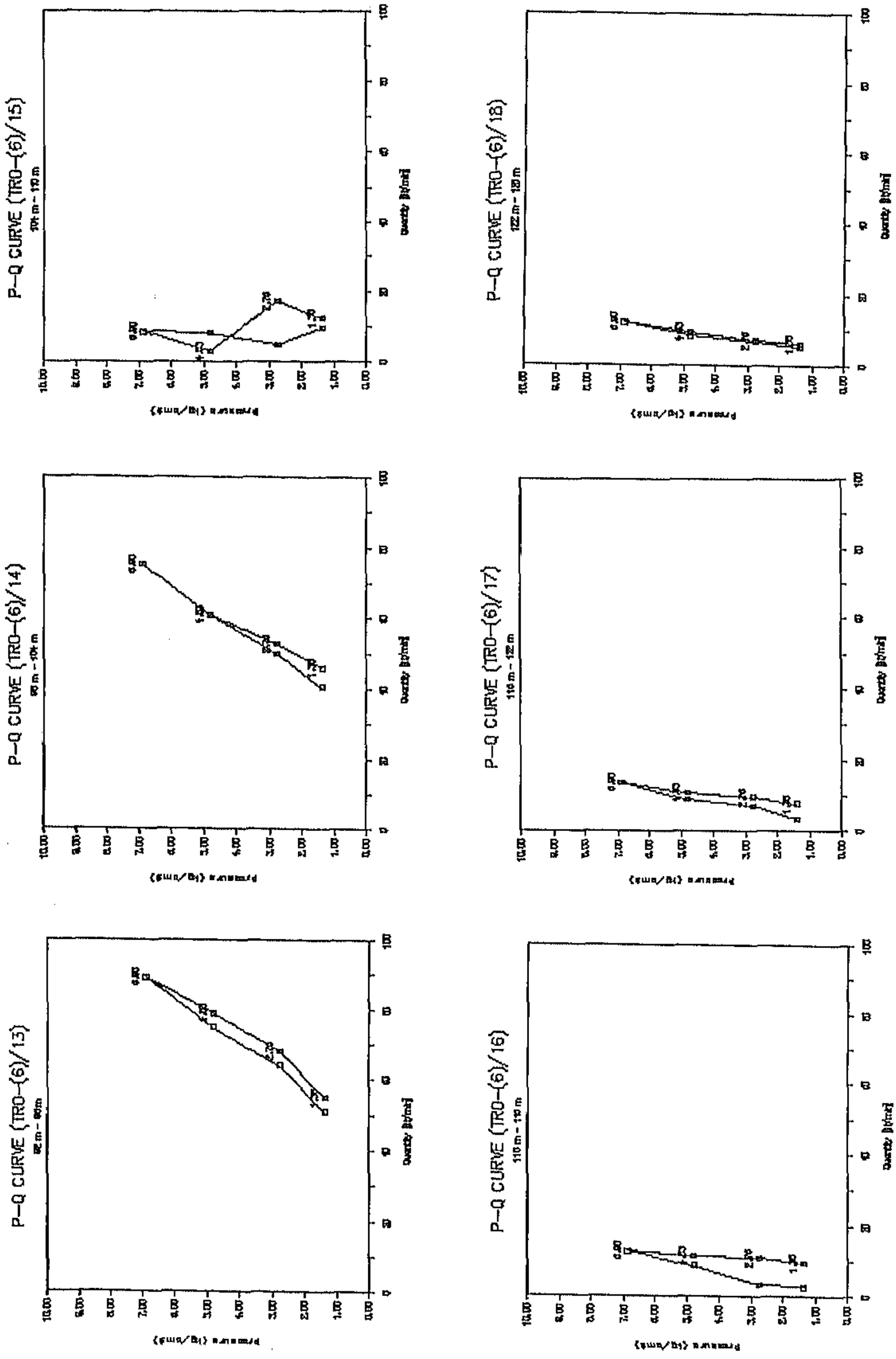
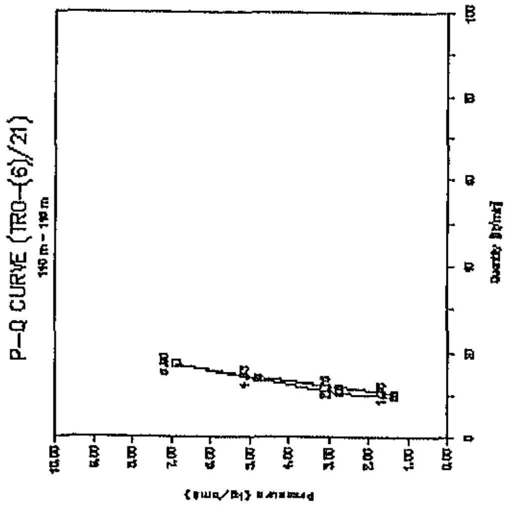
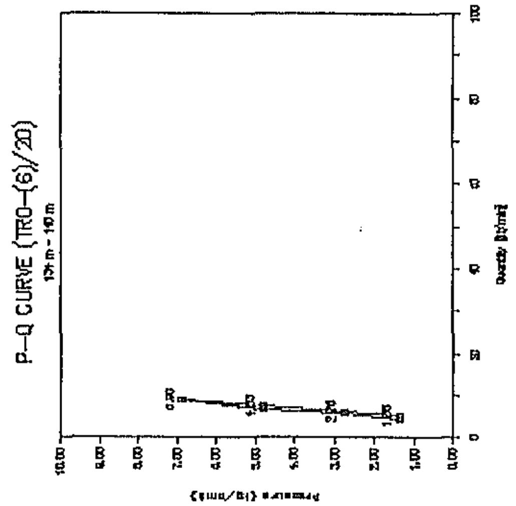
Fig. B.2.12(13)

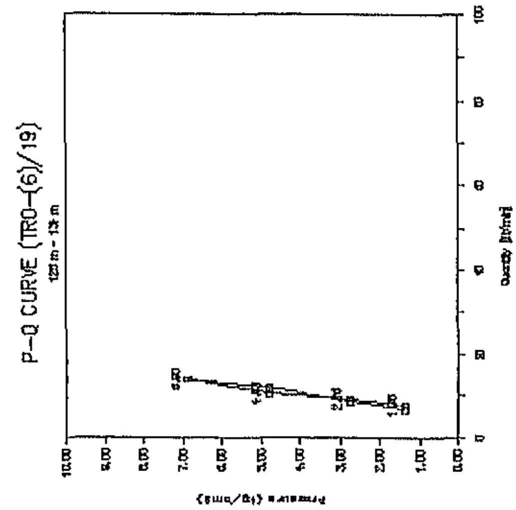


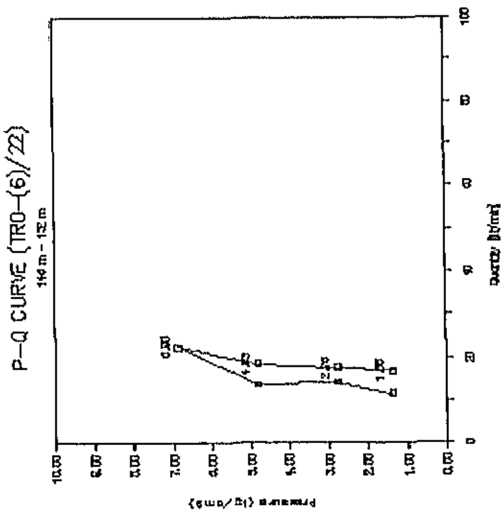
P-Q CURVE, TRO-(6)-3/4	GOVERNMENT OF MAURITIUS PORT LOUIS WATER SUPPLY PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. B.2.12(14)



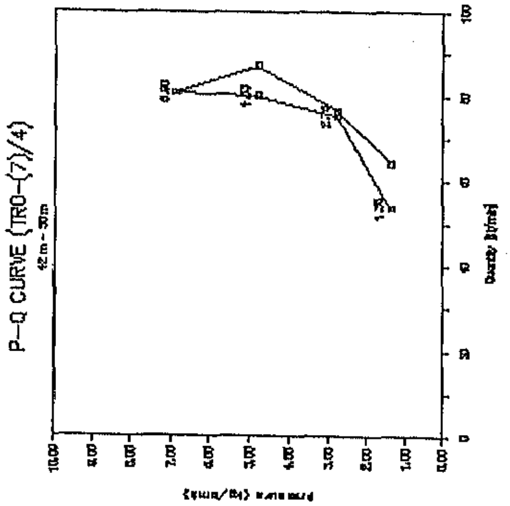


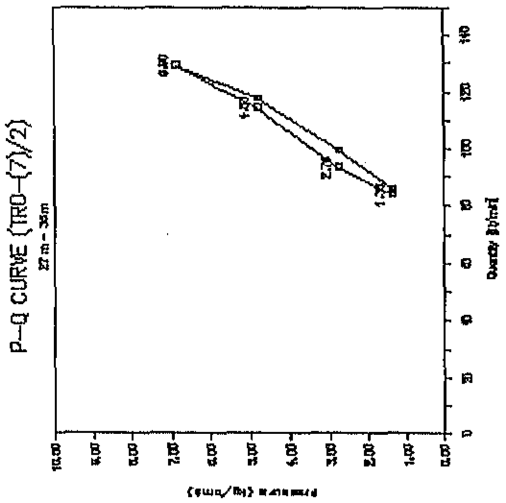


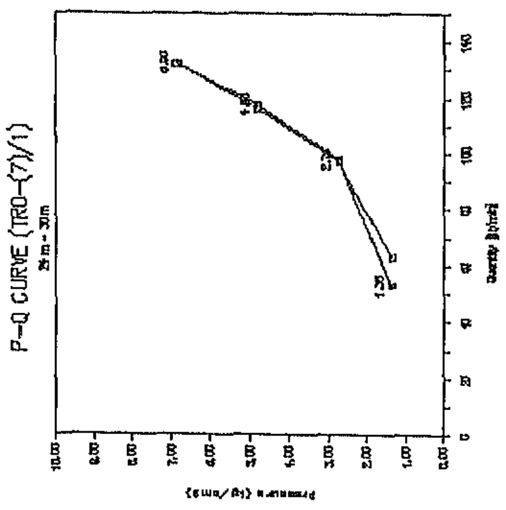


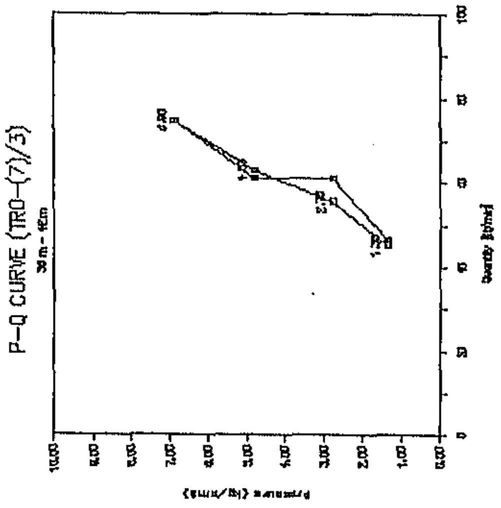
P-Q CURVE, TRO-(6)-4/4	GOVERNMENT OF MAURITIUS PORT LOUIS WATER SUPPLY PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. B.2.12(15)



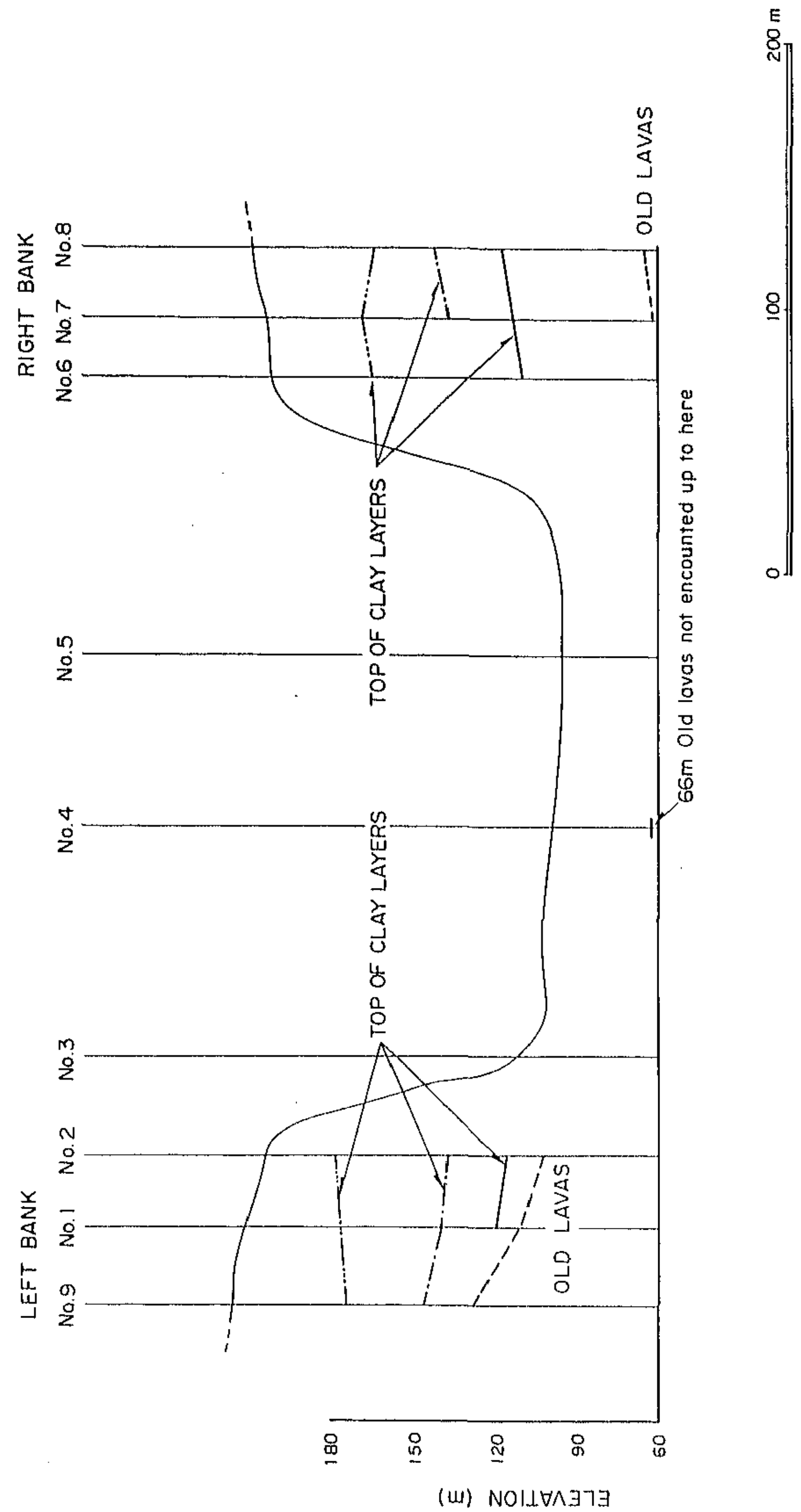






P-Q CURVE, TRO-(7)	GOVERNMENT OF MAURITIUS PORT LOUIS WATER SUPPLY PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY

