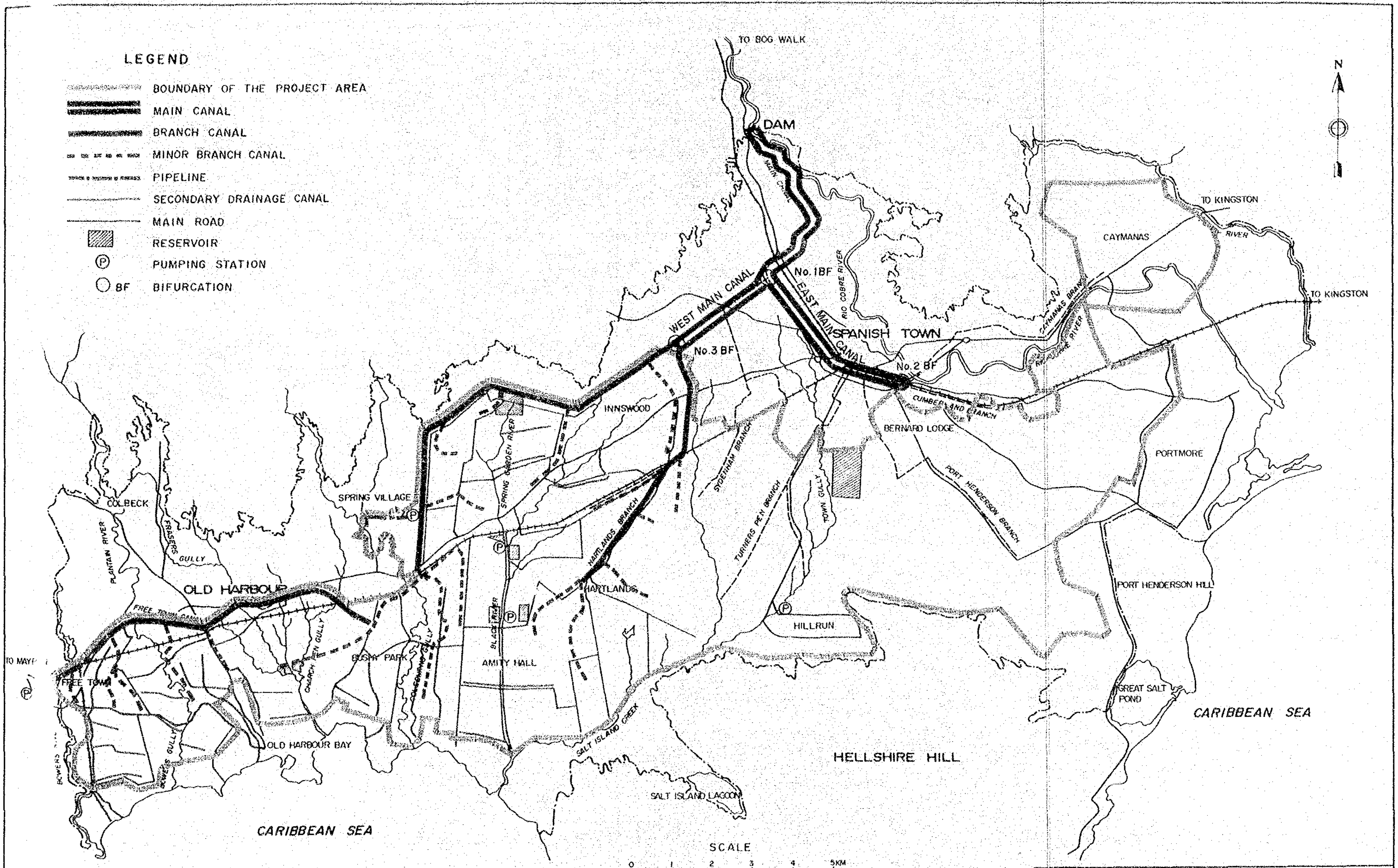


RIVER DISCHARGE —
8 (m3/s)
10(m3/s)
12(m3/s)

THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

Fig. I-3 (3/3)
DISCHARGE UNDER DIFFERENT CANAL DESIGN CAPACITY

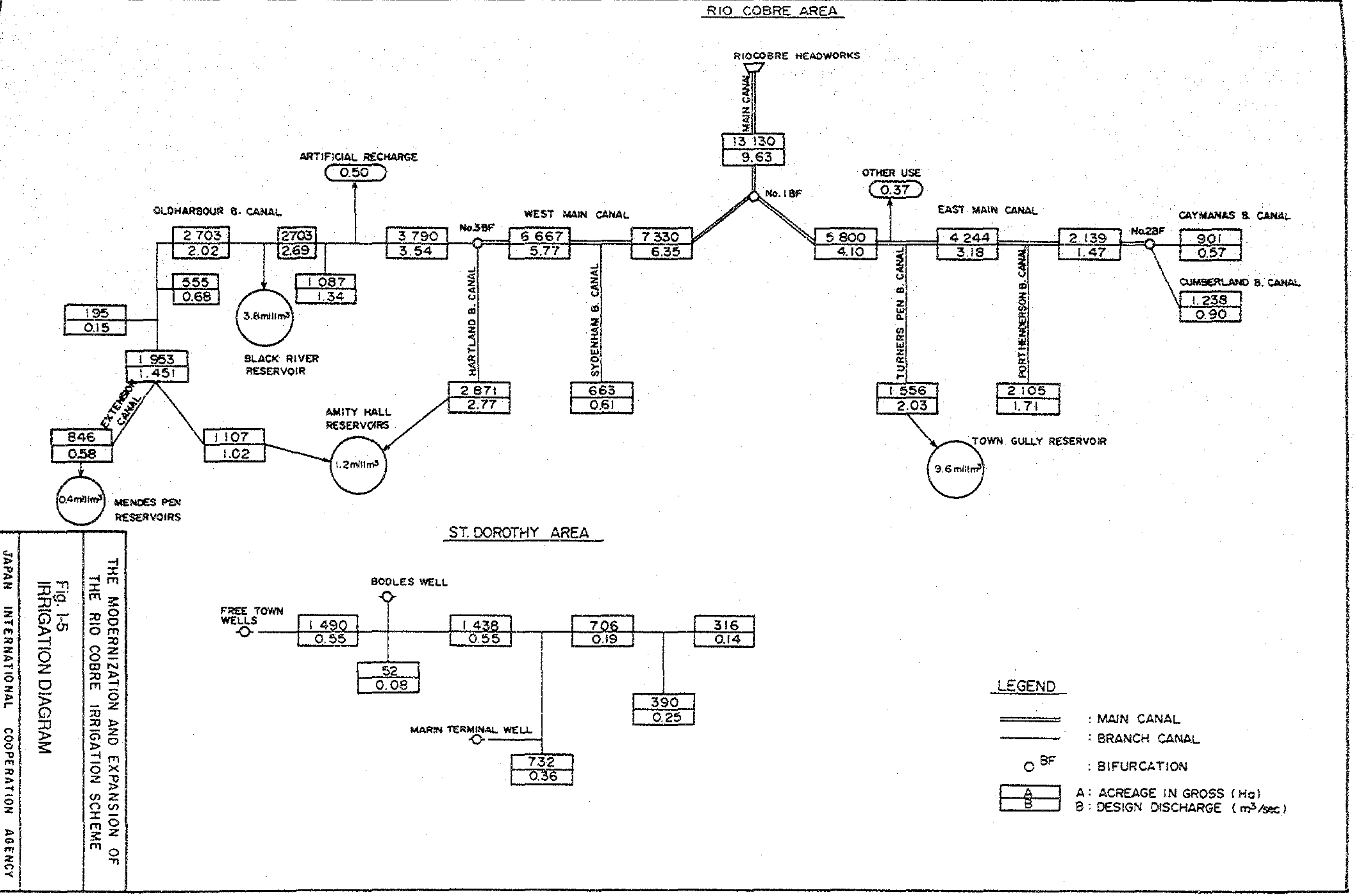
JAPAN INTERNATIONAL COOPERATION AGENCY



THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

Fig. I-4 GENERAL LAYOUT MAP OF THE PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY



THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

Fig. I-5
IRRIGATION DIAGRAM

JAPAN INTERNATIONAL COOPERATION AGENCY

ANNEX - J

ON-FARM DEVELOPMENT

ANNEX-J

ON-FARM DEVELOPMENT

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. PRESENT WATER USE ON TERTIARY UNIT BASIS AND DOWNWARDS

1.1 General

There are two irrigation schemes in operation in the study area. One is the Rio Cobre Irrigation scheme, built in 1874 and operated directly by the Rio Cobre Irrigation Works. The other is the St. Dorothy Irrigation Scheme, initiated in 1963 and operated by the St. Dorothy Irrigation Authority.

According to information obtained from both operating organizations, the two schemes irrigate approximately 12,000 ha (30,000 acres) of land in the study area. However, much of the land in the study area is understood to receive insufficient water for farming especially in the dry season due to deteriorated irrigation facilities, water weeds and poor water management, etc. There are many farms receiving supplementary irrigation from underground water, pumped up from deep and shallow wells in the study area. In addition, Agro 21 is undertaking irrigation development in the eastern half of the study area.

In view of the above a detailed survey was made in the Rio Cobre west area and in the St. Dorothy Irrigation Scheme area to clarify present water use on a tertiary unit basis and downwards based on the different water sources. The results are shown in Fig. J-1, and Table J-1.

As illustrated in Fig. J-1, the rainfed and ruinated areas lie in the southern part of the study area along the coast in both Rio Cobre west and the St. Dorothy irrigation scheme areas where shortage of water is especially serious even though existing canals cross these areas. Improvement of irrigation facilities in these areas is expected to be particularly effective and rewarding.

1.2 Rio Cobre West Area: (Arable land: 5,012 ha)

The area comprises of various sectors such as Innswood Estate (sugarcane), Amity Hall (International Rice Corporation), Cherry Garden (pasture), Bushy Park (sugarcane, vegetable, etc.), Hartlands small farmers area, etc.

(1) Innswood Estat: (2,200 ha)

Innswood Estate has a large sugarcane farm. Most of the area, around 1,500 ha out of 2,200 ha is irrigated by underground water from deep wells. However, water application efficiency to each field is believed to be relatively low due to poor water management and unevenly graded fields. A branch from the Hartlands canal irrigates about 340 ha to the south of the national railway track.

(2) Amity Hall: (386 ha)

Rice cropping is under taken by the International Rice Corporation. Water is diverted from the Black river. In addition, waste water from the Innswood Estate is utilized. Several reservoirs are planned to making up the deficit in irrigation water in the dry season based future expansion of the rice scheme up to 643 ha.

(3) Cherry Garden and Bushy Park: (835 ha)

Cherry garden is pasture land irrigated mainly by underground water. In Bushy Park, along the Coleburns Gully, there are pasture lands, vegetable farms, and sugar cane fields. The area is located at the terminal point of both the Rio Cobre Irrigation Scheme and the St. Dorothy Irrigation Scheme. However, little water is observed in the existing canals in the area despite earnest demands of the farmers. As a consequence irrigated land covers only about 390 ha which is less than 50% of the total arable land.

(4) Hartlands Small Farmers Area: (327 ha)

Hartlands small farmers area is located on the downstream portion of Hartlands Branch canal. Most of the land is covered with acacia bush. Water is consumed in the sugar cane fields along the upper portion of the canal.

1.3 St. Dorothy Irrigation Scheme Area: (Arable land: 2,313 ha)

A detailed survey was made in the following areas:

(1) Alberta Farm (pasture: 54.3 ha : St. Dorothy Irrigation Scheme)
(2) Lloyds Pen (pasture: 139 ha : rainfed)
(3) New Market Pen (pasture : 222 ha underground water)
(4) Brampton Farm (orchard: 81 ha underground water)
(5) Old Harbour Estate (Whim Pen) (sugar cane: 417 ha: combination of underground water and St. Dorothy Irrigation Scheme)
(6) Lodge Pen (sugar cane: 189 ha : underground water)
(7) Others

The area irrigated by two Free Town wells covers approximately 400 ha, which is only about 20 % of the total arable land. A belt of rainfed area lies along the coastal line in the south, although about 600 ha are supplementarily irrigated by underground water from deep wells. A wooden stave pipe from Free Town wells is observed to cause much loss of water due to leakage. Repair or improvement of the wooden stave pipe will be the first step for better water management in the area. There is no farm irrigated by surface water in the area.

2. IRRIGATION WATER REQUIREMENT

2.1 General

In the planning of an irrigation project, a full knowledge of irrigation requirements of crops is needed from the time of seeding until harvest. The peak irrigation requirement of crops must be known in order to determine the capacity of the irrigation system.

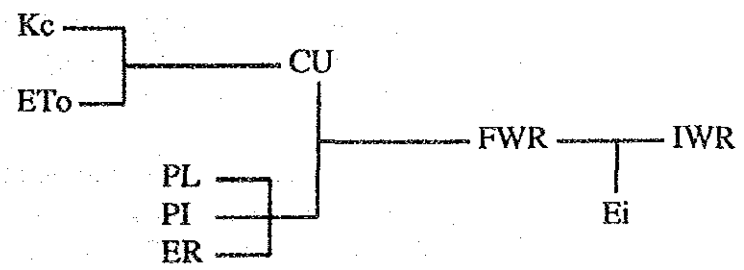
In order to determine water requirements, empirical and theoretical formulas are employed supported with date obtained through the field tests and information from previous studies carried out by various agencies.

Components and the calculation procedure to be used are as follows:

Component

kc	:	crop coefficient
ETo	:	potential evapotranspiration
CU	:	consumptive use of water
PL	:	percolation loss
PI	:	pre-irrigation requirement
ER	:	effective rainfall
Ei	:	irrigation efficiency
FWR	:	field water requirement
DWR	:	diversion water requirement

Calculation procedure



2.2 Cropping Patterns

Eight (9) types of cropping patterns are proposed in the project area as illustrated in Fig. H-5 of Annex-H.

These are:

(1) Rice - Rice
(2) Rice - Grain
(3) Vegetable - Grain
(4) Vegetable - Vegetable
(5) Pasture
(6) Sugarcane

(7) Orchard
(8) Ornamental Horticulture
(9) Aquaculture

2.3 Consumptive Use of Water

The consumptive use of water is the sum of the volume of water used by vegetative growth in a given area and can be calculated by the following formula:

$$CU = ETo \times kc$$

where, CU = consumptive use of water
ETo = potential evapotranspiration
kc = crop coefficient

2.3.1 Potential evapotranspiration (ETo)

For areas where measured data on temperature, humidity, wind and sunshine duration or radiation are available, an adaptation of the Penman method (1948) is suggested; compared with other methods, it is likely to provide the most satisfactory results.

The original Penman (1948) equation predicted evaporation losses from an open water surface (Eo). Experimentally determined crop coefficients ranging from 0.6 in winter months to 0.8 in summer months relate Eo to grass evapotranspiration for the climate in England. The Penman equation consists of two terms; the energy (radiation) term and the aerodynamic (wind and humidity) term. The relative importance of each term varies with climatic conditions. Under calm weather conditions the aerodynamic term is usually less important than the energy term. In such conditions the original Penman Eo equation using a crop coefficient of 0.8 has been shown to predict ETo closely not only in cool, humid regions as in England but also in very hot, and semi-arid regions. It is under windy conditions that errors can result in predicting ETo when using 0.8 Eo.

A slightly modified Penman equation is suggested here to determine ETo, involving a revised wind function term. The method uses mean daily climatic data, since day and night time weather conditions considerably affect the level of evapotranspiration, and adjustment for this is included.

The procedure to calculate ETo may seem rather complicated. This is due to the fact that the formula contains components which need to be derived from measured related climatic data when no direct measurements of the needed variables are available, for instance, for places where no direct measurements of net radiation are available, or cloudiness observations, together with measured humidity and temperature. Computation techniques and tables are given here to facilitate the necessary calculations. A format for calculation is also given.

The form of the equation used in this method is:

$$ETo = c \times [\,W \times Rn \;+\; (1\text{-}W) \times f(u) \times (ea\text{-}ed)\,]$$

radiation term   aerodynamic term

where, ETo = reference crop evapotranspiration in mm/day
W = temperature-related weighting factor
Rn = net radiation in equivalent evaporation in mm/day
f(u) = wind-related function
(ea-ed) = difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air, both in mbar
c = adjustment factor to compensate for the effect of day and night weather conditions

The mean reference crop evapotranspiration in the project area was calculated using the meteorological data at Bernard Lodge by the modified Penman method as presented in Table J-2 and as summarized below:

(Unit : mm/day)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4.47	5.63	5.86	6.79	6.67	6.56	7.56	6.89	5.71	5.34	4.23	4.35

2.3.2 Crop coefficient (Kc)

Crop coefficients are the values which are employed to relate the potential evapotranspiration (ETo) to the consumptive use of water (CU). The values vary on the basis of crop characteristics, time of planting and climatic conditions. Appropriate values are obtainable from FAO paper No. 24 (Ref. 5), and as given for each crop and each growing stage in Table J-3.

2.4 Unit Irrigation Water Requirement

Unit irrigation water requirement is calculated from the following equation.

(1) For rice

$$IWR = (CU + Pl + PI - ER)/Ei$$

(2) For upland crop

IWR = (CU + PI - ER)/Ei

where,	IWR	=	unit irrigation water requirement
	CU	=	consumptive use of water
	Pl	=	percolation loss
	PI	=	pre-irrigation water requirement
	ER	=	effective rainfall
	Ei	=	irrigation efficiency

2.4.1 Percolation loss

Percolation loss must be provided for in the case of a rice crop. The soil at Amity Hall where rice is proposed to be planted is classified as clay (POc5). The percolation loss for this kind of clay soil is estimated at 1 mm per day.

2.4.2 Pre-irrigation water requirement

In order to create suitable soil moisture conditions before the sowing of seeds, pre-irrigation water is required. The quantity of water required for pre-irrigation is:

(1) For rice

(a)	soil depth	:	300 mm
(b)	void ratio of soil (clay)	:	50 %
(c)	soil vapour phase after saturation	:	5 %
(d)	soil moisture before water supply	:	15 %
(e)	water required to saturate soil	:	90 mm

(2) For upland crops

(a)	soil depth	:	300 mm
(b)	void ratio of soil (silt loam)	:	45 %
(c)	soil vapour phase after irrigation	:	10 %
(d)	soil moisture before water supply	:	15 %
(e)	water required for first irrigation	:	60 mm

2.4.3 Effective rainfall

Effective rainfalls for rice and upland crops are assessed from the daily rainfall data at Bernard Lodge station.

There are various methods for estimating effective rainfall. In general, effective rainfall estimated by the daily water/moisture balance method offers the best results for predicting water requirement. The dependable rainfall efficiency of each soil and each crop was computed by this method based on daily rainfall data. The computation was done for all years of data available, and then results obtained were averaged.

Basic conditions for water/moisture balance calculation are;

(1) A daily rainfall of more than 5 mm and less than 100 mm for paddy fields and of more than 5 mm and less than 40 mm for upland fields are effective.

(2) 25 mm for paddy and 0 mm for upland field are adopted as a lower limit of field water/moisture level to be kept, and 100 mm for paddy and 60 mm for upland field are adopted as the upper limit,

(3) 75 mm for paddy and 40 mm for upland fields are normal irrigation water applications for one interval,

(4) Irrigation intervals are estimated as 5 days for paddy and 10 days for upland crops,

(5) Percolation rate, potential evapotranspiration, water requirements for pre-irrigation and standing water and crop coefficients (Kc) have been discussed in the previous section.

The average effective rainfall was estimated from records at Bernard Lodge Meteorological Station for Rio Cobre area, and from records at Old Harbour Meteorological Station for St. Dorothy area, as shown in Table J-4.

3. IRRIGATION EFFICIENCY

3.1. General

After determining net irrigation water requirements an estimate of the expected field irrigation efficiency is needed to determine irrigation water requirements at the on-farm level. No irrigation system is capable of applying an exact amount of water with perfectly uniformity. In addition, some water will be lost by evaporation during application, especially with sprinkler systems. Surface runoff, water spillage and leakage from the on-farm water distribution system also affect the expected farm irrigation efficiency. Seepage from unlined farm ditches and deep percolation through the soil profile due to non-uniform and excessive water applications usually cannot be recovered for use on a given farm. This affects the design irrigation efficiency.

3.2 Irrigation Efficiency at On-Farm Level

The overall farm irrigation efficiency to be used in design should be estimated by considering all components that affect irrigation efficiency. In order to determine such irrigation efficiency, however, empirical data are obtained through the field tests as well as information from previous studies carried out by various agencies.

The following table gives the recommendable irrigation efficiencies for different irrigation methods:

Irrigation Method		Field Application Efficiency
Rice	(flood)	100 %
Upland	(furrow)	60 %
	(sprinkler)	75 %
	(drip)	85 %

It is noted in the above table that no application losses are considered for rice cultivation since percolation loss is included in the net water requirement for flood irrigation methods with continuous water supply.

3.3 Conveyance Loss and Operation Loss

During conveyance of water from an intake to field, seepage or leakage and evaporation from canal and canal operation losses occur. The magnitude of such losses depends on the type of canal and canal operation and maintenance. Taking into account these conditions for the project the following efficiencies are adopted:

- Main and branch canals with provision of lining : 90 %
- Minor branch canal with lining : 80-90 %

3.4 Overall Irrigation Efficiency

On the above assumptions, the overall irrigation efficiency (Ei) is estimated as a product of application efficiency (Ea), operation efficiency (Eo) and conveyance efficiency (Ec) as summarized below:

(Unit: %)

Irrigation Method		Ea	Eo	Ec	Ei
Rice	(flood)	100	80	90	72
Upland	(furrow)	60	90	90	49
	(sprinkler)	75	-	90	68
	(drip)	85	-	90	77

3.5 Unit Water Requirements

The diversion water requirements, gross water requirements in other words, for the proposed cropping pattern in the project area are estimated based on effective rainfall with dependability of 80 %.

Unit diversion water requirement for various crops were calculated by dividing the net water requirement by the overall irrigation efficiency as shown in Table J-5. Table J-6 summarizes Table J-5.

4. FIELD MEASUREMENTS

4.1 General

Field tests were carried out to assess irrigation efficiency and consumptive use of crops.

(1) Irrigation efficiency

- for furrow irrigation at Innswood Estate
- for sprinkler irrigation at vegetable farm (Block A)

(2) Consumptive use

- for sugarcane at Innswood Estate
- for vegetable at vegetable farm (Block A)

4.2 Field Experiments

(1) Furrow irrigation (30/8/86) at Innswood Estate

(a) field : 1.60 (m) x 2 (rows) x 200 (m) = 640 (m^2)
(b) water application : 3.1 (lit/sec) x 3,600 (sec/hr) x 6.5 (hr) = 72.54 (m^3)
(c) water depth : 72.54 (m^3)/640 (m^2) = 113 mm
(d) recharge of water in soil : 0 to 70 cm

0 m	50 m	100 m	150 m	200 m
119.62 mm (106 %)	68.22 mm (60 %)	76.00 mm (67 %)	88.77 mm (79 %)	84.28 mm (75 %)

(2) Sprinkler irrigation (25/8/86) at Vegetable Farm (Block A)

		Moisture Content (0 to 30 cm)			
	Unit	I	II	III	IV
(a) Before irrigation	mm	52.00	52.00	52.00	52.00
(b) After irrigation	mm	74.11	75.02	75.43	77.00
(c) Balance	mm	22.11	23.02	23.43	25.00

(d) Irrigation efficiency : 22.11 mm/25.00 mm = 88 %

(3) Consumptive use of sugarcane (0 to 70 cm)

(a) Moisture content sampled on 22/8 : 233.88 mm
(b) Moisture content sampled on 3/9 : 194.56 mm
(c) Effective rain fall on 29/8 and 30/8 : 22.70 mm
(d) Balance : 60.02 mm

(e) Consumptive use : 60.02 mm/12 days = 5.17 mm/day

(4) Consumptive use of vegetable (0 to 30 cm)

(a) Moisture content sampled on 22/8	:	74.71 mm
(b) Moisture content sampled on 25/8	:	57.45 mm
(c) Balance	:	17.26 mm

(d) Consumptive use : 17.26 mm/3 days = 5.75 mm/day

4.3 Experimental Results

As seen in the above calculations, irrigation efficiency of furrow method is more than 60%, whereas that of sprinkler is more than 88%.

Consumptive use of sugarcane and vegetable (cucumber) is 5.17 mm/day and 5.75-mm/day, respectively.

5. IRRIGATION INTERVAL

5.1 Sugarcane

Decisions on the frequency of irrigation in the St. Catherine plains are made depending on meteorological conditions, type and growth stage of the irrigated crop, soil type, irrigation system (e.g. furrow irrigation, overhead sprinkler), source of water supply (well or canal) and various other aspects, which may differ from estate to estate and one private land owner to the other.

Summarizing all available information, mainly that obtained from Bernard Lodge and Innswood Estates, it seems that, in general, irrigation takes place every 10 to 21 days. Higher frequencies are associated with gravity irrigation on sandy loam (average is every 14 days), lower frequencies with sugarcane on clay loams (18 to 21 days) and sprinkler irrigation in general (18 to 20 days). Irrigation is usually postponed for 7 to 14 days (depending on soil type), if rainfall in excess of 40 mm falls within four days. It was decided to assume an irrigation frequency of one application every 15 days for all irrigated sub-areas. This meant that the mathematical model split the given monthly irrigation gifts into two equal portions, applying them twice monthly. The actual dates of irrigation were assumed to systematically vary between sub-areas, starting with the first and 15th of the month for the first irrigated sub-area, taking the second and 16th day of the month for the next sub-area and so on.

In the context of irrigation frequency allowance has to be made for the fact that during a certain period prior to the reaping of sugarcane no irrigation water is applied, in order to increase the sucrose content of the plants. From information gathered at the sugar estates it seems that the duration of this "drying out period" is more or less uniformly set at four (4) to six (6) weeks, four (4) weeks being the average duration for sugarcane on lighter soils and 5 to 6 weeks the mean value for sugarcane on heavier soils, although variations in the length of the drying out period occur, depending on meteorological conditions and the whole cycle of reaping in different fields.