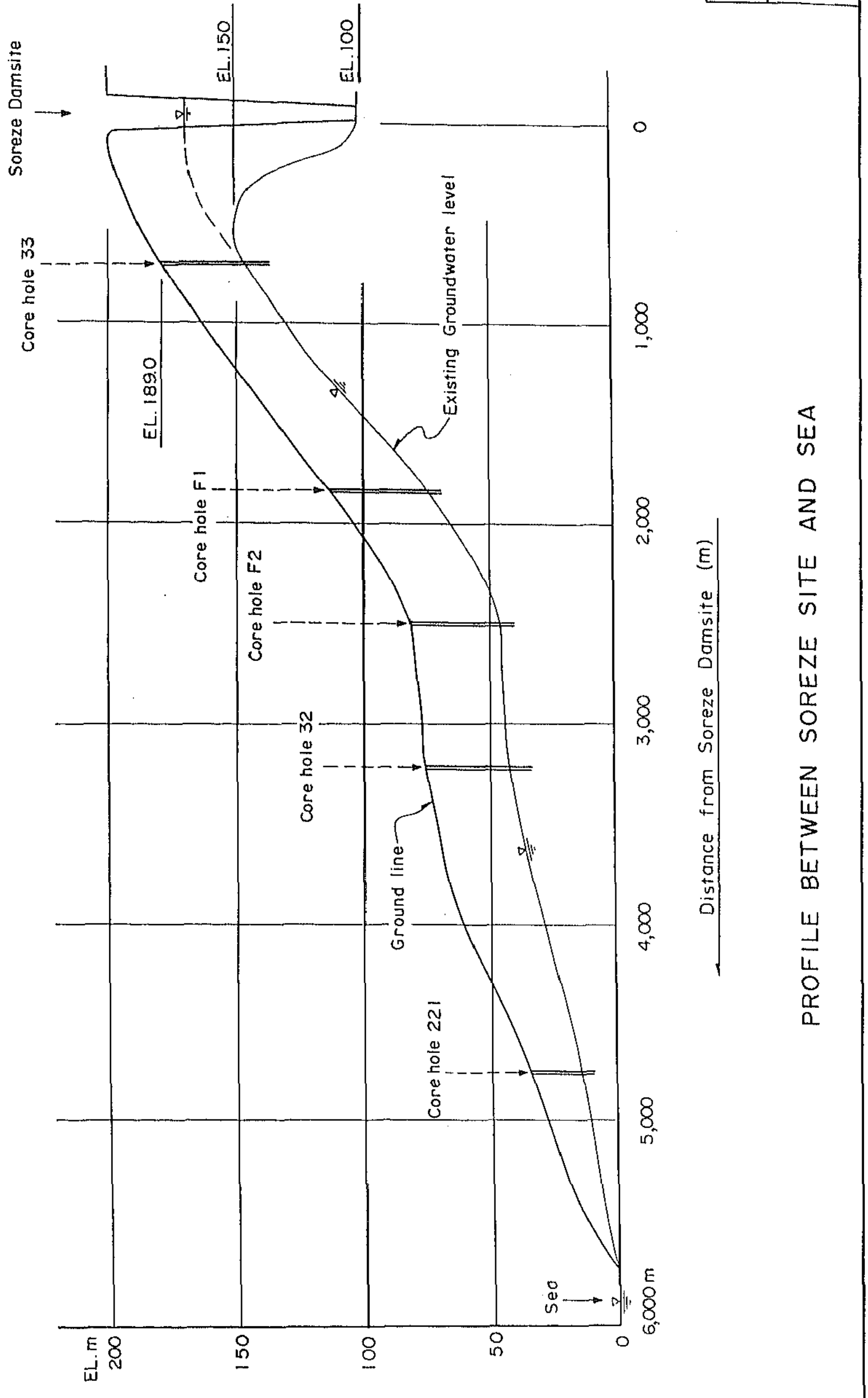
Fig. B.2.13



GEOLOGICAL SECTION AT SOREZE GORGE

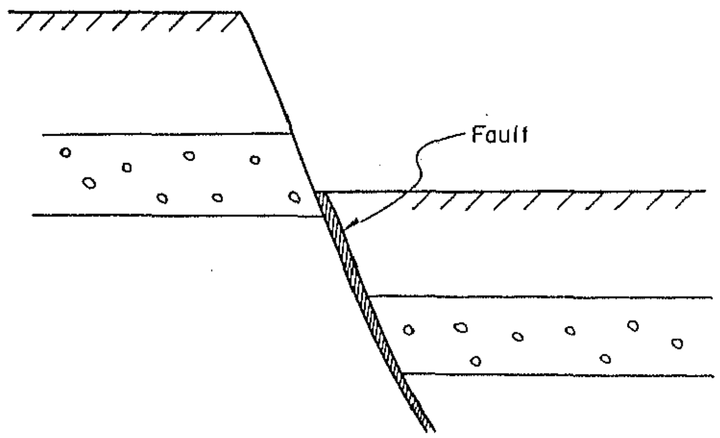
GEOLOGICAL SECTION AT SOREZE GORGE	GOVERNMENT OF MAURITIUS PORT LOUIS WATER SUPPLY PROJECT
	JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. B.2.14

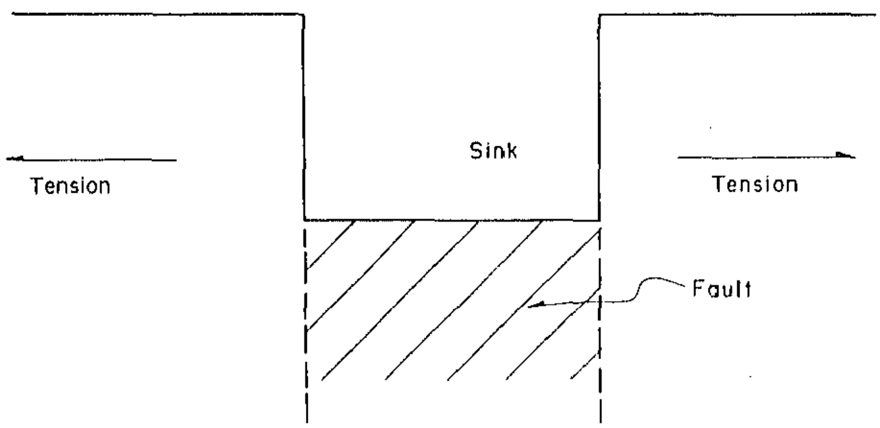


PROFILE BETWEEN SOREZE SITE AND SEA

PROFILE BETWEEN SOREZE SITE AND THE SEA	GOVERNMENT OF MAURITIUS PORT LOUIS WATER SUPPLY PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY



(a) : Case (1) Caused Due To Fault

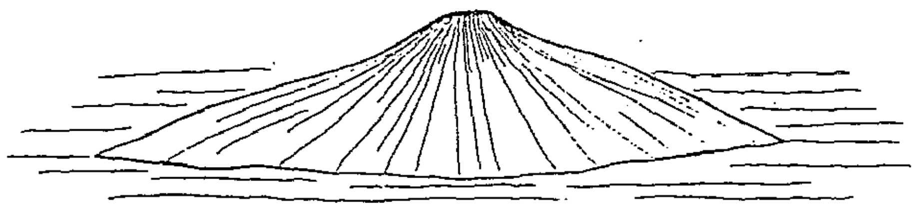


(b) : Case (2) Caused Due To Fault

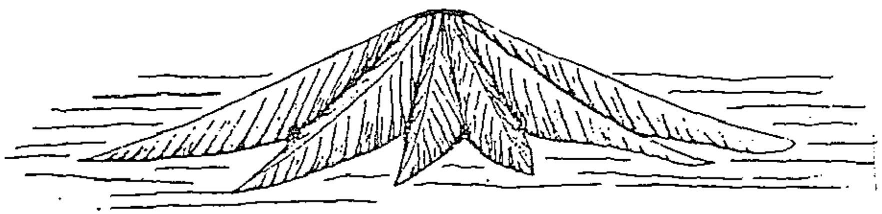
CONCEIVABLE CASES OF FAULT

CONCEIVABLE CASES OF FAULT	GOVERNMENT OF MAURITIUS PORT LOUIS WATER SUPPLY PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY

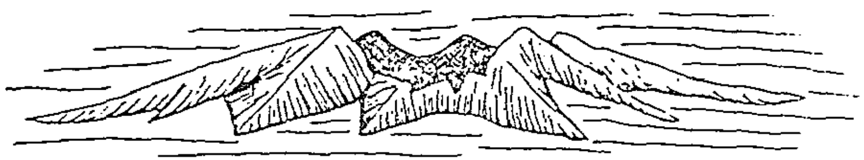
GEOLOGICAL FORMATION OF MAURITIUS



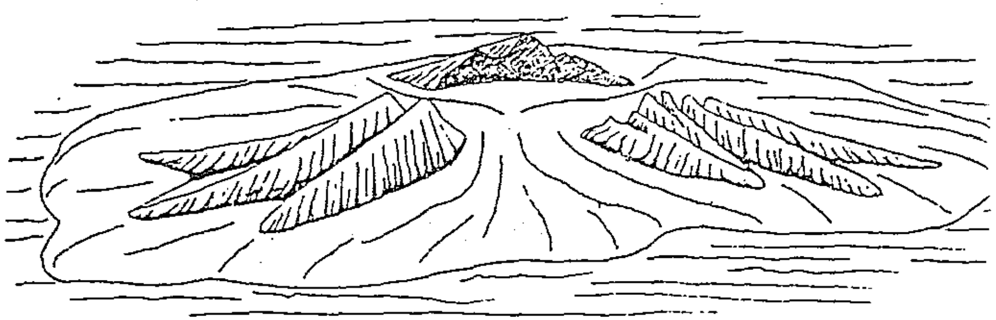
1. Eruption of Older Volcanic Series as a shield volcano



2. Erosion of the shield, leading to spurs & deeply incised valleys



3. Caldera collapse, or preferential erosion of the centre of the shield



4. Eruption of Younger Volcanic Series, isolating the eroded remnants of the Older Volcanic Series shield

Story of Geology

Mauritius is essentially composed of volcanic rocks of basic composition. The geology of Mauritius was first studied in detail by E.S.W. Simpson in 1951. The nomenclature established by Simpson has been officially adopted in Mauritius, and while more recent researchers, such as McDougall and Chamalaun, in 1969, have disputed Simpson's tentative dating of the rocks, his simple divisions into different volcanic series remain valid. The isotopic dates established by McDougall et al. are convincing and are given below.

	Age, million years before present
Younger Volcanic Series (Late Lavas)	0,17 - 0,7
Younger Volcanic Series (Early Lavas)	2,0 - 3,5
Older Volcanic Series	6,8 - 7,8

The Early Lavas of the Younger Volcanic Series are found only in the south-west of the island.

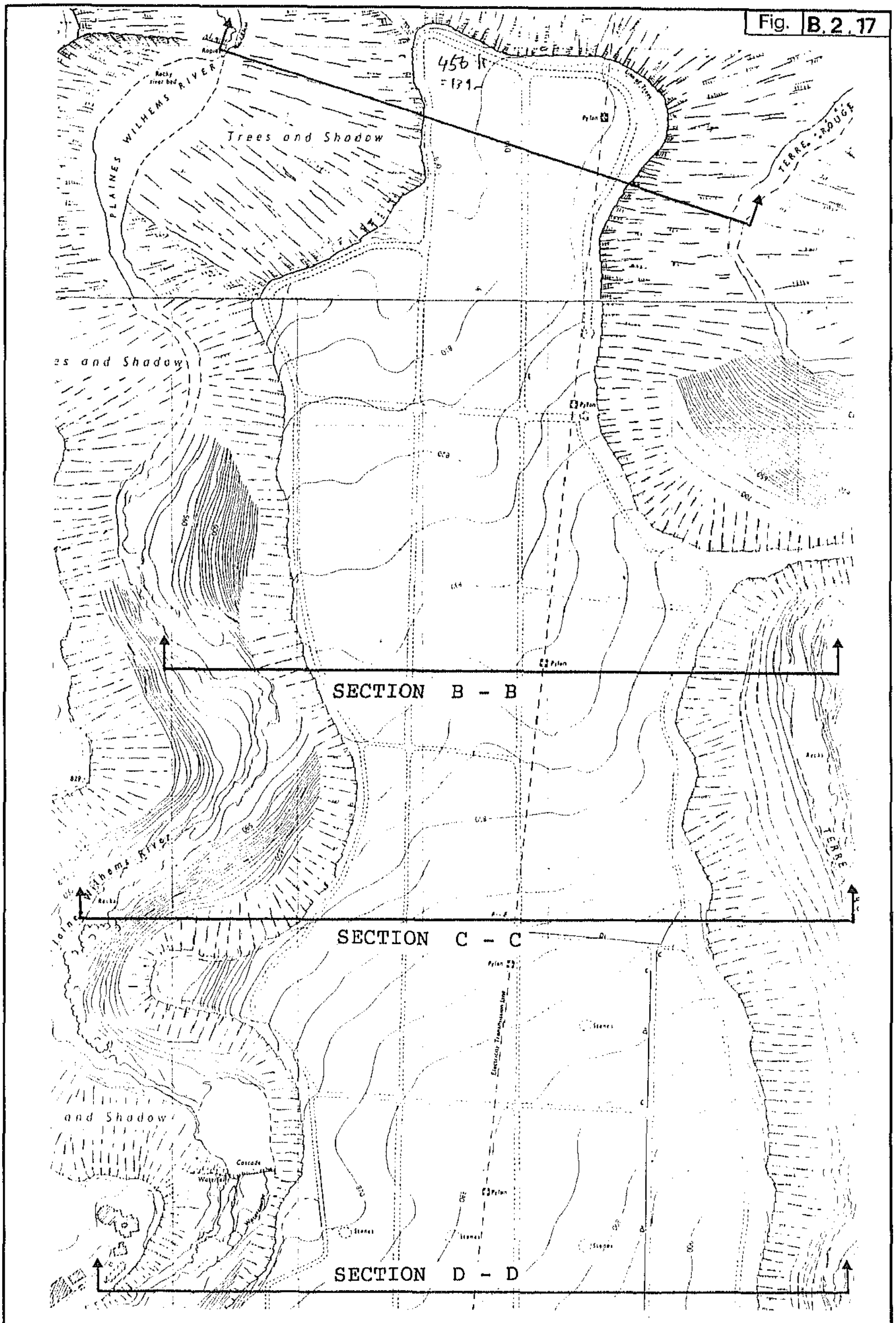
The lavas of the Older Volcanic Series were erupted from a single shield volcano which was active above sea level 6,8 - 7,8 million years ago. Erosion of this shield volcano produced spurs and deeply incised valleys radiating from the centre of the island. The present landforms of the Older Volcanic Series consistently show deep incision of the coastal side of the mountains with the remaining spurs dipping at the angle of flow of the lavas (15° in the Port Louis area, nearer horizontal elsewhere) towards the sea. In contrast, the inland slopes of these mountain ranges are steep, suggesting rapid preferential erosion of the centre of the shield or, quite probably, caldera collapse (see figure 7).

The deeply incised coastal valleys were therefore left with an insignificant catchment area for further incision. Subsequent erosion in these valleys was confined to the gradual wasting of the cliffs on either side. Great thicknesses of

colluvium developed since the restricted drainage was insufficient to wash the material further downstream.

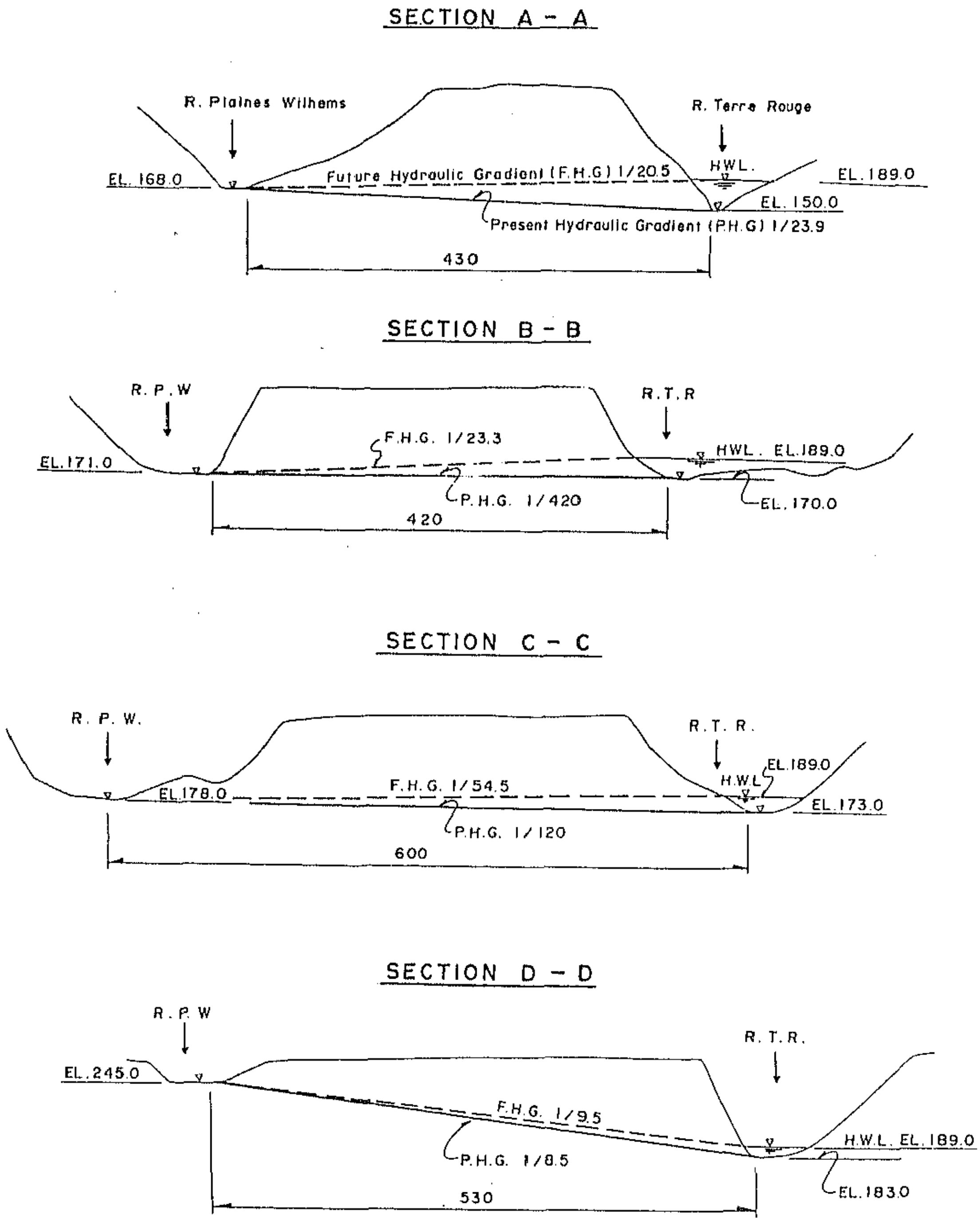
After this long period of erosion, renewed volcanism produced the Younger Volcanic Series. These lavas infilled much of the rugged topography, covering colluvial and residual soil development and leaving gently undulating plains with only the higher mountains of the Older Volcanic Series prominently exposed.

Erosion of the Late Lavas of the Younger Volcanic Series is not well advanced, the landscapes being structural rather than erosional in origin. Where these Late Lavas are in close contact with the mountains of the Older Volcanic Series, as in the Port Louis area, further development of colluvium from the mountains has overlain the margins of the Late Lava surface.



GROUNDWATER PROFILES IN THE LEFT BANK OF TR0 DAM RESERVOIR (1)	GOVERNMENT OF MAURITIUS PORT LOUIS WATER SUPPLY PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. B.2.18



GROUNDWATER PROFILES IN THE LEFT BANK OF TRO DAM RESERVOIR (2)

GOVERNMENT OF MAURITIUS
PORT LOUIS WATER SUPPLY PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

ANNEX (B-1)

STUDY ON CONTINUOUS OPENINGS IN DAMSITE AND RESERVOIR AREA

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4.	Examination for CASE (I) to CASE (K)	2
5.	Examination for CASE (O) and CASE (P)	3
6.	Judgement based on investigation of existing wells and coreholes	3
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ATTACHMENT	LIST	PAGE
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3	PROFILE OF ASSUMED OPENING CASE (I) TO (K)	7
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Study on Continuous Openings in Damsite and Reservoir Area

1. Assumed Openings

Attachment-1 shows all the cases of continuous opening if any, although the Team considers those openings are not likely to exist.

This paper tries to verify the water tightness of dam and reservoir through examinations on all the cases of continuous openings assumed above.

2. Examination for CASE (A) to CASE (H)

CASE (A) to (H) will not cause any problems, since CASE (A), (B), (D) and (H) are situated outside the reservoir and in CASE (C() and (E) to (G), both inlet and outlet of opening are situated within the reservoir.

3. Examination for CASE (L) and CASE (M)

CASE (L) and (M) are the case that the continuous opening exists in the damsite.

Attachment-2 shows the cross section of damsite together with the groundwater table investigated by boring.

As seen, a quite normal groundwater table is shown in the right bank.

Although the groundwater level in left bank is lowered near the riverbed level, it is understandable in consideration that the left bank has no water source.

The present groundwater level in the right bank generally coincide with estimated groundwater table without lava tunnels.

Assuming that the continuous opening of CASE (L) or CASE (M) exists as shown in Attachment-2, the present groundwater level may not be maintained; that is, an unusual groundwater table as shown with dotted lines may be indicated.

Besides that, the water in the openings should be subject to some pressure due to groundwater, resulting in the spring water at the outlet. The field reconnaissance confirms no existence of such spring waters in the are. Further, the boring investigations indicate a very good core recovery. Non-core recovery appears with a few percentage, for which it is considered highly weathered materials were discharged in the process of drilling, since the permeability tests show a normal foundation condition with permeability coefficients of 10^{-4} to 10^{-6} cm/sec, suggesting no existence of any continuous openings there.

Thus, the Team comes to a conclusion that the openings of CASE (L) or (M) will not exist.

4. Examination for CASE (I) to CASE (K)

Attachment-3 shows a profile of CASE (I) to (K). It seems that a continuous opening is not created in this direction in consideration of the process of creation of a lava tunnel; that is, a lava tunnel is created along the slope of lava, i.e. in the direction of mountain side to sea side. However, assuming that this kind of continuous opening exists, the rainfall will come out from the opening. This discharge from the opening forms a gully near its outlet for a very long time.

The Team carried out a careful reconnaissance throughout the reservoir area to find out such a sign or any openings.

The above reconnaissance did not find any sign of the existence of such openings, coming to a judgment that CASE (I) to (K) may not exist in the area.

5. Examination for CASE (O) and CASE (P)

Attachment-4 shows a profile of CASE (O) or CASE (P)

Assuming the existence of opening of CASE (O), a detectable excessive water loss should occur through the continuous opening.

On the other hand, the discharge measurements carried out for confirming any water loss in the river stretches clarify no water loss in the river, certifying the continuous opening of CASE (O) does not exist.

The continuous opening of CASE (P), if any, has to pass through below the riverbed of Moka River. It must largely effect on the Moka river water and groundwater in surrounding area. However, the Moka river water and groundwater in surrounding area keep just normal flow without any disturbance by the opening below riverbed. It suggests no existence of such an opening.

6. Judgment based on investigation of existing wells and coreholes

There are many existing wells and coreholes in the surrounding area.

Attachment-5 gives the water levels in the existing wells and coreholes.

As seen in Attachment-5, the water levels in the existing wells and coreholes mostly appear at shallow depths less than 30 m where the boundary between the weathered soil materials and firm rock exists, meaning that continuous openings do not exist below these water levels.

Then, it can be said generally that the existence of continuous opening should be very rare in the area even if it exists.