5.2 Other Crops

Irrigation on pasture is practiced every 10 to 14 days. The quantity of water applied per irrigation ranges from 80 mm to 120 mm. For vegetables (cucumber), the irrigation interval is much shorter, usually 4 to 6 days since the effective root zone of the crop is assumed to be shallow and hence the irrigation water which can be applied at one time is less, 30 mm to 50 mm.

6. STANDARD ON-FARM DEVELOPMENT DESIGN

6.1 Upland Crops

Three types of irrigation method will be applied for upland crops taking into account the varieties of crops to be introduced, topographic conditions in the field and the characteristics of each irrigation method. They are furrow irrigation for sugarcane, sprinkler irrigation for vegetable and pasture and drip irrigation system for orchard crop, respectively.

6.1.1 Furrow method

(1) General

Furrow irrigation method is commonly applied for sugarcane fields in the project area namely, Caymanas, Innswood, and Old Harbour Estate, etc. However, most of the fields are not fully graded or prepared and water application efficiency is believed to be rather low irrespective of the heavy water consumption of sugarcane. A moderate to high water application efficiency can be achieved if water management practices are followed and the land is properly prepared.

(2) Advantages of furrow irrigation method

(a) Many different kinds of crop can be grown in sequence without major changes in design or layout, or operating procedures.
(b) The capital investment is relatively low on lands not requiring extensive land forming as the furrows are constructed by common farm implements.
(c) Water does not contact plant stems and scalding is thus avoided.

(3) Disadvantages of the furrow irrigation method

(a) Surface run-off occurs except where the field is level and water is impounded until intake is completed.
(b) Labour requirements may be high as irrigation schemes must be carefully regulated to achieve uniform water distribution.
(c) Land levelling is normally required to provide uniform furrow grades.

(4) Principles of water control

There are three principles of water control which define the type of furrow system. These are:

(a) gradient with open ends - continuous uniform inflow for the entire irrigation period and recirculation or recovery of surface run-off for reuse,

(b) cutback inflow with open ends - reduced inflow rate after water has advanced to the furrow end and continuation of the reduced inflow for the time required to apply the desired application; and
(c) level impoundment - impoundment of the water until intake is achieved thus eliminating surface run-off.

Of the three, (b) is recommended in the light of the fact that less water is required and that it is relatively efficient and has high water application.

(5) Design conditions for the furrow irrigation system

Design conditions for the furrow irrigation system are summarized in Table J-7. The design was developed so as to integrate present farming conditions with those proposed now.

6.1.2 Sprinkler method

(1) General

Sprinkler irrigation is commonly used in the project area, for vegetable and pasture. This method is adaptable to many crops and topographic conditions and usually achieves a high application efficiency. However, the lateral layout must be carefully designed in a windy area with due regard to wind direction.

(2) Type of sprinkler systems

Sprinkler systems are classified according to whether the sprinkler heads are operated individually (gun or boom sprinklers), or as a group along a lateral, and according to how they are moved (or cycled) to irrigate the entire field. Sprinkler laterals can be:

(a) periodically moved from one set (irrigation) position to another by hand or mechanically until the entire field is irrigated,
(b) set so closely together (solid set) that the field can be irrigated without moving them,
(c) continuously moved around a pivot point (centre pivot) to irrigate a large circular area, or
(d) continuously moved along a closed or open channel water supply (travelling lateral) to irrigate a large rectangular area.

The above is summarized in Table J-8.

(3) Advantages of the sprinkler irrigation system

Advantages of the sprinkler irrigation system are as follows:

(a) Small, continuous streams of water can be used effectively
(b) Run off and erosion can be eliminated.

(c) Steep and rolling topography can be easily irrigated.
(d) Light frequent waterings can be efficiently applied.
(e) High water application efficiency can be achieved by a properly designed and operated system.

(4) Disadvantages of the sprinkler irrigation system

(a) High initial costs must be depreciated.
(b) Sprinklers are not well adapted to soils having an intake rate of less than about 5 mm/hr.
(c) Water supply must be capable of being cut off at odd hours when the soil moisture deficiency is satisfied.
(d) Careful management must be exercised to obtain the high potential efficiency of the method.

(5) Selection of the type of sprinkler system

Periodic movable (hand-move) system is recommended taking into account the small farm size of most of the farmers in the project area (smaller than 5 acres) and the small cost investment as compared with that of the solid set system.

(6) Design condition of the sprinkler irrigation system

The design condition is summarized in Table J-9, in which cucumber is chosen as a representative introduced crop. The Sprinkler system is summarized in Table J-10. A farm pond of half day storage of the peak water requirement of the system will be associated with the system for improvement of water management.

6.1.3 Drip method

(1) General

The drip irrigation requires high initial investment. Therefore, in the project area, it is applied in only two big farms, namely Thetford Farm and Brompton Farm. In general, drip irrigation can be used for economically for highly valuable row crops or trees, which require a low soil moisture tension. The irrigation system is more suitable for perennial than for annual crops since the water supply lines have to be removed prior to land preparation.

(2) Advantages of drip irrigation system

(a) Water application efficiency is very high because only small areas around the trees or plants are wet.
(b) Fertilizer, applied via the system, gives optimum efficiency. Since the inter-row space remains dry, weed development is reduced.

(3) Disadvantages of drip irrigation system

(a) The emission uniformity is greatly reduced when emitter clogging occurs.
(b) The system is rather more complicated. It requires efficient organization and management, highly skilled operators and conscientious maintenance.

(4) Design conditions for the drip irrigation system

Design conditions for the standard Drip Irrigation system are summarized in Table J-11. The spacing of mango trees was decided in the light of the existing drip irrigation of mango orchards in the project area. Table J-12 shows the specification of the application system.

6.2 Paddy Field

(1) General

Approximately 400 ha mechanized rice cropping is being practiced by the International Rice Corporation at Amity Hall. The plot size at Amity Hall is relatively large, eight (8) ha on average. However, the proposed plot size of paddy field is decidedly smaller taking into account that small farmers are expected to settle in the proposed site, which is located just to the east of Amity Hall. Water management on large scale plots as practiced at Amity Hall is rather difficult due to incomplete land levelling work. Therefore, land levelling work should be appropriately achieved in the proposed paddy fields for easy water management and high yields.

(2) Standard paddy field design

Since small farmers are expected to settle in the area, a relatively small plot size is proposed in consideration of their farm management ability. Concerning the irrigation facilities, simple facilities such as wooden stop logs, and division boxes composed of concrete panels are recommended. Design conditions are summarized in Table J-13.

REFERENCES

(1) Scs National Engineering Handbook Section 15 Chapter 11

(2) Design and Operation of Farm Irrigation System (the American Society of Agricultural Engineering)

(3) Irrigation (Corona-sha)

(4) Sprinkle Irrigation (Toyo Sprinkler Co., Ltd.)

(5) Irrigation and Drainage Paper 24 revised 1977, FAO

Table J-1 PRESENT IRRIGATED AREA BASED ON WATER SOURCE IN THE PROJECT AREA

(Unit : ha)

Description	Name of Area and Water Source		Total
	East of Colebums (West Rio Cobre)	West of Colebums (St. Dorothy)	
1. Underground Water	1,854(37%)	1,041 (45%)	2,895 (40%)
2. Surface Water	802 (16%)	-	802 (11%)
3. Combination of the above	150 (3%)	-	150 (2%)
4. Rainfed area	502 (10%)	486 (21%)	988 (13%)
5. Bush, grassland, etc.	1,704 (34%)	786 (34%)	2,490 (34%)
Total	5,012 (100%)	2,313 (100%)	7,325 (100%)

Table J-2 MODIFIED PENMAN EVAPOTRANSPIRATION; BERNARD LODGE

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean temperature (C)	23.4	23.4	23.5	24.3	25.0	25.9	26.1	26.2	26.5	25.8	25.0	23.9
Mean relative humidity (%)	78.0	76.0	75.0	73.5	76.0	74.5	72.0	76.0	78.5	78.5	77.5	76.0
ea	28.8	28.8	29.0	30.4	31.7	33.4	33.8	34.0	34.6	33.2	31.7	29.6
ed	22.5	21.9	21.8	22.3	24.1	24.9	24.3	25.8	27.2	26.1	24.6	22.5
ea-ed	6.3	6.9	7.2	8.1	7.6	8.5	9.5	8.2	7.4	7.1	7.1	7.1
U2 (km/day) at 2 m height	209	253	257	241	293	358	335	271	236	191	171	188
f(u)	0.84	0.95	0.96	0.92	1.06	1.23	1.17	1.00	0.90	0.78	0.73	0.78
(l-W)	0.28	0.28	0.27	0.27	0.26	0.25	0.25	0.25	0.24	0.25	0.26	0.27
(l-w) . f(u) . (ea-ed)	1.48	1.84	1.87	2.01	2.09	2.61	2.78	2.05	1.60	1.38	1.35	1.50
Ra*	11.6	13.0	14.6	15.6	16.1	16.1	16.1	15.8	14.9	13.6	12.0	11.1
Sunshine hours (n)*	8.3	8.6	8.4	9.2	8.7	8.1	8.9	8.3	7.5	7.9	7.1	8.3
N	11.1	11.5	12.0	12.6	13.0	13.2	13.1	12.7	12.3	11.7	11.3	11.0
n/N	0.75	0.75	0.70	0.73	0.67	0.61	0.68	0.65	0.61	0.68	0.63	0.75
Rs = Ra (0.25 + 0.50 n/N)**	7.28	8.15	8.76	9.57	9.44	8.80	9.44	9.05	8.15	7.97	6.72	6.96
Rns = (1 - 0.25) Rs	5.46	6.11	6.57	7.18	7.08	6.60	7.08	6.79	6.11	5.98	5.04	5.22
f(T)	15.3	15.3	15.3	15.4	15.7	15.9	15.9	15.9	16.0	15.9	15.7	15.4
f(ed)	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
f(n/N)	0.78	0.78	0.73	0.76	0.70	0.65	0.71	0.69	0.65	0.71	0.67	0.78
Rnl = f(T) .f(ed).f(n/N)	1.43	1.43	1.34	1.40	1.32	1.24	1.35	1.32	1.25	1.35	1.26	1.44
Rnc = Rns-Rnl	4.03	4.68	5.23	5.78	5.76	5.36	5.73	5.47	4.86	4.63	3.78	3.78
W	0.72	0.72	0.73	0.73	0.74	0.75	0.75	0.75	0.76	0.75	0.74	0.73
W.Rnc	2.90	3.37	3.82	4.22	4.26	4.02	4.29	4.10	3.96	3.47	2.80	2.76
W.Rnc + (1-W).f(u).(ea-ed)	4.38	5.21	5.69	6.23	6.35	6.63	7.07	6.15	5.29	4.85	4.15	4.26
(unaccounted ETo)												
adjustment factor (c)	1.02	1.08	1.03	1.09	1.05	0.99	1.07	1.12	1.08	1.10	1.02	1.02
adjusted ETo (mm/day)	4.47	5.63	5.86	6.79	6.67	6.56	7.56	6.89	5.71	5.34	4.23	4.35
ETo (mm/month)	139	158	182	204	207	197	234	214	171	166	127	135

Remarks : * ; Latitude 18N

** ;mm/day

Table J-3 CROP COEFFICIENT (kc)

Crops	Initial Stage	Crop Develop Stage	Mid-Season Stage	Late Stage
Rice	1.00	1.10	1.25	1.00
Grain (1) Soya bean	0.40	0.70	1.00	0.45
Grain (2) Cowpea	0.40	0.70	1.00	0.90
Grain (3&4) Corn	0.40	0.73	1.05	0.55
Veg. (1) Carrot	0.43	0.72	1.00	0.70
Veg. (2) Cucumber	0.43	0.67	0.90	0.70
Pasture		0.90 throughout the year		
Sugarcane	0.50/0.70	0.90/1.00	1.05	0.80/0.60
Orchard- Mango		0.60 throughout the year		

Table J-4 EFFECTIVE RAINFALL

(Unit:mm)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
(1) Bernard Lodge	Station (Rio Cobre Area)												
Monthly Mean	22	26	23	42	92	78	35	80	100	187	98	38	820
1/5 year	14	17	15	27	60	50	23	52	65	121	64	25	533
Rice													
(mm/month)	10.5	12.8	11.3	20.3	45.0	37.5	17.3	39.0	48.8	90.8	48.0	18.8	400.1
(mm/day)	0.35	0.43	0.38	0.68	1.50	1.25	0.58	1.30	1.63	3.03	1.60	0.63	
Upland													
(mm/month)	9.8	11.9	10.5	18.9	42.0	35.0	16.1	36.4	45.5	84.7	44.8	17.5	373.1
(mm/day)	0.33	0.40	0.35	0.63	1.40	1.17	0.54	1.21	1.52	2.82	1.49	0.58	
(2) Old Harbour	Station (St.Dorothy Area)												
Monthly Mean	46	46	53	67	141	105	53	131	146	223	118	54	1,183
1/5 year	32	32	36	46	97	72	37	90	100	154	81	37	814
Upland													
(mm/month)	22.4	22.4	25.2	32.2	67.9	50.4	25.9	63.0	70.0	108	56.7	25.9	569.8
(mm/day)	0.75	0.75	0.84	1.07	2.26	1.68	0.86	2.10	2.33	3.59	1.89	0.86	

Table J-5(1/14) CROP WATER REQUIREMENT (RIO COBLE AREA)