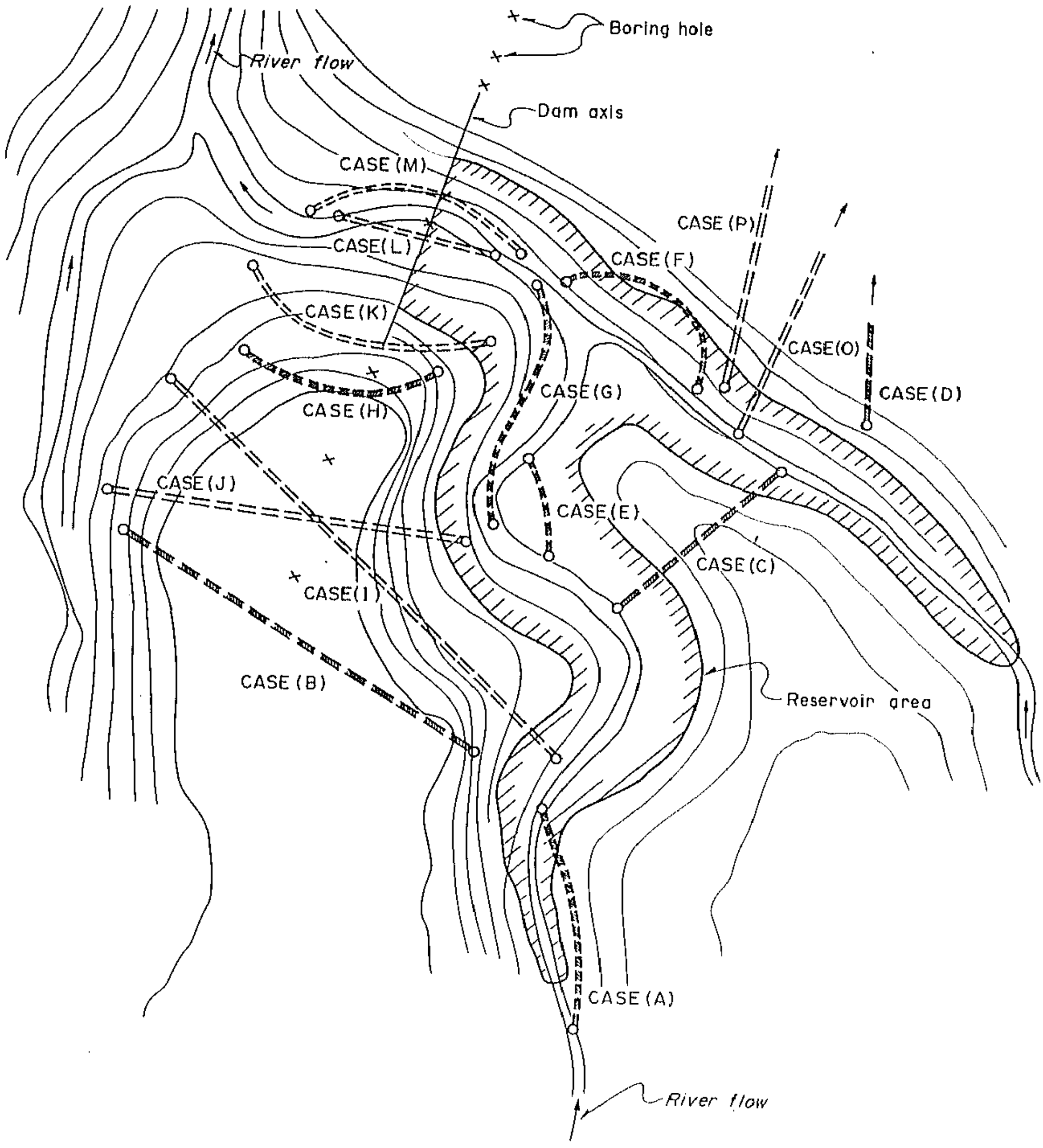
7. Conclusion

As mentioned, all the investigations and studies indicate that such a continuous opening as cause an excessive leakage in future will not exist. Thus, the Team considers that the necessary water tightness of dam and reservoir will be secured.

However, considering the event that there are continuous openings in the reservoir area by any chance, the impoundment in the reservoir will be made gradually. If there is any continuous opening to cause an excessive leakage, its sign will appear. In such an event, the reservoir water level can be lowered with the river outlet system equipped in the dam, and then, the opening will be plugged with concrete. Its cost is considered minor, since it is investigated at least that the continuous opening does not exist in a large scale.

For reference, examples of treatment are shown in Attachment-7. Attachment-8 and 9 list up the past examples of treatment for highly permeable dam foundation in various countries.

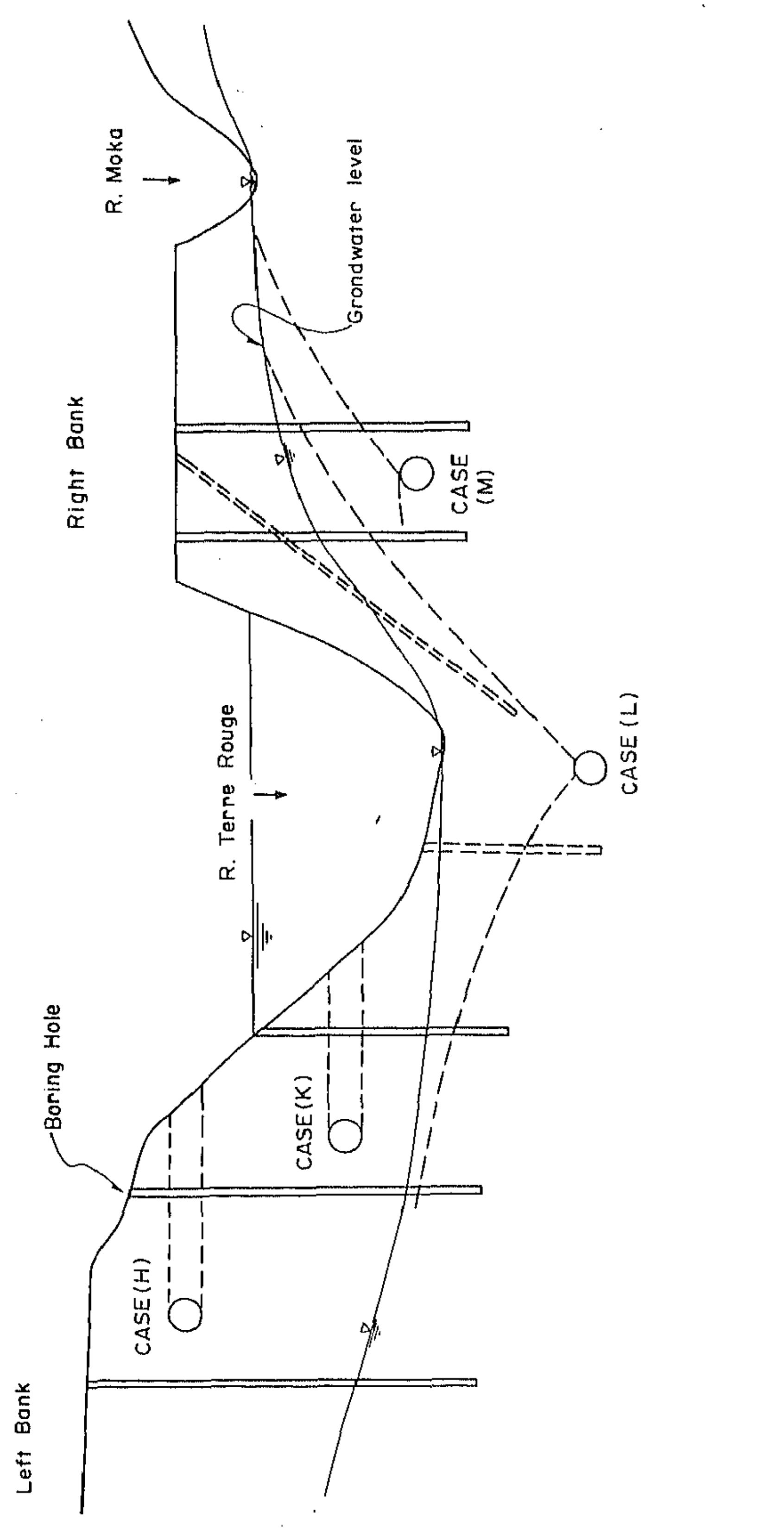
It is noted that the measures of treatment depend largely on the actual situation of opening, requiring a detailed examination in accordance with its location, scale and state, etc.



ASSUMED CASES OF CONTINUOUS OPENINGS

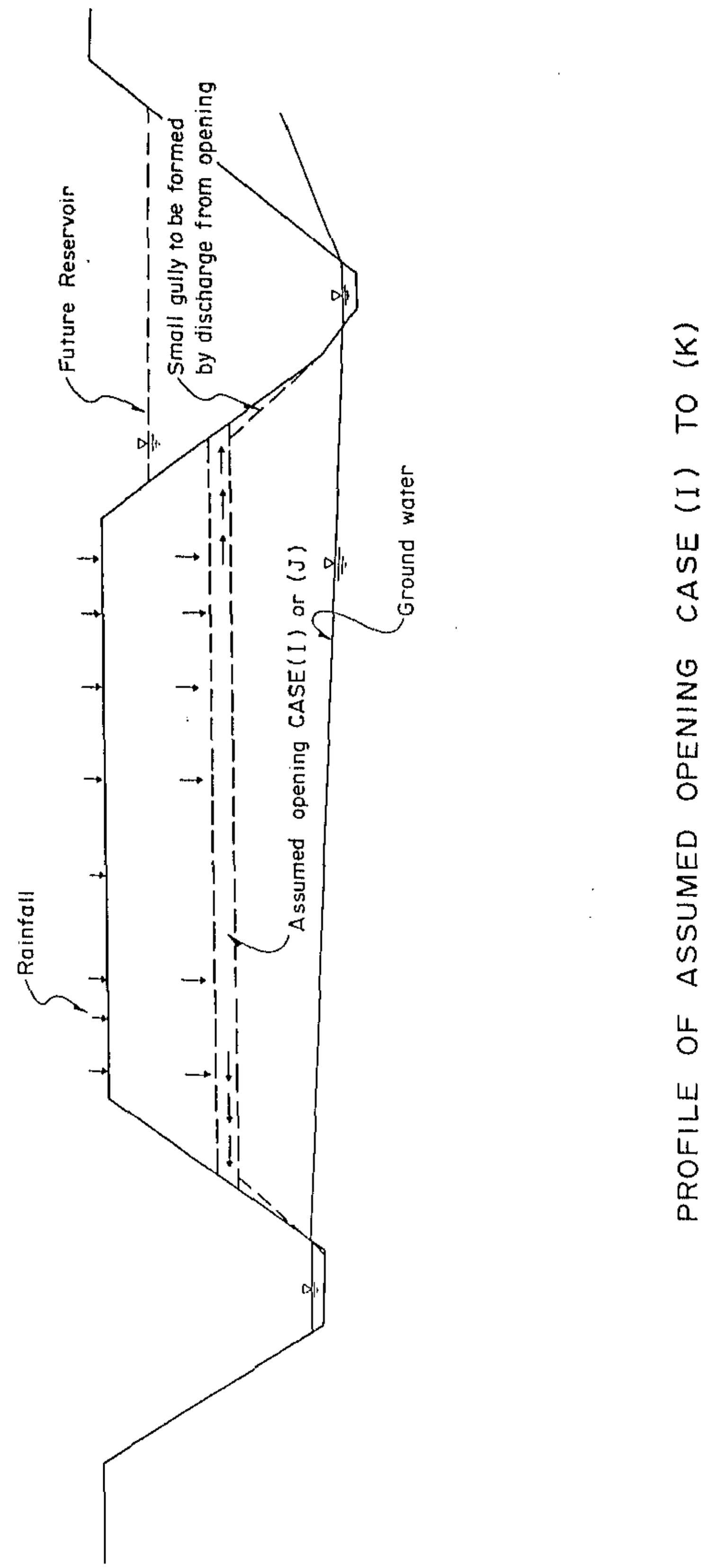
ASSUMED CASE OF CONTINUOUS OPENINGS	GOVERNMENT OF MAURITIUS PORT LOUIS WATER SUPPLY PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY

Annex B-1
Attachment-2

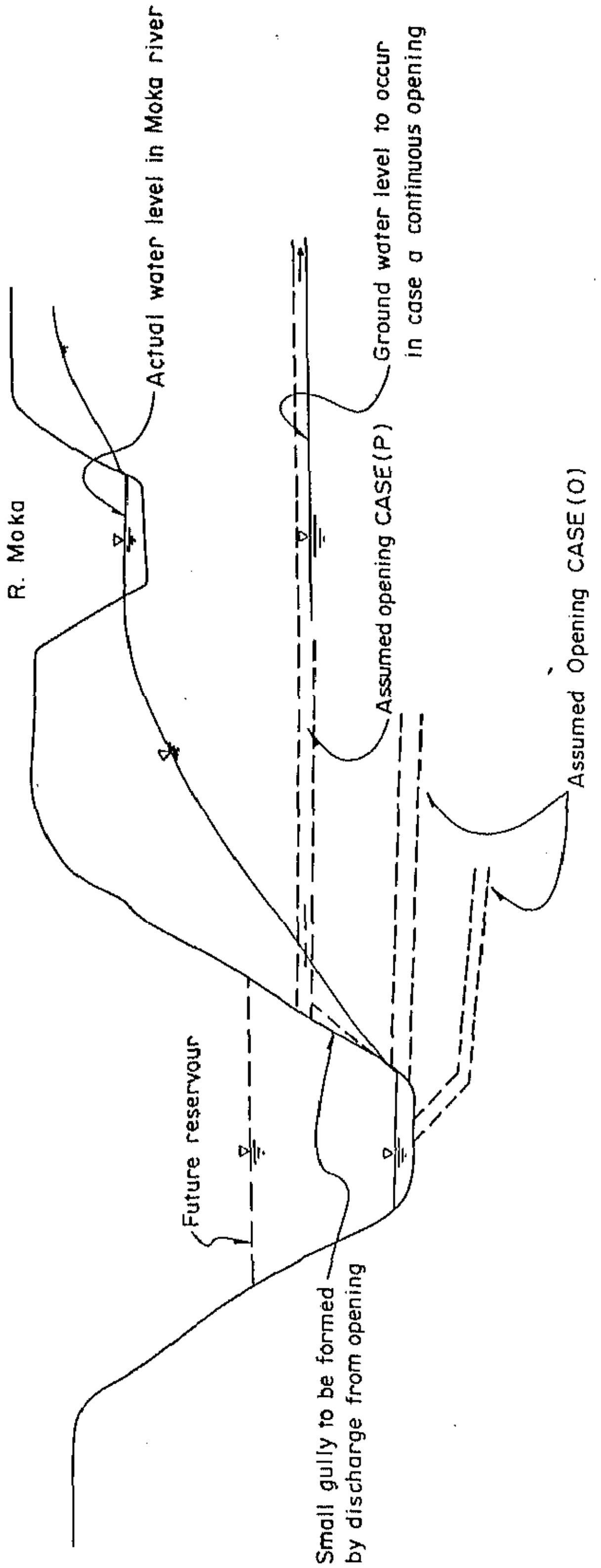


CROSS SECTION OF DAM AXIS (UPSTREAM VIEW)

CROSS SECTION OF DAM AXIS (UP STREAM VIEW)	GOVERNMENT OF MAURITIUS PORT LOUIS WATER SUPPLY PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY



PROFILE OF ASSUMED OPENING CASE (I) TO (K)	GOVERNMENT OF MAURITIUS PORT LOUIS WATER SUPPLY PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY



PROFILE OF ASSUMED OPENING CASE (O) AND (P)

PROFILE OF ASSUMED OPENING CASE (O) TO (P)	GOVERNMENT OF MAURITIUS PORT LOUIS WATER SUPPLY PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY

SURROUND WATER LEVEL IN WELLS AND BOREHOLES IN 1982-1983(1/2)

No.	WELL	LOCATION	ELEVATI (m)	DEPTH WELL(m)	MIN GWL	MAX GWL	DIFFER.
1	F2	PETITE R.	50.22	48.92	31.22	35.30	4.08
2	F3	CANDOS	330.00	47.55	5.50	7.30	1.50
3	F4	HOLLYROOD	432.97	46.02	12.23	15.06	2.83
4	F5	QUINZE C.	413.43	45.72	27.32	28.80	1.48
5	F6	MELROSE	323.67	92.12	11.04	20.76	9.72
6	F7	LA MARIE	497.95	54.86	22.09	24.80	2.80
7	F8	BONNE T.	395.16	55.17	31.54	31.98	0.44
8	F9	PALMA	319.82	55.17	31.95	32.00	0.05
9	F11	HERMITAGE	121.55	55.17	5.55	41.58	36.03
10	F12A	LA MARIE	516.55	31.39	17.74	24.74	7.00
11	F13	ROSE B.	297.88	60.96	6.48	33.63	27.15
12	F14	GOODLANDS	35.70	60.96	35.48	35.64	0.16
13	F16	GAULETTES	312.27	32.06	40.46	42.10	1.64
14	S1	BEAUX B.	235.41	157.28	7.20	7.88	0.68
15	S2	PIERREFOND	275.61	143.36	19.08	23.54	4.46
16	S4	"	269.89	121.92	7.75	19.61	11.86
17	S5	"	272.86	---	14.90	24.16	9.26
18	S8	"	273.96	121.92	10.20	17.25	7.05
19	S9	"	271.65	121.92	12.34	27.74	15.40
20	S10	"	272.96	---	12.90	21.50	8.60
21	S12	"	272.93	---	17.51	20.52	3.01
22	S13	"	271.61	41.61	7.65	16.22	8.57
23	S18	BEAUX B.	277.12	---	1.55	3.52	1.97
24	S19	"	298.52	---	9.68	10.71	1.03
25	S22	PIERR2015	285.65	---	22.67	26.66	3.99
26	S24	PIERR2510	281.32	53.34	24.99	28.90	3.91
27	S25	PIERR2100	279.61	45.72	22.02	25.20	3.18
28	S26	PIERR2600	281.17	45.72	24.15	27.80	3.65
29	S27	PIERR.B.H	282.31	---	21.60	25.57	3.97
30	9	MONTAGNE	207.26	65.53	6.05	12.33	6.28
31	11	LAVENTURE	94.06	73.46	27.35	33.00	5.65
32	12C	PLAINE PAP	85.52	60.96	28.65	31.75	3.10
33	21A	BEARD	546.00	38.36	25.58	30.37	4.79
34	23	CHEBEL B.	167.55	59.74	26.40	27.00	0.60
35	26	PALMYRE	126.35	78.33	14.20	18.40	4.20
36	27A	ST.MARTIN	214.52	53.64	38.65	39.30	0.65
37	28	SOLFERINO	357.99	76.20	10.26	16.32	6.06
38	29	BAMBOUS	128.65	86.26	30.46	31.68	1.22
39	30	LA MEDCVE	95.40	76.20	39.22	39.40	0.18
40	32	KA HINE	77.69	79.55	31.88	34.10	2.22
41	33	CHEBEL C.	199.09	22.30	33.09	33.17	0.08
42	34A	CREPE B.	304.86	76.20	58.07	59.50	1.43
43	35	HOLLYROOD	425.78	84.73	17.24	21.90	4.66
44	36	LA FORET	498.12	60.96	24.53	36.29	11.76
45	37	ANNA	72.61	19.29	11.62	12.30	0.68
46	46	QUEEN V.	147.33	70.10	10.25	11.90	1.65

No.	WELL No.	LOCATION	ELEVATION (m)	DEPTH WELL(m)	MIN GWL	MAX GWL	DIFFER.
101	181	EAU BLEUE	398.78	60.96	18.12	23.54	5.42
102	182	CALEBASSES	38.45	68.58	3.24	3.94	0.70
103	183	EAU BLEUE	394.67	59.06	16.42	19.52	3.10
104	186	ARGY 2	32.95	57.30	9.77	13.74	3.97
105	187	CHEBEL	165.45	45.72	13.15	14.12	0.97
106	191	PONT FER	379.74	54.56	8.55	11.32	2.77
107	193	TRIANON 2	371.18	66.14	9.85	12.56	2.71
108	194	BOIS ROUGE	79.64	42.06	4.84	8.32	3.48
109	195	NOUVELLE F	467.98	57.91	29.17	33.34	4.17
110	199	MON DESERT	36.70	39.62	18.49	19.43	0.94
111	202	MON LOISIR	50.63	45.72	30.78	31.94	1.16
112	204	UNION VALE	71.99	60.96	4.60	14.43	9.83
113	205	SCHOENFELD	35.10	36.58	2.33	3.25	0.92
114	207	LE BOSQUET	146.92	30.48	10.10	11.27	1.17
115	208	EAU BLEUE	316.91	53.04	17.79	19.50	1.71
116	210	"	413.61	30.48	13.49	18.78	5.29
117	211	"	352.63	60.96	15.20	23.30	8.10
118	214	"	305.90	60.05	14.90	25.68	10.78
119	215	"	410.79	60.96	17.04	30.95	13.91
120	216	BAMBOUS	126.14	30.48	2.22	3.50	1.28
121	221	PRE AUX SA	33.95	51.82	12.72	25.00	12.28
122	227	UNION VALE	58.90	38.10	3.65	38.10	34.45
123	229	"	39.90	---	1.40	6.64	5.24
124	233	HOLLYROOD	432.20	41.45	7.25	12.02	4.77
125	235	CLUNY 10	398.30	71.63	3.65	5.68	2.03
126	236	HOLLYROOD	429.05	48.77	14.56	18.67	4.11
127	237	HAUTE RIVE	7.78	83.82	4.33	6.18	1.85
128	239	CLUNY 12	404.86	54.86	2.90	5.45	2.55
129	242	CLUNY 14	301.33	64.62	9.00	16.07	7.07
130	243	EAU BLEUE	397.65	73.46	12.82	14.68	1.86
131	244	GEOFFROY R	167.23	67.06	18.60	26.20	7.60
132	245	EBENE 1	256.87	79.25	15.10	16.11	1.01
133	249	GEOFFROY R	151.67	44.50	5.60	6.56	0.96
134	255	"	154.63	37.80	7.90	9.55	1.65
135	256	TROU dEAU	29.56	61.26	5.90	18.00	12.10
136	257	GEOFFROY R	168.16	60.05	19.33	24.47	5.14
137	258	TROU dEAU	37.83	54.86	25.53	29.38	3.85
138	260	GEOFFROY	168.17	72.54	18.16	18.90	0.74
139	261	PONCER 1	319.30	73.16	6.26	7.77	1.51
140	262	BELLE VUE	99.31	18.29	13.05	16.43	3.38
141	270	BAIE DE TO	5.12	---	2.80	4.36	1.56
142	276	GEOFFROY 7	70.91	64.92	26.35	27.50	1.15
143	278	PONCER 2	306.41	100.58	11.96	14.00	2.04
144	279	ANNA 1	56.30	---	12.57	16.80	4.23
145	280	PONCAR 3	305.64	67.06	18.25	19.35	1.10
146	282	ANNA 3	56.21	30.48	12.50	15.40	2.90

No.	WELL No.	LOCATION	ELEVATION (m)	DEPTH WELL(m)	MIN GWL	MAX GWL	DIFFER.
201	406	ST.FELIX	17.85	79.25	17.51	17.87	0.36
202	411	BEL ETANG	276.79	79.25	3.95	5.80	1.85
203	412	PROVIDENCE	393.69	103.63	6.30	9.54	3.24
204	413	BEL ETANG	284.23	91.44	11.09	13.87	2.79
205	416	LA GAITE	56.42	88.39	1.00	1.57	0.57
206	424	LA FLORA-B	343.14	73.15	2.34	4.56	2.22
207	425	"	316.34	73.15	3.10	8.40	5.30
208	427	LA GAITE	---	91.44	10.80	21.14	10.34
209	428	RIVIERE DU	263.42	36.58	2.37	6.41	4.04
210	429A	DEEP RIVER	---	56.45	5.90	10.17	4.27
211	437A	BASSIN	295.13	54.86	11.90	14.10	2.20
212	437C	BASSIN	295.46	56.08	5.91	16.30	10.39
213	442	SANS SOUCI	---	77.72	12.02	14.00	1.98
214	443	DEEP RIVER	---	60.96	3.21	4.50	1.29
215	444	BEAU CHAMP	---	77.72	1.71	5.10	3.39
216	445	ST.ANTOINE	17.95	60.96	3.90	5.55	1.65
217	446	POUDRE d'O	19.03	60.96	5.30	6.84	1.54
218	448	"	12.14	60.66	8.46	9.55	1.09
219	450	ST.ANTOINE	14.14	60.96	14.72	14.95	0.23
220	452	RUISSEAU R	134.49	56.39	6.65	7.98	1.33
221	453	GRAND BOIS	344.06	36.58	0.84	1.70	0.86
222	455	DEUA BRASI	169.82	60.96	9.20	11.85	2.65
223	472A	BEL AIR,ST	88.12	68.58	5.12	7.05	1.93
224	472D	"	106.86	94.49	11.05	16.20	5.15
225	6C	POUDRE dOr		45.72	7.34	12.20	4.86
226	7H	ESPERANCE		45.72	13.96	17.32	3.36
227	7I	---		45.72	14.17	17.92	3.75
228	14B	COTTAGE		39.62	10.00	13.25	3.25
229	16B	SCHOENFELD		39.62	6.10	8.35	2.25
230	16C	"		39.62	3.55	5.52	1.97
231	16I	"		39.62	10.53	19.70	9.17
232	16N	"		39.62	11.45	14.60	3.15
233	16O	"		35.97	12.18	14.42	2.24
234	20A	ST.JEAN 1		39.62	12.04	13.05	1.01
235	23B	HUSSONIA		34.14	14.10	16.26	2.16
236	57A	SURINAM		30.48	16.55	16.72	0.17
237	57B	"		45.11	22.12	24.22	2.10
238	59A	CHAMOUNY		49.38	22.68	25.17	2.49
239	59B	"		53.80	16.82	16.95	0.13
240	59C	"		44.20	15.47	21.90	6.43
241	63A	PONT FER-P		43.15	14.73	19.25	4.52
242	63C	HIGHLANDS-		39.32	7.34	9.37	2.03
		MINMUM		0.00	0.00		
		MAXIMUM		467.98		467.98	
		AVERAGE		53.09	50.13	49.80	