CROP:RICE 1

		Feb			Mar			Apr			May			Jun			Jul			Aug		
Month		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
					1.00	1.00	1.00	1.10	1.10	1.10	1.25	1.25	1.25	1.25	1.25	1.00	1.00	0.00				
						1.00	1.00	1.00	1.10	1.10	1.10	1.25	1.25	1.25	1.25	1.25	1.00	1.00	0.00			
Kc							1.00	1.00	1.00	1.10	1.10	1.10	1.25	1.25	1.25	1.25	1.25	1.00	1.00	0.00		
								1.00	1.00	1.00	1.10	1.10	1.10	1.25	1.25	1.25	1.25	1.25	1.00	1.00	0.00	
Ave.Kc		0.00	0.00	0.00	1.00	1.00	1.00	1.03	1.05	1.08	1.14	1.18	1.21	1.25	1.25	1.19	1.13	0.81	0.67	0.50	0.00	0.00
AREA FACTER		0.00	0.00	0.00	0.25	0.50	0.75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.75	0.50	0.25	0.00
ETo	(mm/day)	5.63	5.63	5.63	5.86	5.86	5.86	6.79	6.79	6.79	6.67	6.67	6.67	6.56	6.56	6.56	7.56	7.56	7.56	6.89	6.89	6.89
CU	(mm/day)	0.00	0.00	0.00	5.86	5.86	5.86	6.96	7.13	7.30	7.59	7.84	8.09	8.20	8.20	7.79	8.51	6.14	5.04	3.45	0.00	0.00
PERC.	(mm/day)	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
EFF.RAIN	(mm/day)	0.43	0.43	0.43	0.38	0.38	0.38	0.68	0.68	0.68	1.50	1.50	1.50	1.25	1.25	1.25	0.58	0.58	0.58	1.30	1.30	1.30
Sub-Total	(mm/day)	0.00	0.00	0.00	1.62	3.24	4.86	7.28	7.45	7.62	7.09	7.34	7.59	7.95	7.95	7.54	8.93	6.56	4.10	1.57	0.00	0.00
PRE IRR.	(mm/day)			3.00	3.00	3.00																
FWR	(mm/day)	0.00	0.00	3.00	4.62	6.24	4.86	7.28	7.45	7.62	7.09	7.34	7.59	7.95	7.95	7.54	8.93	6.56	4.10	1.57	0.00	0.00
IRR.EFFICIENCY	Canal Eff.(%) :		72%		Field Eff.(%) :			100%														
IWR	(mm/day)	0.00	0.00	4.17	6.42	8.67	6.75	10.11	10.35	10.58	9.84	10.19	10.54	11.04	11.04	10.47	12.40	9.11	5.69	2.18	0.00	0%
Equi	(mm/month)		42			218			310			306			326			272			22	
Equi	(l/sec/ha)		0.16			0.84			1.20			1.18			1.26			1.05			0.08	

Table J-5(2/14) CROP WATER REQUIREMENT (RIO COBLE AREA)

CROP:RICE 2

		Aug			Sep			Oct			Nov			Dec			Jan		
Month		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
			1.00	1.00	1.00	1.10	1.10	1.10	1.25	1.25	1.25	1.25	1.25	1.00	1.00	0.00			
				1.00	1.00	1.00	1.10	1.10	1.10	1.25	1.25	1.25	1.25	1.25	1.00	1.00	0.00		
Kc					1.00	1.00	1.00	1.10	1.10	1.10	1.25	1.25	1.25	1.25	1.25	1.00	1.00	0.00	
						1.00	1.00	1.00	1.10	1.10	1.10	1.25	1.25	1.25	1.25	1.25	1.00	1.00	0.00
Ave.Kc		0.00	1.00	1.00	1.00	1.03	1.05	1.08	1.14	1.18	1.21	1.25	1.25	1.19	1.13	0.81	0.67	0.50	0.00
AREA FACTER		0.00	0.25	0.50	0.75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.75	0.50	0.25
ETo	(mm/day)	6.89	6.89	6.89	5.71	5.71	5.71	5.34	5.34	5.34	4.23	4.23	4.23	4.35	4.35	4.35	4.47	4.47	4.47
CU	(mm/day)	0.00	6.89	6.89	5.71	5.85	6.00	5.74	6.07	6.27	5.13	5.29	5.29	5.17	4.89	3.53	2.98	2.24	0.00
PERC.	(mm/day)	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
EFF.RAIN	(mm/day)	1.30	1.30	1.30	1.63	1.63	1.63	3.03	3.03	3.03	1.60	1.60	1.60	0.63	0.63	0.63	0.35	0.35	0.35
Sub-Total	(mm/day)	0.00	1.65	3.30	3.81	5.22	5.37	3.71	4.04	4.24	4.53	4.69	4.69	5.54	5.26	3.90	2.72	1.44	0.00
PRE IRR.	(mm/day)	3.00	3.00	3.00															
FWR	(mm/day)	3.00	4.65	6.30	3.81	5.22	5.37	3.71	4.04	4.24	4.53	4.69	4.69	5.54	5.26	3.90	2.72	1.44	0.00
IRR.EFFICIENCY	Canal Eff.(%) :		72%		Field Eff.(%) :			100%											
IWR	(mm/day)	4.17	6.45	8.74	5.29	7.25	7.45	5.15	5.62	5.90	6.29	6.51	6.51	7.69	7.31	5.42	3.78	2.00	0.00
Equi	(mm/month)		194			200			167			193			204			58	
Equi	(l/sec/ha)		0.75			0.77			0.64			0.75			0.79			0.22	

Table J-5(3/14) CROP WATER REQUIREMENT (RIO COBLE AREA)

CROP:GRAIN 1

Month		Jan 1	Jan 2	Jan 3	Feb 1	Feb 2	Feb 3	Mar 1	Mar 2	Mar 3	Apr 1	Apr 2	Apr 3	May 1	May 2	May 3	Jun 1	Jun 2	Jun 3
			0.40	0.40	0.70	0.70	1.00	1.00	1.00	1.00	0.45	0.45							
				0.40	0.40	0.70	0.70	1.00	1.00	1.00	1.00	0.45	0.45						
					0.40	0.40	0.70	0.70	1.00	1.00	1.00	1.00	0.45	0.45					
						0.40	0.40	0.70	0.70	1.00	1.00	1.00	1.00	0.45	0.45				
							0.40	0.40	0.70	0.70	1.00	1.00	1.00	1.00	0.45	0.45			
Kc								0.40	0.40	0.70	0.70	1.00	1.00	1.00	1.00	0.45	0.45		
									0.40	0.40	0.70	0.70	1.00	1.00	1.00	1.00	0.45	0.45	
Ave.Kc		0.00	0.40	0.40	0.50	0.55	0.64	0.70	0.74	0.83	0.84	0.80	0.82	0.78	0.73	0.63	0.45	0.45	0.00
AREA FACTER		0.00	0.14	0.28	0.42	0.56	0.70	0.85	1.00	1.00	1.00	1.00	0.85	0.70	0.56	0.42	0.28	0.14	0.00
ETo	(mm/day)	4.47	4.47	4.47	5.63	5.63	5.63	5.86	5.86	5.86	6.79	6.79	6.79	6.67	6.67	6.67	6.56	6.56	6.56
CU	(mm/day)	0.00	1.79	1.79	2.82	3.10	3.60	4.10	4.35	4.86	5.67	5.43	5.55	5.20	4.84	4.22	2.95	2.95	0.00
EFF.RAIN	(mm/day)	0.33	0.33	0.33	0.40	0.40	0.40	0.35	0.35	0.35	0.63	0.63	0.63	1.40	1.40	1.40	1.17	1.17	1.17
Sub-Total	(mm/day)	0.00	0.20	0.41	1.01	1.51	2.24	3.19	4.00	4.51	5.04	4.80	4.18	2.66	1.92	1.19	0.50	0.25	0.00
PRE IRR.	(mm/day)	1.00	1.00	1.00	1.00	1.00	1.00												
FWR	(mm/day)	1.00	1.20	1.41	2.01	2.51	3.24	3.19	4.00	4.51	5.04	4.80	4.18	2.66	1.92	1.19	0.50	0.25	0.00
IRR.EFFICIENCY	Canal	Eff.(%) :		72%	Field	Eff.(%) :		65%											
IWR	(mm/day)	2.14	2.57	3.01	4.30	5.36	6.93	6.81	8.55	9.63	10.78	10.26	8.93	5.69	4.11	2.53	1.07	0.53	0.00
Equi	(mm/month)		77			166			250			300			123			16	
Equi	(1/sec/ha)		0.30			0.64			0.96			1.16			0.48			0.06	

Table J-5(4/14) CROP WATER REQUIREMENT (RIO COBLE AREA)

CROP:GRAIN 2

Month		Mar 1	Mar 2	Mar 3	Apr 1	Apr 2	Apr 3	May 1	May 2	May 3	Jun 1	Jun 2	Jun 3	Jul 1	Jul 2	Jul 3	Aug 1	Aug 2	Aug 3	Sep 1	Sep 2	Sep 3
					0.40	0.40	0.73	0.73	0.73	1.05	1.05	1.05	0.55	0.55	0.55							
						0.40	0.40	0.73	0.73	0.73	1.05	1.05	1.05	0.55	0.55	0.55						
							0.40	0.40	0.73	0.73	0.73	1.05	1.05	1.05	0.55	0.55	0.55					
								0.40	0.40	0.73	0.73	0.73	1.05	1.05	1.05	0.55	0.55	0.55				
									0.40	0.40	0.73	0.73	0.73	1.05	1.05	1.05	0.55	0.55	0.55			
Kc										0.40	0.40	0.73	0.73	0.73	1.05	1.05	1.05	0.55	0.55	0.55		
											0.40	0.40	0.73	0.73	0.73	1.05	1.05	1.05	0.55	0.55	0.55	
Ave.Kc		0.00	0.00	0.00	0.40	0.40	0.51	0.57	0.60	0.67	0.73	0.82	0.84	0.82	0.79	0.80	0.75	0.68	0.55	0.55	0.55	0.00
AREA FACTER		0.00	0.00	0.00	0.14	0.28	0.42	0.56	0.70	0.85	1.00	1.00	1.00	1.00	1.00	0.85	0.70	0.56	0.42	0.28	0.14	0.00
ETo	(mm/day)	5.86	5.86	5.86	6.79	6.79	6.79	6.67	6.67	6.67	6.56	6.56	6.56	7.56	7.56	7.56	6.89	6.89	6.89	5.71	5.71	5.71
CU	(mm/day)	0.00	0.00	0.00	2.72	2.72	3.46	3.77	3.99	4.49	4.77	5.38	5.52	6.17	5.97	6.05	5.17	4.65	3.79	3.14	3.14	0.00
EFF.RAIN	(mm/day)	0.35	0.35	0.35	0.63	0.63	0.63	1.40	1.40	1.40	1.17	1.17	1.17	0.54	0.54	0.54	1.21	1.21	1.21	1.52	1.52	1.52
Sub-Total	(mm/day)	0.00	0.00	0.00	0.29	0.58	1.19	1.33	1.81	2.63	3.60	4.21	4.35	5.63	5.43	4.68	2.77	1.93	1.08	0.45	0.23	0.00
PRE IRR.	(mm/day)			1.00	1.00	1.00	1.00	1.00	1.00													
FWR	(mm/day)	0.00	0.00	1.00	1.29	1.58	2.19	2.33	2.81	2.63	3.60	4.21	4.35	5.63	5.43	4.68	2.77	1.93	1.08	0.45	0.23	0.00
IRR.EFFICIENCY	Canal	Eff.(%) :		90%	Field	Eff.(%) :		75%														
IWR	(mm/day)	0.00	0.00	1.48	1.91	2.35	3.24	3.45	4.17	3.89	5.33	6.24	6.44	8.34	8.05	6.94	4.10	2.85	1.61	0.67	0.34	0.00
Equi	(mm/month)		15			75			115			180			233			86			10	
Equi	(1/sec/ha)		0.06			0.29			0.44			0.69			0.90			0.33			0.04	

Table J-5(5/14) CROP WATER REQUIREMENT (RIO COBLE AREA)