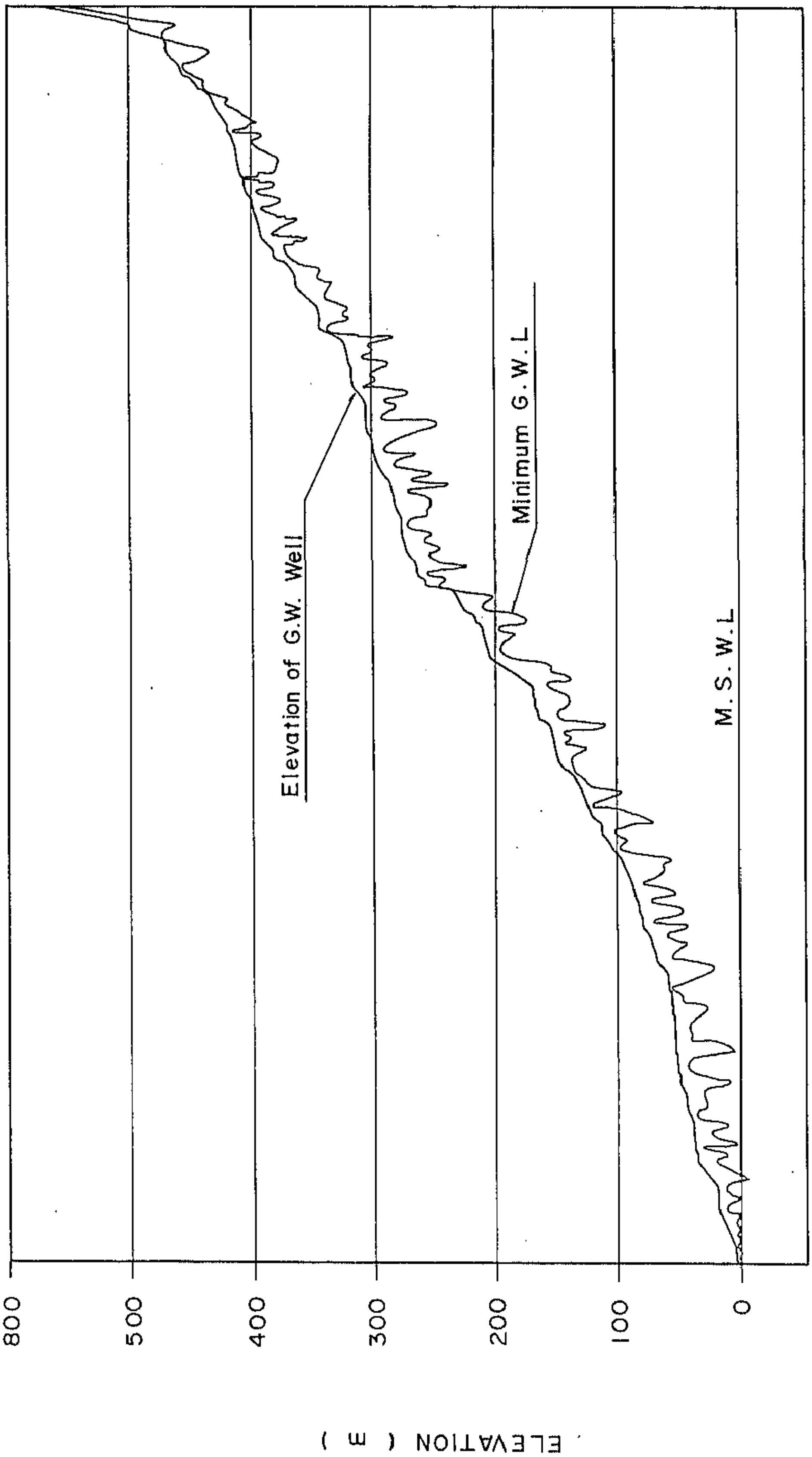
Annex B-1
Att0chment-5(1)

Annex B-1
Attachment-5(2)

SURROUND WATER LEVEL IN WELLS AND BOREHOLES IN 1982-1983(2/2)

47	54	UNION VALE	90.54	38.10	16.45	26.01	9.56	147	283	ALBION 1	4.18	48.77	1.25	2.25	1.00
48	55	LA BARAGUE	114.00	53.34	36.88	45.27	8.39	148	285	PONDAR 4	302.26	56.39	19.82	31.86	12.04
49	56	MON DESERT	42.21	57.00	10.85	15.91	5.06	149	286	FLIC EN F1	3.73	60.96	0.80	1.32	0.52
50	61A	SALAZIE	390.95	42.06	30.85	35.40	4.55	150	290	FLIC EN F2	4.79	60.96	2.90	6.10	3.20
51	93	LATANIERS3	16.13	59.44	3.30	4.76	1.46	151	292	PONDER 6	304.36	70.10	42.62	50.10	7.48
52	101	NEW GROVE	216.32	53.64	21.31	39.40	18.09	152	296A	FOND DU SA	46.83	34.38	18.52	19.00	0.48
53	103	ST.ANTOINE	53.30	54.86	20.80	28.40	7.60	153	297	PONT BON B	285.41	60.96	48.20	48.40	0.20
54	104	*	57.29	60.96	26.44	30.30	3.86	154	299	ST. RAUL	434.68	60.96	3.69	4.80	1.11
55	105	LA CAVE 1	10.56	128.02	10.14	10.14	0.00	155	300	MORCELLEME	51.92	36.58	8.62	11.28	2.66
56	106	RIVIERE R.	36.93	172.82	6.30	11.45	5.15	156	301	*	51.50	39.62	7.10	13.88	6.78
57	107B	LA CAVE 4	23.00	67.06	25.10	30.42	5.32	157	302	ALLEE BRIL	445.85	60.96	3.53	4.30	0.77
58	108	TROU AUX B	2.29	2.93	2.30	2.80	0.50	158	304	PONT BON 3	293.01	44.20	37.82	39.58	1.56
59	110	TRIANON	305.20	228.42	10.95	11.17	0.22	159	305	STE.MARIE	122.63	91.44	19.50	25.40	5.90
60	114	MAPOU STAT	90.75	121.92	24.60	31.40	6.80	160	306D	MORCELLEME	52.00	---	8.93	11.44	2.51
61	117	MORCELLEME	62.13	124.97	8.50	15.70	7.20	161	308	RICH FUND	209.96	79.25	5.48	9.00	3.52
62	120	BELLE RIVE	477.75	174.35	4.12	5.52	1.40	162	309	MORCELLEME	49.98	39.62	5.62	8.66	3.04
63	121A	MOULIN P.	50.87	143.26	46.50	46.90	0.40	163	313	CANDOS 2	362.61	45.72	19.94	24.10	4.16
64	121B	*	50.88	60.96	7.73	37.70	29.97	164	314	LALLMATIE	164.80	53.34	6.13	17.08	10.95
65	121C	*	50.73	15.24	6.00	13.50	7.50	165	316	ALMA	466.18	38.10	16.20	28.00	11.80
66	122	TROU BLEU	1.48	24.38	0.96	1.38	0.42	166	317	UNION BARU	48.59	76.20	41.10	41.20	0.10
67	123	POUDRE dOr	52.42	144.78	17.78	24.35	6.57	167	319	FORBACH HI	64.71	53.34	41.15	44.40	3.25
68	123A	*	51.19	64.01	12.70	12.76	0.06	168	322	L'ETOLIE-D	131.33	30.48	4.55	9.10	4.55
69	124	MOULIN POU	54.77	11.58	3.80	8.55	4.75	169	324	MONT IDA	317.26	60.96	11.57	14.08	2.51
70	133	FLOREAL	457.54	106.68	5.22	6.20	0.98	170	334	SEBASTOPOL	205.53	29.41	6.05	10.25	4.20
71	137	POINTE AUX	17.92	10.67	7.75	8.43	0.68	171	335	CHEBEL BOS	147.09	53.34	10.70	11.46	0.76
72	145	PLAINE PAP	68.66	73.76	14.60	21.30	6.70	172	336	MONTAGNE	264.28	54.86	35.84	41.00	5.16
73	146	SOLITUDE	43.83	91.44	9.54	15.90	6.36	173	339	PETIT PAGU	235.68	42.67	9.15	16.12	6.97
74	149	ARBY STATI	42.77	121.92	9.10	11.15	2.05	174	340	MONTAGNE B	276.17	42.67	3.61	5.63	2.02
75	149A	*	42.66	14.33	12.50	14.90	2.40	175	341	*	298.97	60.96	7.51	8.77	1.26
76	150	BEAUX SORI	228.72	54.56	19.40	20.32	0.92	176	343	BEL ETANS	256.04	64.01	1.85	3.91	2.06
77	151A	LA LOUISE	327.73	88.39	37.70	43.73	6.03	177	345	BELVEDERE	195.61	91.44	18.42	40.05	21.63
78	152	MESNIL	469.32	82.30	5.87	6.35	0.48	178	346	GRANDE RET	106.47	73.15	7.62	8.80	1.18
79	153	ST.PAUL 2	420.49	91.44	16.80	24.56	7.76	179	347	BON ESPOIR	140.05	70.10	4.00	5.82	1.82
80	156	RAMPE LE	2136.52	91.44	29.85	48.52	18.67	180	348	LALLMATIE	209.55	82.30	12.06	22.60	10.54
81	157	BEAUX SONG	226.30	60.96	15.10	16.14	1.04	181	349	STE.THERES	207.73	73.15	9.87	14.60	4.73
82	159	ROSE HILL	277.69	121.92	21.70	24.60	2.90	182	351	PROVIDENCE	365.10	91.44	17.52	20.70	3.18
83	160	PETITE RIV	151.09	60.96	18.35	25.95	7.60	183	352	BONNE VEIN	453.72	34.59	2.57	3.08	0.51
84	161	BEAUX SONG	229.80	60.96	27.22	27.55	0.33	184	353	MOLROSE 1	364.82	103.63	23.77	31.27	7.50
85	162	*	201.88	60.35	17.84	18.73	0.89	185	356	PLAINE MAR	94.65	45.72	7.80	34.95	27.15
86	163	ST.PAUL 3	412.34	58.52	21.24	25.11	3.87	186	357	*	83.92	60.96	4.63	11.14	6.51
87	164	ST.PAUL 4	419.54	67.06	2.85	3.41	0.56	187	359A	SOLFERINO	369.60	85.34	21.70	25.45	3.75
88	165	ST.PAUL 5	408.45	60.96	2.68	3.70	1.02	188	360	PROVIDENCE	401.72	143.26	20.64	21.60	0.96
89	166	CANDOS	345.00	77.72	16.50	20.70	4.20	189	361	STE.MARIE	112.59	91.44	12.35	12.50	0.15
90	166B	*	345.64	54.86	16.00	26.40	10.40	190	371	*	112.97	21.95	6.75	8.80	2.05
91	166D	*	345.00	39.62	19.18	27.00	7.82	191	375	FOREST SID	566.29	106.68	18.77	21.88	3.11
92	168	LAMBIQUE	39.23	---	0.98	1.55	0.57	192	381	MELROSE	318.07	39.62	15.05	21.55	6.50
93	168A	*	39.34	---	1.05	1.56	0.51	193	388	ST.JEAN	322.34	45.72	21.10	23.00	1.90
94	171	SAUVETERR	48.39	33.53	8.04	10.35	2.31	194	389	HERMITAGE	463.80	59.44	4.43	8.25	3.82
95	172	SALAZIE 2	386.36	57.30	10.70	12.55	1.85	195	393	*	446.85	106.07	5.90	7.72	1.82
96	174	SAUVETERRE	27.12	102.72	24.50	25.20	0.70	196	395	CHEMIN GRE	62.46	58.52	12.77	13.86	1.09
97	175	CLAIRFONDS	410.42	66.75	27.01	32.27	5.26	197	400	MON BLANC	152.43	79.25	12.95	14.70	1.75
98	175B	*	412.30	59.44	28.95	35.70	6.75	198	401	COTE d'OR	414.62	82.30	9.24	14.76	5.52
99	178	CALEBASSES	41.27	71.62	4.63	6.07	1.44	199	404	MON BLANC	131.40	79.25	34.62	41.80	7.18
100	180	EAU BLEUE	405.79	91.44	14.10	25.52	11.42	200	405	MON DESIR-	94.71	31.70	4.30	6.35	2.75

ELEVATION OF WELL AND MAXIMUM DRAWDOWN
(Hydrologicar Year 1983)

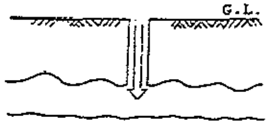


EVALATION OF WELL AND MAXIMUM DRAWDOWN	GOVERNMENT OF MAURITIUS PORT LOUIS WATER SUPPLY PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY

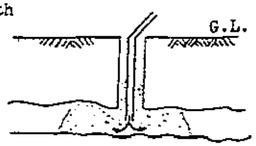
EXAMPLE SKETCH OF TREATMENT FOR CAVITIES OR FAULTS

I.1. Small cavity (less than 1.0m)

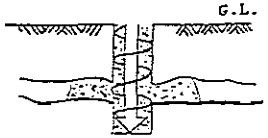
(1) Pilot drilling with d=300mm casing for securing vertical accuracy



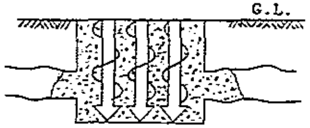
(2) Injection of mortar with high viscosity and low strength



(3) Drilling by rock auger after consolidation of mortar

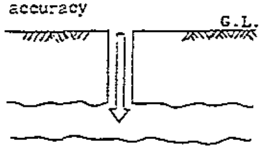


(4) Widening of the zone with additional drilling and injection of mortar

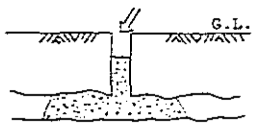


I.2. Medium size cavity (several meters in size)

(1) Pilot drilling with d=300mm casing for securing vertical accuracy



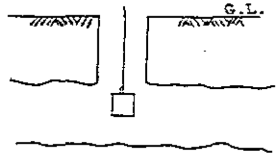
(2) Throwing concrete



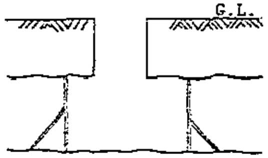
(3) and (4) are same as for the case of small cavity.