CROP:VEGITABLE 1

Month		Jan			Feb			Mar			Apr			May			Jun			Jul			Aug		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
			0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70											
				0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70										
Kc					0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70									
						0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70								
							0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70							
								0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70						
									0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70					
										0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70				
											0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70			
												0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70		
Ave.Kc		0.00	0.43	0.43	0.51	0.55	0.57	0.63	0.67	0.70	0.72	0.74	0.76	0.79	0.80	0.82	0.84	0.83	0.82	0.80	0.77	0.70	0.70		
AREA FACTER		0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.00	1.00	0.90	0.80	0.70	0.60	0.50	0.40	0.30	0.20	0.10	0.00	0.00
ETo	(mm/day)	4.47	4.47	4.47	5.63	5.63	5.63	5.86	5.86	5.86	6.79	6.79	6.79	6.67	6.67	6.67	6.56	6.56	6.56	7.56	7.56	7.56	6.89	6.89	6.89
CU	(mm/day)	0.00	1.92	1.92	2.87	3.10	3.23	3.68	3.91	4.08	4.88	5.00	5.19	5.28	5.37	5.48	5.53	5.47	5.38	6.05	5.80	5.29	4.82	0.00	0.00
EFF.RAIN	(mm/day)	0.33	0.33	0.33	0.40	0.40	0.40	0.35	0.35	0.35	0.63	0.63	0.63	1.40	1.40	1.40	1.17	1.17	1.17	0.54	0.54	0.54	1.21	1.21	1.21
Sub-Total	(mm/day)	0.00	0.16	0.32	0.74	1.08	1.42	2.00	2.49	2.98	3.83	4.37	4.56	3.88	3.57	3.26	3.05	2.58	2.10	2.20	1.58	0.95	0.36	0.00	0.00
PRE IRR.	(mm/day)	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60														
FWR	(mm/day)	0.60	0.76	0.92	1.34	1.68	2.02	2.60	3.09	3.58	4.43	4.37	4.56	3.88	3.57	3.26	3.05	2.58	2.10	2.20	1.58	0.95	0.36	0.00	0.00
IRR.EFFICIENCY	Canal	Eff.(%) :		90%	Field	Eff.(%) :		75%																	
IWR	(mm/day)	0.89	1.12	1.36	1.99	2.49	2.99	3.85	4.58	5.31	6.56	6.48	6.75	5.74	5.29	4.83	4.52	3.82	3.12	3.26	2.34	1.41	0.54	0.00	0.00
Equi	(mm/month)		34			75			137			198			159			115			70			5	
Equi	(1/sec/ha)		0.13			0.29			0.53			0.76			0.61			0.44			0.27			0.02	

Table J-5(6/14) CROP WATER REQUIREMENT (RIO COBLE AREA)

CROP:VEGITABLE 2

Month		Aug			Sep			Oct			Nov			Dec			Jan			Feb			Mar		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
					0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70									
						0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70								
Kc							0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70							
								0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70						
									0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70					
										0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70				
											0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70			
												0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70		
													0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70	
														0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70
Ave.Kc		0.00	0.00	0.00	0.43	0.43	0.47	0.51	0.55	0.59	0.63	0.67	0.70	0.72	0.74	0.76	0.79	0.80	0.82	0.83	0.83	0.82	0.80	0.77	0.73
AREA FACTER		0.00	0.00	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.00	1.00	0.90	0.80	0.70	0.60	0.50	0.40	0.30	0.20	0.10
ETo	(mm/day)	6.89	6.89	6.89	5.71	5.71	5.71	5.34	5.34	5.34	4.23	4.23	4.23	4.35	4.35	4.35	4.47	4.47	4.47	5.63	5.63	5.63	5.86	5.86	5.86
CU	(mm/day)	0.00	0.00	0.00	2.46	2.46	2.68	2.72	2.94	3.15	2.66	2.82	2.95	3.13	3.22	3.32	3.51	3.60	3.67	4.68	4.69	4.62	4.69	4.49	4.30
EFF.RAIN	(mm/day)	1.21	1.21	1.21	1.52	1.52	1.52	2.82	2.82	2.82	1.49	1.49	1.49	0.58	0.58	0.58	0.33	0.33	0.33	0.40	0.40	0.40	0.35	0.35	0.35
Sub-Total	(mm/day)	0.00	0.00	0.00	0.09	0.19	0.35	0.00	0.06	0.20	0.82	1.07	1.31	2.55	2.64	2.74	2.86	2.61	2.34	2.57	2.15	1.69	1.30	0.83	0.39
PRE IRR.	(mm/day)			0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60												
FWR	(mm/day)	0.00	0.00	0.60	0.69	0.79	0.95	0.60	0.66	0.80	1.42	1.67	1.91	2.55	2.64	2.74	2.86	2.61	2.34	2.57	2.15	1.69	1.30	0.83	0.39
IRR.EFFICIENCY	Canal	Eff.(%) :		90%	Field	Eff.(%) :		75%																	
IWR	(mm/day)	0.00	0.00	0.89	1.03	1.17	1.41	0.89	0.98	1.18	2.10	2.47	2.83	3.77	3.91	4.06	4.24	3.87	3.46	3.81	3.18	2.50	1.93	1.23	0.53
Equi	(mm/month)		9			36			30			74			118			116			95			37	
Equi	(1/sec/ha)		0.03			0.14			0.12			0.29			0.45			0.45			0.37			0.14	

Table J-5(7/14) CROP WATER REQUIREMENT (RIO COBLE AREA)

CROP:PASTURE

Month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ave.Kc		0.90	0.90	0.90	0.90	0.00	0.90	0.90	0.90	0.00	0.00	0.90	0.90
AREA FACTER		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ETo	(mm/day)	4.47	5.63	5.86	6.79	6.67	6.56	7.56	6.89	5.71	5.34	4.23	4.35
CU	(mm/day)	4.02	5.07	5.27	6.11	0.00	5.90	6.80	6.20	0.00	0.00	3.81	3.92
EFF.RAIN	(mm/day)	0.33	0.40	0.35	0.63	1.40	1.17	0.54	1.21	1.52	2.82	1.49	0.58
Sub-Total	(mm/day)	3.69	4.67	4.92	5.48	0.00	4.73	6.26	4.99	0.00	0.00	2.32	3.34
FWR	(mm/day)	3.69	4.67	4.92	5.48	0.00	4.73	6.26	4.99	0.00	0.00	2.32	3.34
IRR.EFFICIENCY	Canal	Eff.(%) :		90%	Field	Eff.(%) :		75%					
IWR	(mm/day)	5.47	6.91	7.29	8.12	0.00	7.01	9.28	7.39	0.00	0.00	3.43	4.94
Equi	(mm/month)	164	207	219	244	0	210	278	222	0	0	103	148
Equi	(1/sec/ha)	0.63	0.80	0.84	0.94	0.00	0.81	1.07	0.86	0.00	0.00	0.40	0.57

Table J-5(8/14) CROP WATER REQUIREMENT (RIO COBLE AREA)

CROP:SUGARCANE

Month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		0.50	0.50	0.70	0.70	0.90	1.00	1.00	1.05	1.05	0.80	0.60	0.60
		0.60	0.50	0.50	0.70	0.70	0.90	1.00	1.00	1.05	1.05	0.80	0.60
Kc		0.60	0.60	0.50	0.50	0.70	0.70	0.90	1.00	1.00	1.05	1.05	0.80
		0.80	0.60	0.60	0.50	0.50	0.70	0.70	0.90	1.00	1.00	1.05	1.05
		1.05	0.80	0.60	0.60	0.50	0.50	0.70	0.70	0.90	1.00	1.00	1.05
		1.05	1.05	0.80	0.60	0.60	0.50	0.50	0.70	0.70	0.90	1.00	1.00
		1.00	1.05	1.05	0.80	0.60	0.60	0.50	0.50	0.70	0.70	0.90	1.00
Ave.Kc		0.80	0.73	0.68	0.63	0.64	0.70	0.76	0.84	0.91	0.93	0.91	0.87
AREA FACTER		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ETo	(mm/day)	4.47	5.63	5.86	6.79	6.67	6.56	7.56	6.89	5.71	5.34	4.23	4.35
CU	(mm/day)	3.58	4.10	3.98	4.27	4.29	4.59	5.72	5.76	5.22	4.96	3.87	3.79
EFF.RAIN	(mm/day)	0.33	0.40	0.35	0.63	1.40	1.17	0.54	1.21	1.52	2.82	1.49	0.58
Sub-Total	(mm/day)	3.25	3.70	3.63	3.64	2.89	3.42	5.18	4.55	3.70	2.14	2.38	3.21
FWR	(mm/day)	3.25	3.70	3.63	3.64	2.89	3.42	5.18	4.55	3.70	2.14	2.38	3.21
IRR.EFFICIENCY	Canal	Eff.(%) :		72%	Field	Eff.(%) :		65%					
IWR	(mm/day)	6.94	7.91	7.75	7.77	6.17	7.31	11.08	9.72	7.91	4.57	5.08	6.86
Equi	(mm/month)	208	237	232	233	185	219	332	292	237	137	152	206
Equi	(1/sec/ha)	0.77	0.88	0.86	0.87	0.69	0.81	1.23	1.08	0.88	0.51	0.57	0.76

Table J-5(9/14) CROP WATER REQUIREMENT (RIO COBLE AREA)

CROP:ORCHARD

Month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AVE.Kc		0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
AREA FACTER		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ETo	(mm/day)	4.47	5.63	5.86	6.79	6.67	6.56	7.56	6.89	5.71	5.34	4.23	4.35
CU	(mm/day)	2.68	3.38	3.52	4.07	4.00	3.94	4.54	4.13	3.43	3.20	2.54	2.61
EFF.RAIN	(mm/day)	0.33	0.40	0.35	0.63	1.40	1.17	0.54	1.21	1.52	2.82	1.49	0.58
Sub-Total	(mm/day)	2.35	2.98	3.17	3.44	2.60	2.77	4.00	2.92	1.91	0.38	1.05	2.03
FWR	(mm/day)	2.35	2.98	3.17	3.44	2.60	2.77	4.00	2.92	1.91	0.38	1.05	2.03
IRR.EFFICIENCY	Canal	Eff.(%) :		90%	Field	Eff.(%) :		85%					
IWR	(mm/day)	3.07	3.89	4.14	4.50	3.40	3.62	5.22	3.82	2.49	0.50	1.37	2.65
Equi	(mm/montl	92	117	124	135	102	108	157	115	75	15	41	80
Equi	(1/sec/ha)	0.36	0.45	0.48	0.52	0.39	0.42	0.60	0.44	0.29	0.06	0.16	0.31

Table J-5(10/14) UNIT WATER REQUIREMENT (ST. DOROTHY AREA)

CROP:VEGITABLE 1

		Jan			Feb			Mar			Apr			May			Jun			Jul			Aug		
Month		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
			0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70											
				0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70										
Kc					0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70									
						0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70								
							0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70							
								0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70						
									0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70					
										0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70				
											0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70			
												0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70		
Ave.Kc			0.43	0.43	0.51	0.55	0.57	0.63	0.67	0.70	0.72	0.74	0.76	0.79	0.80	0.82	0.84	0.83	0.82	0.80	0.77	0.70	0.70		
AREA FACTER			0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.00	1.00	0.90	0.80	0.70	0.60	0.50	0.40	0.30	0.20	0.10	0.00	0.00
ETo	(mm/day)	4.47	4.47	4.47	5.63	5.63	5.63	5.86	5.86	5.86	6.79	6.79	6.79	6.67	6.67	6.67	6.56	6.56	6.56	7.56	7.56	7.56	6.89	6.89	6.89
CU	(mm/day)	0.00	1.92	1.92	2.87	3.10	3.23	3.68	3.91	4.08	4.88	5.00	5.19	5.28	5.37	5.48	5.53	5.47	5.38	6.05	5.80	5.29	4.82	0.00	0.00
EFF.RAIN	(mm/day)	0.75	0.75	0.75	0.75	0.75	0.75	0.84	0.84	0.84	1.07	1.07	1.07	2.26	2.26	2.26	1.68	1.68	1.68	0.86	0.86	0.86	2.10	2.10	2.10
Sub-Total	(mm/day)	0.00	0.12	0.23	0.64	0.94	1.24	1.71	2.15	2.59	3.43	3.93	4.12	3.02	2.80	2.57	2.69	2.27	1.85	2.08	1.48	0.89	0.27	0.00	0.00
PRE IRR.	(mm/day)	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60														
FWR	(mm/day)	0.60	0.72	0.83	1.24	1.54	1.84	2.31	2.75	3.19	4.03	3.93	4.12	3.02	2.80	2.57	2.69	2.27	1.85	2.08	1.48	0.89	0.27	0.00	0.00
IRR.EFFICIENCY	Canal	Eff.(%) :		90%	Field	Eff.(%) :		75%																	
IWR	(mm/day)	0.89	1.06	1.24	1.83	2.28	2.73	3.42	4.07	4.73	5.97	5.83	6.10	4.47	4.14	3.81	3.99	3.37	2.74	3.07	2.19	1.31	0.40	0.00	0.00
Equi	(mm/month)		32			68			122			179			124			101			66			4	
Equi	(1/sec/day)		0.12			0.26			0.47			0.69			0.48			0.39			0.25			0.02	

Table J-5(11/14) UNIT WATER REQUIREMENT (ST. DOROTHY AREA)