I.3. Large cavity (more than 5.0m in size)

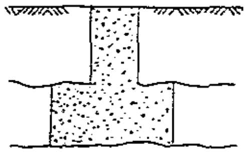
(1) Construction of vertical shaft



(2) Installation of forms

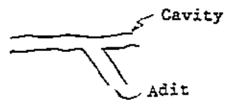


(3) Filling cavity with concrete

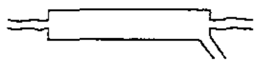


I.4. Plugging through adit

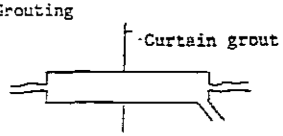
(1) Adit excavation



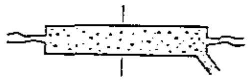
(2) Enlargement of cavity



(3) Grouting

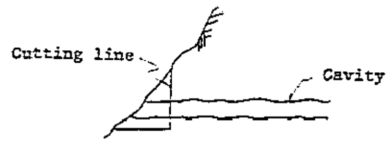


(4) Concrete filling

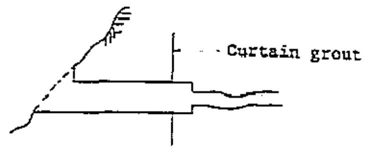


I.5. Plugging from ground surface

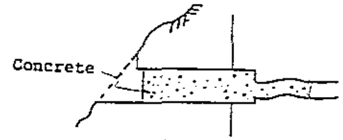
(1) Removing of weathered zone



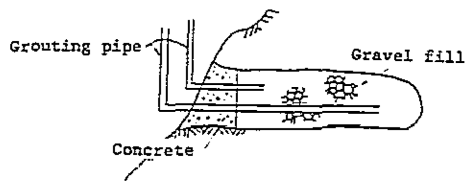
(2) Enlargement of cavity and grouting



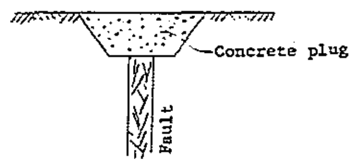
(3) Concrete filling



I.6. Treatment of closed cavity



II. Treatment of fault zone



DAMS IN HIGH PERMEABLE FOUNDATION ROCKS IN JAPAN

DAM	COPLETION	HEIGHT (m)	C.LENGTH (m)	GEOLOGY	TECHNICAL PROBLEMS	FOUNDATION TRETMENT (stressed in improvement of permeability mainly)
KASSA	1977	90.0	487.0	Volcanic rocks of Neogene, Quaternary	High permeability and mechanical strength	Treatment by cement milk and mortar through steel pipes inserted into foundation rocks in fissure developed zones (cement: L-11551 m, Q-3160 tons; mortar: L-2696 m, Q-4615 cu. m). Providing grout garalley for re-grouting
TEDORIGAW	1979	153.0	420.0	Sedimentary rocks of Paleozoic and Mesozoic	A fault accompanied by 25 m wide fractured zones	Providing grout garalley for minimizing construction period and re-grouting; Low pressure grouting into high permeable fractured zones with horizontal and radial grouting after completion of dam embankment in the same zone (L-23984 m, Q-1960 tons in fractured zones). Injection of cement milk and mortar in cavities confirmed by pilot drilling and normal grouting holes (L-10994 m, Q-550 tons)
GOSHO	1980	52.5	327.0	Andesitic agglomerate, tuffaceous shale and tuff breccia of Neogene	High permeability in crack developed tuffaceous rocks	Curtain grouting was performed from the grout gallarey for securing easy grouting when water leakage is occured. Sub-surtain grouting was made in partailly confirmed high permeable zones in volcanic mud flows on the left abutment.
TAMAHARA	1982	116.0	570.1	Tuff breccia and volcanic breccia of Neogene and andesite and thick volcanic breccia	High permeability of andesite becuase of developed joints and 20-30 m wide fault	Providing grout gralley for curtain grouting; blanket grouting in the area of core zone; faults and open cracks were treated by filling mortar and cement paste The fault which crosses the dam was treated by blanket grouting with extending the length of grout holes. Total grout amount is 4331 tons for 50576 m.
OOUCHI	1977 -	102.0	340.0	Tuffaceous rocks of Neogene	Fractured foundation rocks because of a fault crossing dam axis	Dam foundation of the core zone is treated by low pressured blanket grouting with closing spaces of grout holes, and by providing three lines of curtain grout and sub-curtain grout along the center of dam axis. Grout injection was performed in the fault zones for improving permeability. The zones in which open cracks are developed were covered by mortar with rasing pipes for draining seepage water and treated by grouting finally.

DAMS IN LIMESTONE AREA IN FOREIGN COUNTRIES

COUNTRY	NAME OF DAM	COMPLETED YEAR	HEIGHT OF DAM(m)	CREST LENGTH(m)	DEGREE OF CORROSION	TREETMENT
USA	J.PERCY PRIEST	1968	39.6	828.0	Karst in general	Corrosion cavities are excavated for about 3 times of the cavities width. and replaced by concrete. Curtain grouting for 28782 m; filters and drain blanket at the downstream of the dam
USA	HALES BAR	1914	33.6	694.5	"	Concrete cut-off wall for 6 - 30 m; asphalt and cement grouting into corrosion cavities
USA	KENTUCKY	1944	62.8	2569.0	"	Sheet piling in earth-fill zone with grouting at the upstream side Concrete cut-off wall for large corrosion cavities by large diameter drilling
USA	GUNTEERS-VILLE	1939	28.2	1193.7	"	Surfacial zones in which weathering is developed are excavated and removed. Cavities in deeper parts are replaced by concrete by large diameter drilling Grouting for preventing water leakages
USA	CHICKA-MAUGA	1940	38.7	1740.0	"	Cut-off trench in earth-fill zones with concrete core-wall at rock fixing zones Limestones in which karst is developed were removed from the major structure sites. Cavities in deeper zones are filled with concrete by large diameter drilling.
USA	FORT LOUDOUN	1943	36.6	1257.0	"	Karst limestones were excavated and removed. Grouting at structure bases and concrete walls; concrete wall in earth-fill zones and concrete core wall
USA	NORRIS	1936	79.5	558	"	Cavities in abutments were pluged through adits (left abutment 8 adits for 390 m, right abutment: 3 adits for 78 m). Consolidation grouting and curtain grouting: 1-59166 m, rim grouting: 1-13383 m, Q-69630 cu.m
ALGERIA	FOUM EL GHERZA	1950	65.0	126.0	Cavities at parts	Grouting from grout gallerys of along dam foundation and along left abutment ridges for 160 m and right abutment side for 500 m.
FRANCE	CHARMINE MOUX	1950	17.0	180.0	Karst in general	First grouting of 16400 cu.m using mixtures of sand materials; second grouting of 540 tons using mixtures of sand materials
FRANCE	GENISSIAT	---	104.0	---	"	Concrete filling into natural wells and cavities; curtain grouting of 50 kg/m
FRANCE	SERRE	---	120.0	---	---	Grouting into fissure zones in limestones and zones between alluvial deposits

DAMS IN LIMESTONE AREA IN FOREIGN COUNTRIES

FRANCE	Saint-Giulhelm-le-Desert	---	55.0	---	Karst in general	Grouting was perfromed until third stages and permeability was improved less than 1 Lugeon. Detaila numbers and quantities are unkown.
MEXICO	La ANGOSTURO	---	145.0	300.0	Cavities at parts	Weathered zones and weak zones in thw core zone were excavated and replaced by concrete. Curtain grouting and blanket grouting for 64600 m (4563 tons)
SPAIN	CANELLES	1960	156.0	203.0	Karst in general	Concrete pluges into two cavities in the left abutment; Curtain grouting from grouting tunnel in the left abutment (238000 cu.m)
TAILAND	SRINAGA-RIND	1978	140.0	610.0	"	Surfacial zones in which cavities are developed were excavated and removed and cavities in deeper zones were filled by concrete or pipe grouting (concrete; 9450 cu.m and moltar; 86 cu.m). Core zones were treated by grouting using soil cement and mortar
TURKEY	KEBAN	---	---	---	"	After cleaning cavities filled with clayey materials, the cavities were filled up with concrete in the core zones, left abutment and gravity dam portions. Curtain grouting from horizontal garalley, concrete cut-off wall at left abutment
GERMANY	GLEMS	---	---	---	"	Surfacial zones in which cavaities are developed were excavated and removed. Cavities were cleaned removing clayey materials and filled up with mortar and concrete.

ANNEX (B-2)

ANALYSIS ON GROUNDWATER
LEVEL AND LEAKAGE

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1. Analysis of Groundwater Level at Present Condition

1.1 General

An analysis is made to confirm whether the groundwater level measured in the left bank of the proposed damsite is reasonable or not.

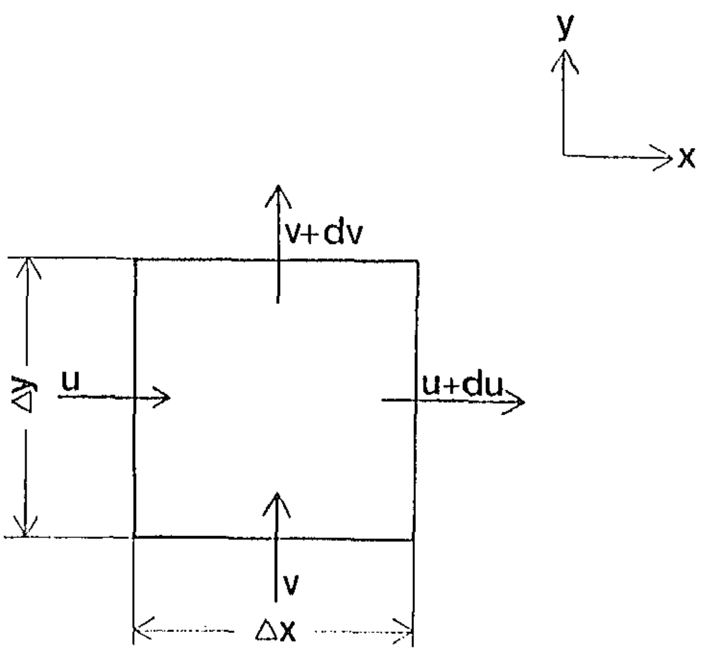
1.2 Methodology

The analysis is based on the following equation:

$$\frac{\partial}{\partial x}\left(K_x \frac{\partial h}{\partial x} \right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial h}{\partial y} \right) = 0 \qquad \cdots\cdots\cdots\cdots (2)$$

where,
K_x, K_y = Permeability coefficient in x and y direction respectively,
h = Water head

The above equation is obtained as follows:



Assuming no increase or decrease in discharge,

$$u\,\Delta y - (u + du)\Delta y + v\Delta x - (v + dv)\Delta x = 0$$
$$- du\,\Delta y - dv\,\Delta x = 0$$

$$\therefore \quad \frac{du}{\Delta X} + \frac{dv}{\Delta Y} = 0 \qquad \cdots\cdots\cdots\cdots\cdots\cdots (1)$$

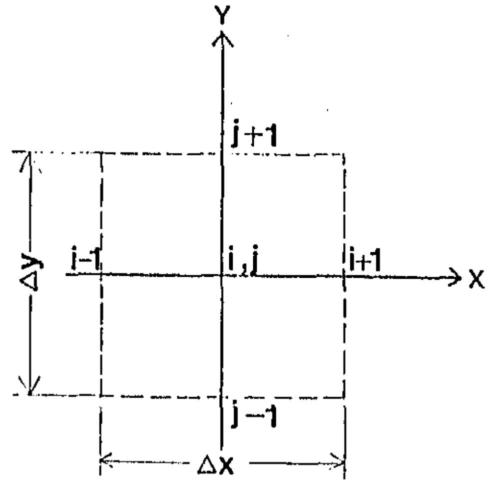
On the one hand, u and v are given by Darcy's formula as follows:

$$u = K_x \frac{\partial h}{\partial x} \quad , \quad v = K_y \frac{\partial h}{\partial y}$$

Substituting the above for Equation (1),

$$\frac{\partial}{\partial x}\left(K_x \frac{\partial h}{\partial x} \right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial h}{\partial y} \right) = 0 \qquad \ldots\ldots\ldots\ldots \text{(2)}$$