CROP:VEGITABLE 2

Month		Aug 1	Aug 2	Aug 3	Sep 1	Sep 2	Sep 3	Oct 1	Oct 2	Oct 3	Nov 1	Nov 2	Nov 3	Dec 1	Dec 2	Dec 3	Jan 1	Jan 2	Jan 3	Feb 1	Feb 2	Feb 3	Mar 1	Mar 2	Mar 3
					0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70									
						0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70								
Kc							0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70							
								0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70						
									0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70					
										0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70				
											0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70			
												0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70		
													0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70	
														0.43	0.43	0.67	0.67	0.67	0.90	0.90	0.90	0.90	0.90	0.70	0.70
Ave.Kc		0.00	0.00	0.00	0.43	0.43	0.47	0.51	0.55	0.59	0.63	0.67	0.70	0.72	0.74	0.76	0.79	0.80	0.82	0.83	0.83	0.82	0.80	0.77	0.73
AREA FACTER		0.00	0.00	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.00	1.00	0.90	0.80	0.70	0.60	0.50	0.40	0.30	0.20	0.10
ETo	(mm/day)	6.89	6.89	6.89	5.71	5.71	5.71	5.34	5.34	5.34	4.23	4.23	4.23	4.35	4.35	4.35	4.47	4.47	4.47	5.63	5.63	5.63	5.86	5.86	5.86
CU	(mm/day)	0.00	0.00	0.00	2.46	2.46	2.68	2.72	2.94	3.15	2.66	2.82	2.95	3.13	3.22	3.32	3.51	3.60	3.67	4.68	4.69	4.62	4.69	4.49	4.30
EFF.RAIN	(mm/day)	2.10	2.10	2.10	2.33	2.33	2.33	3.59	3.59	3.59	1.89	1.89	1.89	0.86	0.86	0.86	0.75	0.75	0.75	0.75	0.75	0.75	0.84	0.84	0.84
Sub-Total	(mm/day)	0.00	0.00	0.00	0.01	0.03	0.11	0.00	0.00	0.00	0.54	0.75	0.95	2.27	2.36	2.46	2.49	2.28	2.04	2.36	1.97	1.55	1.15	0.73	0.35
PRE IRR.	(mm/day)			0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60												
FWR	(mm/day)	0.00	0.00	0.60	0.61	0.63	0.71	0.60	0.60	0.60	1.14	1.35	1.55	2.27	2.36	2.46	2.49	2.28	2.04	2.36	1.97	1.55	1.15	0.73	0.35
IRR.EFFICIENCY	Canal	Eff.(%) :		90%	Field	Eff.(%) :		75%																	
IWR	(mm/day)	0.00	0.00	0.89	0.91	0.93	1.05	0.89	0.89	0.89	1.69	1.99	2.30	3.36	3.50	3.65	3.68	3.37	3.03	3.50	2.92	2.29	1.71	1.08	0.51
Equi	(mm/month)		9			29			27			60			105			101			87			33	
Equi	(1/sec/ha)		0.03			0.14			0.12			0.29			0.45			0.45			0.37			0.14	

Table J-5(12/14) UNIT WATER REQUIREMENT (ST. DOROTHY AREA)

CROP:PASTURE

Month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ave.Kc		0.90	0.90	0.90	0.90	0.00	0.90	0.90	0.90	0.00	0.00	0.90	0.90
AREA FACTER		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ETo	(mm/day)	4.47	5.63	5.86	6.79	6.67	6.56	7.56	6.89	5.71	5.34	4.23	4.35
CU	(mm/day)	4.02	5.07	5.27	6.11	0.00	5.90	6.80	6.20	0.00	0.00	3.81	3.92
EFF.RAIN	(mm/day)	0.75	0.75	0.84	1.07	2.26	1.68	0.86	2.10	2.33	3.59	1.89	0.86
Sub-Total	(mm/day)	3.27	4.32	4.43	5.04	0.00	4.22	5.94	4.10	0.00	0.00	1.92	3.06
FWR	(mm/day)	3.27	4.32	4.43	5.04	0.00	4.22	5.94	4.10	0.00	0.00	1.92	3.06
IRR.EFFICIENCY	Canal	Eff.(%) :		90%	Field	Eff.(%) :		75%					
IWR	(mm/day)	4.85	6.40	6.57	7.47	0.00	6.26	8.81	6.08	0.00	0.00	2.84	4.53
Equi	(mm/month)	145	192	197	224	0	188	264	182	0	0	85	136
Equi	(1/sec/ha)	0.56	0.74	0.76	0.86	0.00	0.72	1.02	0.70	0.00	0.00	0.33	0.52

Table J-5(13/14) UNIT WATER REQUIREMENT (ST. DOROTHY AREA)

CROP:SUGARCANE

Month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		0.50	0.50	0.70	0.70	0.90	1.00	1.00	1.05	1.05	0.80	0.60	0.60
		0.60	0.50	0.50	0.70	0.70	0.90	1.00	1.00	1.05	1.05	0.80	0.60
Kc		0.60	0.60	0.50	0.50	0.70	0.70	0.90	1.00	1.00	1.05	1.05	0.80
		0.80	0.60	0.60	0.50	0.50	0.70	0.70	0.90	1.00	1.00	1.05	1.05
		1.05	0.80	0.60	0.60	0.50	0.50	0.70	0.70	0.90	1.00	1.00	1.05
		1.05	1.05	0.80	0.60	0.60	0.50	0.50	0.70	0.70	0.90	1.00	1.00
		1.00	1.05	1.05	0.80	0.60	0.60	0.50	0.50	0.70	0.70	0.90	1.00
Ave.Kc		0.80	0.73	0.68	0.63	0.64	0.70	0.76	0.84	0.91	0.93	0.91	0.87
AREA FACTER		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ETo	(mm/day)	4.47	5.63	5.86	6.79	6.67	6.56	7.56	6.89	5.71	5.34	4.23	4.35
CU	(mm/day)	3.58	4.10	3.98	4.27	4.29	4.59	5.72	5.76	5.22	4.96	3.87	3.79
EFF.RAIN	(mm/day)	0.75	0.75	0.84	1.07	2.26	1.68	0.86	2.10	2.33	3.59	1.89	0.86
Sub-Total	(mm/day)	2.83	3.35	3.14	3.20	2.03	2.91	4.86	3.66	2.89	1.37	1.98	2.93
FWR	(mm/day)	2.83	3.35	3.14	3.20	2.03	2.91	4.86	3.66	2.89	1.37	1.98	2.93
IRR.EFFICIENCY	Canal	Eff.(%) :		72%	Field	Eff.(%) :		65%					
IWR	(mm/day)	6.04	7.16	6.70	6.83	4.33	6.22	10.39	7.82	6.18	2.92	4.23	6.26
Equi	(mm/month)	181	215	201	205	130	187	312	234	185	88	127	188
Equi	(1/sec/ha)	0.68	0.81	0.76	0.77	0.49	0.70	1.17	0.88	0.70	0.33	0.48	0.71

Table J-5(14/14) UNIT WATER REQUIREMENT (ST. DOROTHY AREA)

CROP:ORCHARD

Month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ave.Kc		0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
AREA FACTER		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ETo	(mm/day)	4.47	5.63	5.86	6.79	6.67	6.56	7.56	6.89	5.71	5.34	4.23	4.35
CU	(mm/day)	2.68	3.38	3.52	4.07	4.00	3.94	4.54	4.13	3.43	3.20	2.54	2.61
EFF.RAIN	(mm/day)	0.75	0.75	0.84	1.07	2.26	1.68	0.86	2.10	2.33	3.59	1.89	0.86
Sub-Total	(mm/day)	1.93	2.63	2.68	3.00	1.74	2.26	3.68	2.03	1.10	0.00	0.65	1.75
FWR	(mm/day)	1.93	2.63	2.68	3.00	1.74	2.26	3.68	2.03	1.10	0.00	0.65	1.75
IRR.EFFICIENCY	Canal	Eff.(%) :		90%	Field	Eff.(%) :		85%					
IWR	(mm/day)	2.53	3.44	3.50	3.93	2.28	2.95	4.81	2.66	1.43	0.00	0.85	2.29
Equi	(mm/month)	76	103	105	118	68	88	144	80	43	0	25	69
Equi	(1/sec/ha)	0.29	0.40	0.40	0.45	0.26	0.34	0.56	0.31	0.17	0.00	0.10	0.26

Table J-6 (1/2) SUMMARY OF UNIT DIVERSION WATER REQUIREMENT (RIO COBRE AREA)

(Unit:l/sec ha)

Name of Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
RICE 1	0.00	0.16	0.84	1.20	1.18	1.26	1.05	0.08	0.00	0.00	0.00	0.00
RICE 2	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.77	0.64	0.75	0.79
GRAIN 1	0.30	0.64	0.96	1.16	0.48	0.06	0.00	0.00	0.00	0.00	0.00	0.00
GRAIN 2	0.00	0.00	0.06	0.29	0.44	0.69	0.90	0.33	0.04	0.00	0.00	0.00
VEG. 1	0.13	0.29	0.53	0.76	0.61	0.44	0.27	0.02	0.00	0.00	0.00	0.00
VEG. 2	0.45	0.37	0.14	0.00	0.00	0.00	0.00	0.03	0.14	0.12	0.29	0.45
PASTURE	0.63	0.80	0.84	0.94	0.00	0.81	1.07	0.86	0.00	0.00	0.40	0.57
SUGARCANE	0.77	0.88	0.86	0.87	0.69	0.81	1.23	1.08	0.88	0.51	0.57	0.76
ORCHARD	0.36	0.45	0.48	0.52	0.39	0.42	0.60	0.44	0.29	0.06	0.16	0.31
HORTCLT	0.36	0.45	0.48	0.52	0.39	0.42	0.60	0.44	0.29	0.06	0.16	0.31
AQUACLT	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55

Table J-6 (2/2) SUMMARY OF UNIT DIVERSION WATER REQUIREMENT (ST.DOROTHY AREA)

(Unit:l/sec ha)

Name of Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
VEG. 1	0.12	0.26	0.47	0.69	0.48	0.39	0.25	0.02	0.00	0.00	0.00	0.00
VEG. 2	0.39	0.34	0.13	0.00	0.00	0.00	0.00	0.03	0.11	0.10	0.23	0.41
PASTURE	0.56	0.74	0.76	0.86	0.00	0.72	1.02	0.70	0.00	0.00	0.33	0.52
SUGARCANE	0.68	0.81	0.76	0.77	0.49	0.70	1.17	0.88	0.70	0.33	0.48	0.71
ORCHARD	0.29	0.40	0.40	0.45	0.26	0.34	0.56	0.31	0.17	0.00	0.10	0.26
AQUACLT	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55

Table J-7 DESIGN CONDITIONS FOR FURROW IRRIGATION

Description		Design Condition
1. Crop		Sugar cane
2. Field size		24 ha(unit) = 200mx200m/field x 6fields
3. Inflow		0.8 lit/s/Furrow channel
4. Furrow space		1.0m
5. Gradient		0.004 (1/250)
5. Peak water requirement of sugar cane		10mm/day
7. Irrigation interval		12 days (TRAM=120mm)
8. Canal type:	Tertiary canal	Trapezoid, Qmax=160 lit/s
	Distributory canal	Trapezoid, Qmax=80 lit/s
9. Farm Road:	Main Road	Width 8.0m (Effective width 7.0m)
	Farm Road	Width 6.0m (Effective width 5.0m)

Table J-8 TYPE OF SPRINKLER SYSTEM

Type of System	Max. Slope	Shape of Field	Field surface Condition	Size of single System
1. Hand move	20%	Rectangular	No limit	1-15 ha
2. Side wheel roll	5-10%	Rectangular	Resonably smooth	10-30 ha
3. Centre pivot	5-15%	Circular	Clear of obstruction	15-65 ha
4. Travelling lateral (gun or boom)	No limit	Rectangular	Lane for winch and hose	15-40 ha
5. Permanent (solid set)	No limit	Any shape	No limit	1 or more

Table J-9 DESIGN CONDITION OF SPRINKLER IRRIGATION SYSTEM

Description	Design Condition
1. Crop	Vegetable cucumber
2. Field size	20ha=0.5ha(1.25acre)/field x 40 fields
3. Peak water requirement	8mm/day (cucumber)
4. Irrigation intemal	5 days (TRAM=40mm)
5. Operation hour	14 hr/day
6. Farm pond	30mx30mx3m
7. Sprinkler system	Periodic movable (hand move system x 4 sets x 24 No/set)
8. Farm Road: Main Road	Width 8.0m (effective width 7.0m)
: Farm Road	Width 6.0m (effective width 5.0m)

Table J-10 SPECIFICATION FOR 20 HA SPRINKLER IRRIGATION UNIT

Description	Specification
1. Sprinkler	
Sprinkler	24pcs/lateral
Design head	2.0kg/cm2
Discharge	17.4 lit/min
Height	1.0m
Spacing	12.0m x 15.0m
2. Lateral set	
Nos.	8 sets
Lines	3 lines
Length	1.080m
Pipe material	aluminium
3. Sub mainline	
Nos	4 nos
Length	900m
Pipe material	UPVC(class VP)
Riser to lateral	5 nos x 50m space
Angle valve dia	75
4. Main line	
Length	200 10m
5. Pump unit	150 200m
Type	single suction volute
TDH	40m
Capacity	1.67 cu.m/min
Suction	2m