The above equation is applied as follows:



$$K_x \frac{\partial h}{\partial x} \quad \text{—} \quad K_{i-1} \frac{(h_i - h_{i-1})}{\Delta x}$$

$$\frac{\partial}{\partial x}\left(K_x \frac{\partial h}{\partial x}\right) \quad \text{—} \quad \frac{K_{i+1} \dfrac{(h_{i+1} - h_i)}{\Delta x} - K_{i-1} \dfrac{(h_i - h_{i-1})}{\Delta x}}{x}$$

$$= \frac{K_{i+1}\, h_{i+1} - (K_{i+1} + K_{i-1}) h_i + K_{i-1} \cdot h_{i-1}}{\Delta x^2}$$

$$K_y \frac{\partial h}{\partial y} \quad \text{—} \quad K_{j-1} \frac{(h_j - h_{j-1})}{\Delta y}$$

$$\frac{\partial}{\partial y}\left(K_y \frac{\partial h}{\partial y}\right) \quad \text{—} \quad \frac{K_{j+1} \dfrac{(h_{j+1} - h_j)}{\Delta y} - K_{j-1} \dfrac{(h_j - h_{j-1})}{\Delta y}}{y}$$

$$= \frac{K_{j+1}\, h_{j+1} - (K_{j+1} + K_{j-1}) h_j + K_{j-1}\, h_{j-1}}{\Delta y^2}$$

Thus, the following equation;

$$\frac{\partial}{\partial x}\left(K_x \frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial h}{\partial y}\right) = 0$$

is represented by this finite differentiation equation.

$$\frac{K_{i+1}\, h_{i+1} - (K_{i+1} + K_{i-1})\, h_i + K_{i-1}\, h_{i-1}}{\Delta x^2}$$

$$+ \frac{K_{j+1}\, h_{j+1} - (K_{j+1} + K_{j-1})\, h_j + K_{j-1}\, h_{j-1}}{\Delta y^2} = 0$$

Substituting $h_i = h$ and $h_j = h$,then,

$$K_{i+1}\, h_{i+1} + K_{i-1}\, h_{i-1} + K_{j+1}\, h_{j+1} + K_{j-1}\, h_{j-1}$$

$$- (K_{i+1} + K_{i-1} + K_{j+1}\, K_{j-1})h = 0$$

,or

$$h = \frac{K_{i+1}\, h_{i+1} + K_{i-1}\, h_{i-1} + K_{j+1}\, h_{j+1} + K_{j-1}\, h_{j-1}}{Ki+1+ Ki-1+ Kj+1+ Kj-1} \quad \ldots\ldots (3)$$

Equation (3) should be satisfied at all the points. Then, simultaneous equations having the water head at each point as unknown quantity can be obtained.

The water head at each point is found by solving the above simultaneous equations.

1.3. Result of Analysis and Comment

The result of analysis is shown in the Attachment-1. In the analysis, the present river water level is given as known groundwater levels, which are shown in bracket.

The groundwater level in the left bank of damsite obtained by the analysis is shown in the Attachment-2 in comparison with that measured actually.

As seen in Attachment-2, an approximate coincidence between the analyzed and measured ones is obtained, indicating that the present low groundwater level in the left bank of damsite is not due to an unusual geological condition.

The flow velocity and direction of groundwater is shown in the Attachment-7.

The maximum flow velocity of 376 cm/day is indicated at western side of southern edge of the plateau, suggesting that a particular problem will not occur at flow velocity less than 376 cm/day.

2. Analysis of Groundwater Level and Leakage After Dam Construction

2.1 Methodology

The same methodology as mentioned in the previous section 1.2.

2.2. Leakage After Dam Construction

After dam construction, water level of dam reservoir will rise in the range of low water level (El. 139 m) and high water level (El. 189 m) except for short period during flood. Attachment-3 to 5 show groundwater level contour maps of the Plateau by several water levels of the reservoir. Stored water in the reservoir flows into the Plaines Wilhems river and its amount is 30 lit/sec at 189 m, 18 lit/sec at 185 m and 6 lit/sec at 180 m. When water level falls down to 176 m amount of ground water flow is balanced and there is no leakage loss through the Plateau Attachment-6 shows the relationship between leakage volume and water level of the reservoir.

2.3 Velocity of Seepage Water

There are two areas where ground water has high velocity in the present condition. One is on the Plaines Wilhems river near the confluence with the Terre Rouge river. Maximum velocity there is 186 cm/day. Another is western side of southern edge of the Plateau. Maximum velocity there is 376 cm/day. Attachment-7 shows distribution of groundwater flow velocity in the analysed area under the present condition.

This distribution pattern does not change compared with the present condition even if dam reservoir is filled with water. *Attachment-8 shows distribution of groundwater flow after dam* construction (EL. 189 m).

Following changes of ground water flow velocity from the present

condition are observed after dam construction.

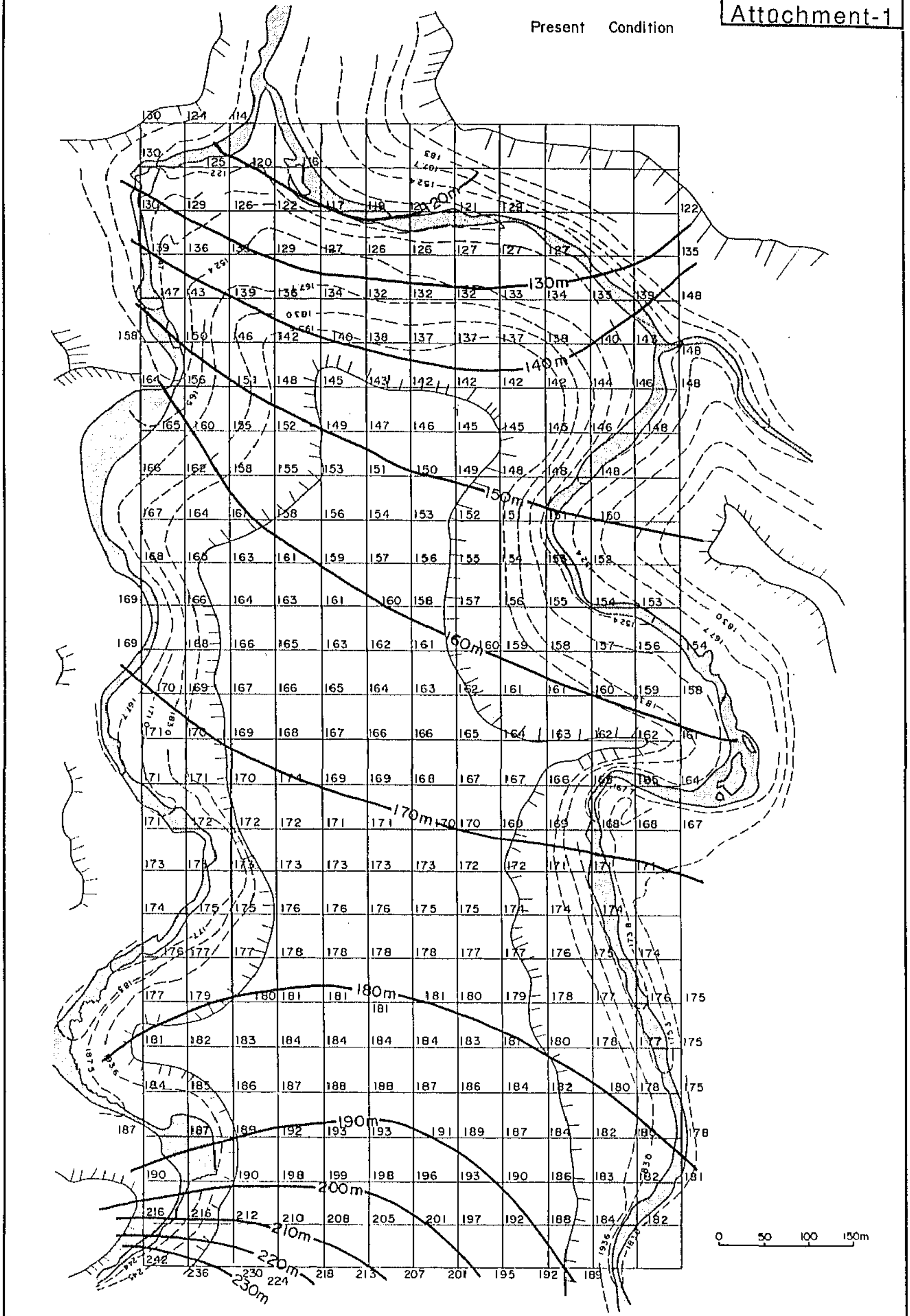
SITE	Present condition	After condition
(1) Plaines Wilhems river near confluence with Terre Rouge river - Max. velocity	186 cm/day	199 cm/day
(2) Western side of southern edge of the plateau: - Max. velocity	376 cm/day	374 cm/day

In Plaines Wilhems river near the confluence with Terre Rouge river, the increase maximum of flow velocity of 13 cm/day occurs due to dam construction. However, this increase is considered insignificant from the aspect of safety.

In the western side of southern edge of the plateau, the flow velocity tends to reduce due to the rise of water level in the downstream, changing the condition to safe side.

Detail of conditions such as permeability distribution in the simulated area, ground water level as boundary and results of simulation
are tabulated in Attachment 10 to 14.

Annex B-2
Attachment-1

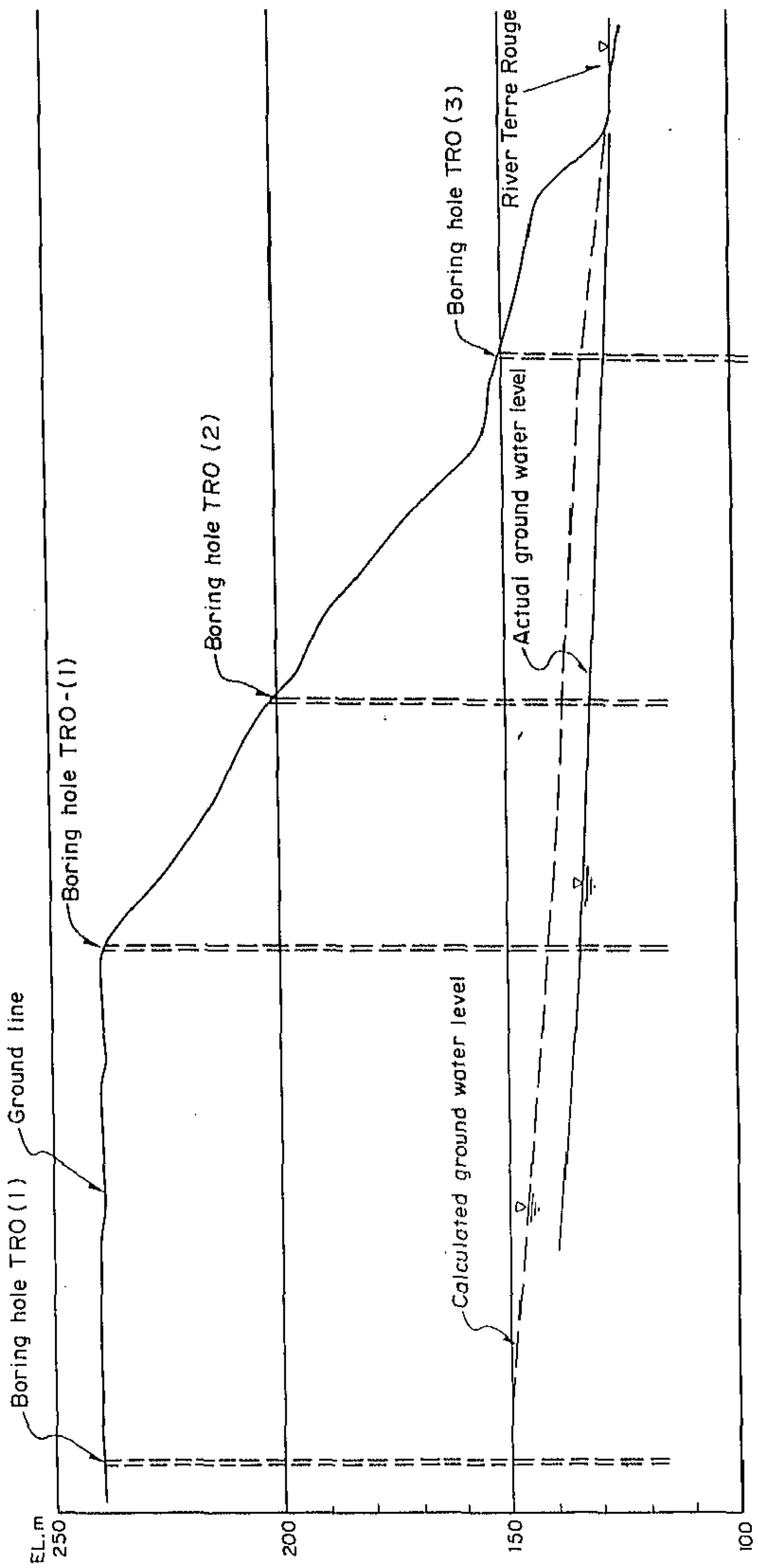


GROUND WATER LEVEL
(PRESENT CONDITION)

GOVERNMENT OF MAURITIUS
PORT LOUIS WATER SUPPLY PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