Table J-11 DESIGN CONDITIONS FOR THE DRIP IRRIGATION SYSTEM

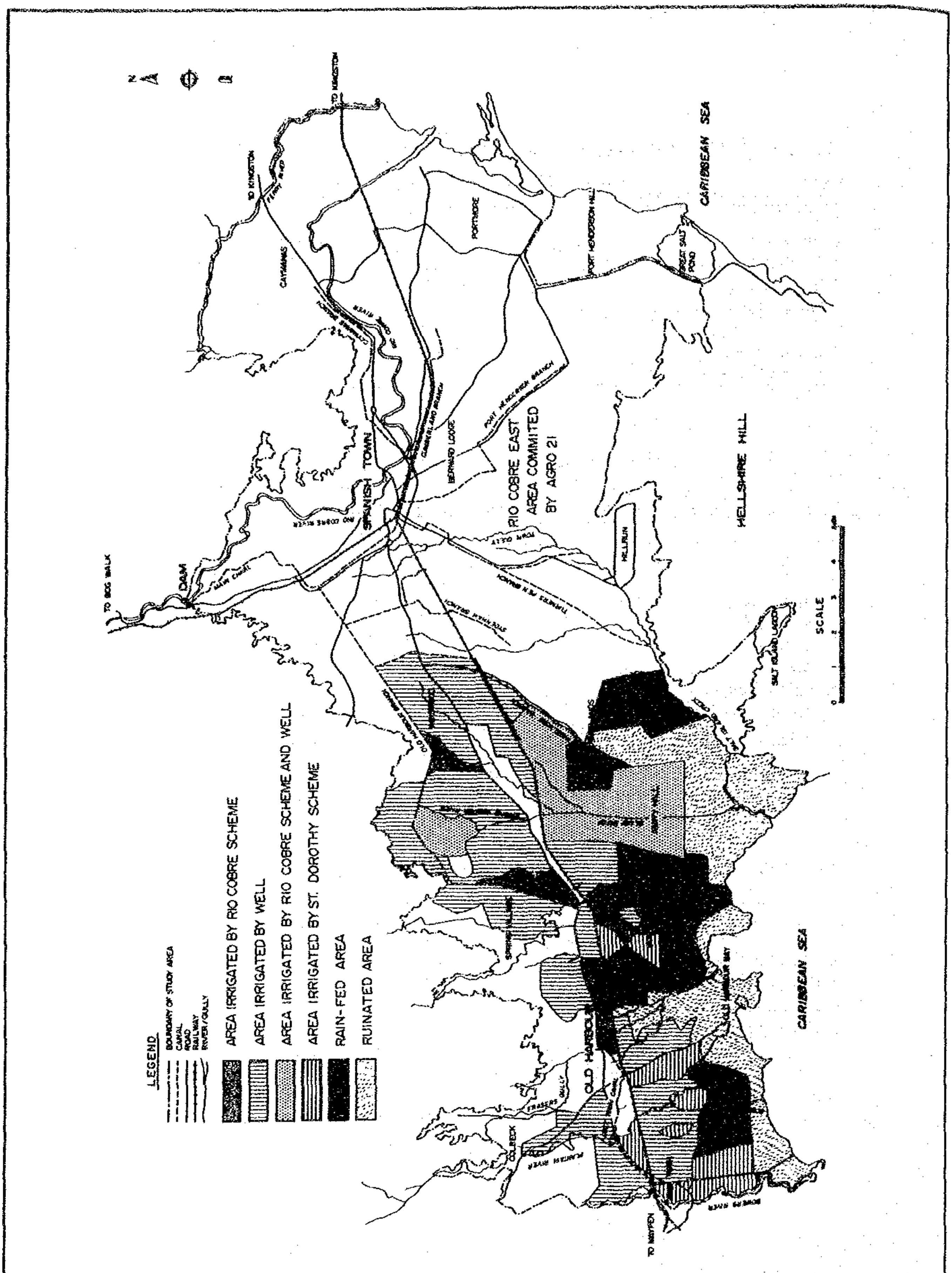
Description	Design Condition
1. Crop	Mango
2. Field size	26 ha (65acres)
3. Maximum water requirement/tree	12mm/day
4. Tree spacing	6m x 6m
5. Gross requirement/tree	432 lit/day
6. Operation hour	20 hr/day
7. Lateral spacing	6m
8. Lateral length	90m/set

Table J-12 APPLICATOR DESIGN FOR DRIP IRRIGATION SYSTEM

Description	Design Condition
1. Type	Emitter
2. Design Head	20m
3. Discharge	5.4 lit/hr
4. Exponent	0.5
5. Mfg. Coefficient of variability	0.04
6. Variability factor	0.97
7. Design emission uniformity	90%
8. Total allowable pressure variation	13m

Table J-13 DESIGN CONDITION FOR PADDY FIELD IRRIGATION

Description	Design Condition
1. Crop	Paddy
2. Plot size	0.5 ha - 2.0 ha
3. Peak water requirement	8.1mm/day
4. Irrigation interval	5 days
5. Canal type:	
Tertiary canal	Trapezoid : Qmax=140 l/s
Distributory canal	Trapezoid : Qmax=35 l/s
6. Farm Road:	
Main Road	Width 8.0m (effective width 7.0m)
Farm Road	Width 6.0m (effective width 5.0m)



THE MODERNIZATION AND EXPANSION OF
THE RIO COBRE IRRIGATION SCHEME

Fig. J-1
PRESENT WATER USE AT RIO COBRE WEST
AND ST. DOROTHY AREA

JAPAN INTERNATIONAL COOPERATION AGENCY

ANNEX - K

PRELIMINARY DESIGN

ANNEX-K

PRELIMINARY DESIGN

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. GENERAL

The project is formulated to utilize the existing irrigation facilities in an optimal manner.

Within this concept, all existing facilities and/or under planning by another agencies including Agro 21 programme in the project area were examined in their functional and structural aspects to assess whether rehabilitation works were necessary and what new facilities would be required to fulfill the projects requirement.

The preliminary design described here covers both the facilities to be rehabilitated, and those to be newly constructed together with the studies which have been undertaken.

In this Annex, the irrigation facilities in the project area are described separately for the Rio Cobre area which depends mainly on surface water from the Rio Cobre, and the St. Dorothy area which depends on groundwater. Drainage and road facilities are planned and discussed for the whole project area.

2. IRRIGATION FACILITIES IN THE RIO COBRE SCHEME

2.1 Headworks

2.1.1 Present conditions and requirements

The existing dam built in 1874 is still in working order even though some related structures have deteriorated and/or been damaged. However, for maximum utilization of surface water from the Rio Cobre, it is essential that the diversion capacity to the main canal be enlarged.

In this connection, the following works are proposed to meet the project's requirements:

(1) Raising the dam's crest
(2) Improvement of the intake gate structure and scour pocket
(3) River protection both up and downstream
(4) Grouting of dam foundation

Further detail explanations above works are stated in following sub-section.

2.1.2 Dam

The flow discharge to be diverted to the main canal is planned at 9.63 m^3/sec and so intake water level should be maintained at El. 42.3 m. This means that the dam crest elevation should be raised to El. 42.4 m including free board of 0.1 m while the crest elevation of the existing dam is El. 41.8 m.

In order to meet this conditions, the crest elevation should be raised by 0.6 m above the existing level. There are two ways of doing this, by fixed weir and by movable weir. A fixed weir would be built onto the crest of the existing dam in concrete, while a movable weir would be built onto it by flap gate. Typical cross sectional views are shown in Fig. K-1.

An economical comparison of these alternatives may be summarized as follows:

Type	Description	Cost (US$)
Fixed weir (concrete)	90 m x 0.6 m x 2 m	65,000
Movable weir (flap gate)	21 m x 0.6 m x 4 Nos.	968,000

The fixed weir type solution thus has a clear economic advantage. It should be noted that the movable weir solution is not only costly but would require rather difficult and complicated operation and maintenance.

From the technical viewpoint, the studies for the influence of the backwater on the flood bridge locating upstream of the dam and stability of the dam body due to raising of the dam crest were also made.

A study on backwater is given in Annex-B and with further discussion in sub-section 2.1.6 of this Annex. As a result of the study, it can be said that there is no significant increment of the influence on the flood bridge as compared with present condition. The result of the study on stability of the dam body shows that the existing dam body is stability even the existing dam crest be raised by mass concrete.

A decision was made to adopt the fix weir solution taking into account the results of economic and technical studies. It is proposed therefore that the existing dam crest be raised by 0.6 m (2 ft.) expanding to whole the crest length by mass concrete construction.

2.1.3 Intake gate

There are eight (8) intake gates at the existing intake structure of which two (2) gates are out of order. The other six (6) gates have also deteriorated to an extent that constrains proper operation. In order to remedy the situation and increase diversion capacity, it is proposed that the eight (8) intake gates be replaced with new ones.

The main features of the intake gates are as follows:

Type	Size	No.
Manually operated slide gate	1.4 m x 2.3 m	8

In addition to renewal of the gates, the upstream and downstream wing walls, and the scouring sluices pocket need reconstruction or replacement. A profile of the intake structure is illustrated on Fig. K-2.

2.1.4 Revetment works

In order to make the dam secure from scour damage up and downstream of the dam, it is recommended that the following works be undertaken:

(1) Apron

Since there is evidence of scour below the sub-dam it is necessary to provide an apron to protect the dam. The recommended length of apron downstream of a dam may be calculated by applying Bligh's formula as expressed below:

$$L = 0.67.C\sqrt{H.q}$$

where, L = length of apron (m)
C = Bligh's coefficient; C = 15
H = difference of height from crest top to apron (m)
42.40 - 33.00 = 9.4 m
q = unit design discharge (m^3/sec/m)
1,640/90 = 18.2 m^3/sec/m

Required length of apron is thus computed to be 130 m including the existing solid apron (water cushion) of 50 m. Thus an additional apron length of 80 m is required of which 30 m would consist of a second water cushion and the remaining 50 m as concrete blocks.

(2) Revetment

Both left and right bank downstream have concrete walls to protect them from erosion. These need to be extended by 100 m on either side.

2.1.5 Grouting

The results of borings at the existing dam reveal that the dam was founded on highly permeable alluvial stata with a thickness of 2 to 3 m and the cracking limestone stratum as discussed in Annex-C, and seepage through dam foundation was estimated to be 0.1 to 0.2 m^3/sec as reported in Annex-B. Consequently it is proposed to improve the dam foundation by curtain grouting using an appropriate chemical grout.

The whole length of the dam, i.e. 90 m and about 9 m in depth below the dam foundation will be grouted.

2.1.6 Study on backwater to the flood bridge

There is a flood bridge about 2.4 km upstream of the existing dam where the principal road (Route A-1) crosses the Rio Cobre. This bridge is designed to allow flood water to pass over it, but with traffic suspended during such flooding. The study was made to determine the influence of higher backwater on the flood bridge at various dam heights, namely 0.6 m and 0.4 m above the existing dam crest level. The minimum flood discharges and associated backwater levels to exceed the flood bridge level, El. 44.5 m, were computed, and total days to be taken by floods passing over the flood bridge were estimated using flood data of the past 29 years.

The results of these studies is shown in the table below:

Raising Height of Dam Crest	Minimum Flood Discharge	Traffic Suspended Days during Past 29 Years
(m)	(m^3/sec)	
0	150	20
0.4	140	22
0.6	130	25

As a result of the above analysis, the minimum flood discharge to exceed the flood bridge level would change from 150 m^3/sec under present condition to 130 m^3/sec when the higher of the crest is raised by 0.6 m which would correspond to an increase from 20 to 25 days during the past 29 years of record when the bridge would have been closed to traffic, or say one day every six years.

Thus there is no serious impact from raising the dam height by 0.6 m. Fig. K-3 shows the profile of the Rio Cobre and water surface elevations under various flood discharge when the dam crest is raised to El. 42.4 m, i.e. raising by 0.6 m.

2.1.7 Study on sediment load

According to the results of the investigation on sediment load in the Rio Cobre, a flood discharge of 10 m^3/sec might carry as much as 700 m^3/day of sediment load as mentioned in Annex-B.

However, since all the intake gates should be replaced under the project it should in future be possible to reduce entry of sediment into the main canal by the proper operation of the intake gates. Furthermore the scouring sluice pocket which has about 1.9 m difference in height between the floor of the pocket and base of the intake (see Fig. K-2) should be reconstructed in front of the intake. It could then be expected that most of the sediment load, especially bed load, should be settle in the pocket and be flushed downstream by appropriate operation of the scouring sluice gates which are being replaced with new ones.

If such improvements are undertaken there will be no need to provide a settling basin for the main canal.

2.1.8 Alternative study on headworks

As an alternative to rehabilitation of the existing headworks the feasibility of a new headworks was examined about 200 m downstream from the existing dam. Fig. K-4 shows the location of the alternative headworks site. On the basis of the results of the topographical survey and exploratory boring at the alternative headworks site, a preliminary design for the new headworks was worked out. The basic features of the new headworks would be as follows:

Type	:	concrete gravity dam
Crest height	:	10.2 m from river bed
Crest length	:	85 m
Apron length	:	140 m

The construction cost was roughly estimated and tabulated below with the cost for rehabilitation of the existing headworks.

(Unit: million US$)

Alternative Plan	Construction Cost
Rehabilitation plan	3.6
Newly construction plan	5.3

As shown above, it is apparent that the rehabilitation plan has the advantage in terms of cost.

At the alternative site the alluvial deposit vary in the thickness from 8 to 14 m. Such conditions would be undesirable for a dam foundation. Taking all this into account it is recommended that the rehabilitation plan for the existing head works be adopted.

2.2 Irrigation Canals and Related Structures

2.2.1 General

The irrigation canal system in the Rio Cobre area consists of the Main canal, East and West main canals, branch canals and minor branch canals. Among these canals, some branch canals have already been rehabilitated under Agro 21 programme. In the light of the conception of the project, a study was made on the need and methodology for rehabilitation works including the canals committed by Agro 21 programme. The following sub-sections give the results of study.

2.2.2 Main canals

The main canal runs from the headworks to No. 1 bifurcation while the east main canal takes off from No. 1 bifurcation to No. 2 bifurcation and the west main canal to No. 3 bifurcation from the No. 1 bifurcation. The length of the main canals are 4.7 km, 4.7 km and 2.8 km respectively.

(1) Design discharge

The required design capacities of the Main canal, and East and West main canals are based on the accumulated seasonal design discharge of respective branch canals, water supply schedule to the reservoirs and ground water recharge, and requirements for other uses such as municipal and industrial water.

The required design discharge of the main canals may be summarized as follows:

Name of Canal	Length	Design Discharge
	(km)	(m^3/sec)
Main canal	4.7	9.63
East main canal	4.7	4.10
West main canal	2.8	6.35

Note: The design discharge above are the required discharges at the head of each canal.

(2) Canal lining

Existing main canals are mostly unlined at present and suffer from weed growth and sedimentation. In order to improve such conditions, main canals are planned to be lined with plain concrete. Furthermore canal lining will have the following advantages:

a) reduction of canal leakage,
b) prevention of weed growth,
c) facilitation of canal maintenance,
d) prevention of erosion, and
e) speeding water distribution

(3) Canal section

Two type of canals are recommended based on site conditions, i.e. a trapezoidal canal lined with plain concrete and a rectangular canal lined with reinforced concrete.

The trapezoidal section should be applied the canal when on embankment. The canal base width was determined considering the existing canal base width and effective water flow. The canal side slope was designed as 1:1.5 to accord with construction conditions. A typical cross section of the main canal is shown in Fig. K-5.

The rectangular section was designed for use where the canal is in deep cut. This canal would have the advantage of keeping excavation to a minimum and in stability against soil pressure in comparison with the trapezoidal section.

2.2.3 Branch canals

There are seven (7) branch canals in the project area of which five (5) are committed under the Agro 21 programme. Consequently the remaining two branch canals, namely Hartlands and Old Harbour branch canals, are planned to be rehabilitated in the scope of this project. In addition to the above two canals, an upstream part of Turners Pen branch canal is required to be enlarged in order to pass the additional discharge required for the Town Gully Reservoir.

(1) Design discharge

The design discharges for the branch canals were determined on the basis of the peak monthly water requirements given in Annex-I. Then may be summarises as follows:

Name of Canal	Length	Design
	(km)	(m^3/sec)
Turners Pen B canal (part)	1.8	2.03
Hartland B canal	7.1	2.77
Old Harbour B canal	10.6	3.54
Old Harbour Extension canal	5.1	0.58

(2) Canal type

All branch canals are designed to be lined. An alternative study on the canal lining was made to compare with two lining methods, namely plain concrete and wet stone masonry as illustrated in Fig. K-6. The results of the study should that plain concrete lining had the advantage of minimum construction cost as shown below:

(Unit: US$/m)

Work Item	Plain Concrete Lining	Stone Masonry Lining
Plain Concrete	70	51
Gravel Foundation	6	4
Stone Masonry	0	32
Total	76	87

It is recommended that plain concrete be adopted for canal lining.

The size of canal varies depending on the design discharge. In the case of a design discharge of more than 2.5 m^3/sec a canal side slope of 1:1.5 is adopted while a canal side slope of 1:1.25 is used for sections with a design discharge of less than 2.5 m^3/sec. Fig. K-5 shows typical cross-sections of the branch canals.

2.2.4 Minor branch canals

Minor branch canals take off from branch canals to carry water to field ditches through lateral canals. In order to reduce the water losses, these canals are also planned to be lined with concrete as illustrated in Fig. K-5. The total length of minor branch canals is estimated at 53 km as summarised below:

(Unit: km)

Name of Branch Canal	Length of Minor Branch Canal
Turners Pen B. canal	6.6
Sydenham B. canal	7.0
Hartland B. canal	14.3
Old Harbour B. canal	25.1
Total	53.0

2.2.5 Canal related structures

A number of canal structures of various types are required in connection with the irrigation canals. The configurations of these structures have to be selected in relation to their functions, the existing canal system, operational programme and social conditions in the project area. Table K-1 gives a list of the structure requiring rehabilitation or reconstruction.

(1) Bifurcation

Three (3) bifurcation structures are proposed at major irrigation water delivery points, namely branching point to the east and west main canals from the main canal, the end points of the east and west main canals. These are called No. 1, No. 2, and No. 3 bifurcation respectively.

The structure will be provided with steel gates for controlling the canal discharges and measuring devices on each branch for measuring of the discharge.

(2) Check gate

In order to maintain the required water level at sites of diversion, even during periods of partial discharge, a check gate would be provided at each turnout for a branch canal on the east and west main canals and at each turnout for a minor branch canal on a branch canal where a fairly large discharge is diverted. Over the project canals, two types of check gates are proposed depending on the topography along the canal. One type simply has the function of a check gate and the other type would be combined with a drop structure.

At sites where main or 0&M road crossings are required from the view point of canal and road layouts, concrete road slabs would be provided at the check gate.

(3) Turnout

Turnout are required to divert the required water from main and branch canals to branch and minor branch canals. A rectangular box barrel culvert or precast concrete pipe would be provided to cross the road or canal embankment depending on the discharge. All turnouts are designed for full capacity at the water level regulated by the check gate.

(4) Bridge and culvert

Bridges or culverts situated on existing main and branch canals will be rehabilitated and/or reconstructed depending on their structural conditions. A bridge or culvert would be newly constructed where a new road crosses over the canal. In accordance with design load conditions and span length, a concrete slab type or T-beam type would be adopted.

(5) Spillway

A spillway or wasteway would be provided in the canal system for the purpose of emptying the canals or spilling out excess flow in case of emergency or for clearing and repairing canals.

2.3 Reservoirs

2.3.1 Function and requirement

Four reservoirs as shown in Fig. K-7 are planned in the project area including two existing reservoir systems. These have been planned on the basis of results of the water balance study as described in Annex-I. Two reservoirs would be newly constructed at Corletts Pen and Innswood. These new reservoirs are called Town gully reservoir and Black river reservoir respectively.

The other two existing reserving systems, located at Amity Hall and Mendes Pen respectively, would be involved in the reservoir system after rehabilitation. The basic features of each reservoir would be as follows:

(1) Town gully reservoir

The storage capacity of this reservoir is planned to be 9.6 million m^3 in an area of 200 ha. Water would be supplied to the reservoir through Turners Pen branch canal and delivered to both Port Henderson and downstream of Turners Pen branch canals. The height of the dike would vary from a maximum of 10.0 m to a minimum of 4.2 m.

(2) Black river reservoir

This reservoir is located about 1 km west of the Innswood sugar factory. Storage capacity of the reservoir would be 3.8 million m^3 in an area of 80 ha.

The reservoir would receive water through the Old Harbour branch canal and would deliver to downstream by the Old Harbour branch canal and by the Black river for Amity Hall. The height of dike will vary from a maximum of 8.8 to a minimum of 4.8.

(3) Amity Hall reservoir

There are five (5) reservoirs constructed and/or planned at Amity Hall by the International Rice Corporation. These reservoirs are involved in the water supply system of the project. Water is supplied to these reservoirs through the minor branch canals of Hartland and Old Harbour branch canals and pumped return flow water from the Black river.

Total storage capacity is designed to be 1.2 million m^3 in an area of 107 ha.

(4) Mendes Pen reservoirs

There are three dams at Mendes Pen to store local water from gullies. These dams are utilized as reserving system in the project. The Old Harbour extension canal would be connected to these dams and supply additional water to them. Total storage capacity would be enlarged at 0.4 million m^3 by appropriate rehabilitation works

2.3.2 Dike

Homogeneous earth dikes are proposed for the two new reservoirs. The height of the dikes will vary from 4.2 to 10.0 m for the Town gully reservoir and from 4.8 to 8.8 m for the Black river reservoir. Inside slopes at 1:3.0 would be armoured with rip-rap stone, while outside slopes at 1:2.0 would be covered by turf sodding. The top width of the dikes will be 4.0 m and minimum freeboard of 1.5 m.

2.3.3 Related structures

Each reservoir will require an inlet and outlet structure to receive and/or deliver water. An open canal or R.C. pipeline would provide the connections to the relevant canals.

2.4 Other Facilities

2.4.1 Pumping station at Nightingale

A pumping Station located at Nightingale will be required to irrigate Nightingale and Spring Village area by pumped water from Old Harbour branch canal. The basic features of pump and pipeline will be as follows:

Design discharge	:	150 lit/sec
Pump	:	4.5 m^3/min x 2 Nos.
Pipeline	:	Ductile iron pipe D = 400 mm, L = 1.5 km
Farm pond	:	50 m x 50 m x 2 m

2.4.2 Syphon at the Rio Cobre

The existing a syphon crossing of the Rio Cobre by the Caymanas branch canal is exposed on the river bed and faces serious damage by flood. The existing structure requires replacement by a new syphon of ductile iron pipe having diameter of 900 mm. For economical comparison, a pipe aqueduct was studied as an alternative plan. The table below shows the comparative construction costs of the two methods.

Method	Description	Cost (US$)
Syphon	Ductile iron pipe, D = 900 mm	153,000
Aqueduct	Steel pipe, D = 900 mm	438,000

2.4.3 Return flow utilization facilities

It is planned to use return flow from the downstream portion of the Town gulley and from the Black river. These streams are serve as main drainage collecting excess water from the sugarcane fields.

Facilities consisting of pumping stations and pipelines are planned at March Pen for the Town Gulley and Amity Hall for the Black river.

General features of these facilities would be;

March Pen Pumping Station

Design discharge	:	142 lit/sec
Pump	:	4.5 m^3/min x 2 Nos.
Pipeline	:	Ductile iron pipe D = 400 mm, L = 1.0 km
Farm pond	:	50 m x 50 m x 2 m

Amity Hall Pumping Stations

- No. 1 (Upstream)

Design discharge	:	150 lit/sec
Pump	:	4.5 m^3/min x 2 Nos.
Pipeline	:	Ductile iron pipe D = 400 mm, L = 0.1 km

- No. 2 (Downstream)

Design discharge	:	150 lit/sec
Pump	:	4.5 m^3/min x 2 Nos.
Pipeline	:	Ductile iron pipe D = 400 mm, L = 0.1 km

3. IRRIGATION FACILITIES IN THE ST. DOROTHY AREA

3.1 General

Three well pumping stations managed by St. Dorothy Irrigation Authority are involved in the project. These are Free Town, Marine Terminal, and Bodles pumping stations.

The water pumped up from Free Town pumping station is carried by a pipeline and discharged into an outlet structure where a main canal commences. Several distributory canals take off from main canal conveying the water to farm ponds or field ditches. The water pumped up from Bodles and Marine Terminal pumping stations is also supplied to Free Town irrigation system.

3.2 Free Town Pipeline

A woodstave pipe is presently used by Free Town but this is in a very bad state of repair and suffers considerable leakage as reported in Annex-B. Investigation showed that losses through the pipeline were 0.036 m^3/sec when the pumped discharge was 0.341 m^3/sec. This corresponds to 11% of the total amount pumped. Furthermore, the economic life of a woodstave pipe is generally expected to be 8 years and this was constructed in 1963. Consequently its replacement is long overdue.

In view of the present situation, it is proposed to replace the existing pipeline with a new one.

(1) Design discharge

Taking into account the present pumping right from wells at the Free Town pumping station, the design discharge of Free Town pipeline was determined to be 0.55 m^3/sec.

(2) Lifting head

The total lifting head is obtained by adding to the static head various losses of head caused by the water flow through the suction and discharge pipes and the velocity head at the end of the discharge pipe. The static head is the vertical height between the suction water surface and the discharge water surface, namely calculated as (El. 27.0 m - El. 13.0 m) + 7.0 m = 21.0 m. Then total lifting head called the total dynamic head (H) is expressed by the equation below:

$$H = Ha + Hl + Vd^2/2g$$

where,
- Ha : static head (m)
- Hl : total head loss (m)
- Vd : flow velocity (m/sec)

Total head loss consists of the friction and bend losses in the pipe, and other losses occurring due to valve, pump and so on.

The friction loss will depend on flow and the diameter of the pipe. The other losses are estimated as 10% of the friction loss. The table below shows the total dynamic head under different diameters of pipe.

(Unit: m)

Diameter (mm)	600	700	800	900
Actual Head	21.00	21.00	21.00	21.00
Losses	19.10	9.24	4.93	2.71
Velocity Head	0.20	0.12	0.07	0.05
Total Head	40.30	30.36	26.00	23.76

(3) Size of pipeline

The diameter of the pipeline should be determined from economic and engineering view points. A small diameter of pipe would results in a low construction cost but the cost of pumping equipment and operation costs would be high due to the large motor required. On the other hand, a large diameter of pipe equates with a high construction cost of pipeline but a low cost of pump equipment as well as operation cost. A cost comparison based on various combinations of pump and pipeline was made as summarized below.

(Unit: 10^3 US$)

Diameter (mm)	500	600	700	800
Cost for Pipeline	660	913	1,100	1,353
Pump set	720	460	330	300
Operation cost (20 years)	3,500	2,100	1,400	1,400
Total cost	4,880	3,473	2,830	3,053

The result indicates that pipe diameter of 700 mm provides an economical combination with pump facilities including operation cost. The diameter of pipeline was therefore determined to be 700 mm.

(4) Pipe material

Various materials for pipe were examined from technical and economic aspects. Three kinds of materials, i.e. ductile iron pipe, steel pipe and glassfiber reinforced pipe were selected from technical considerations and a further economic comparison was made as summarised below: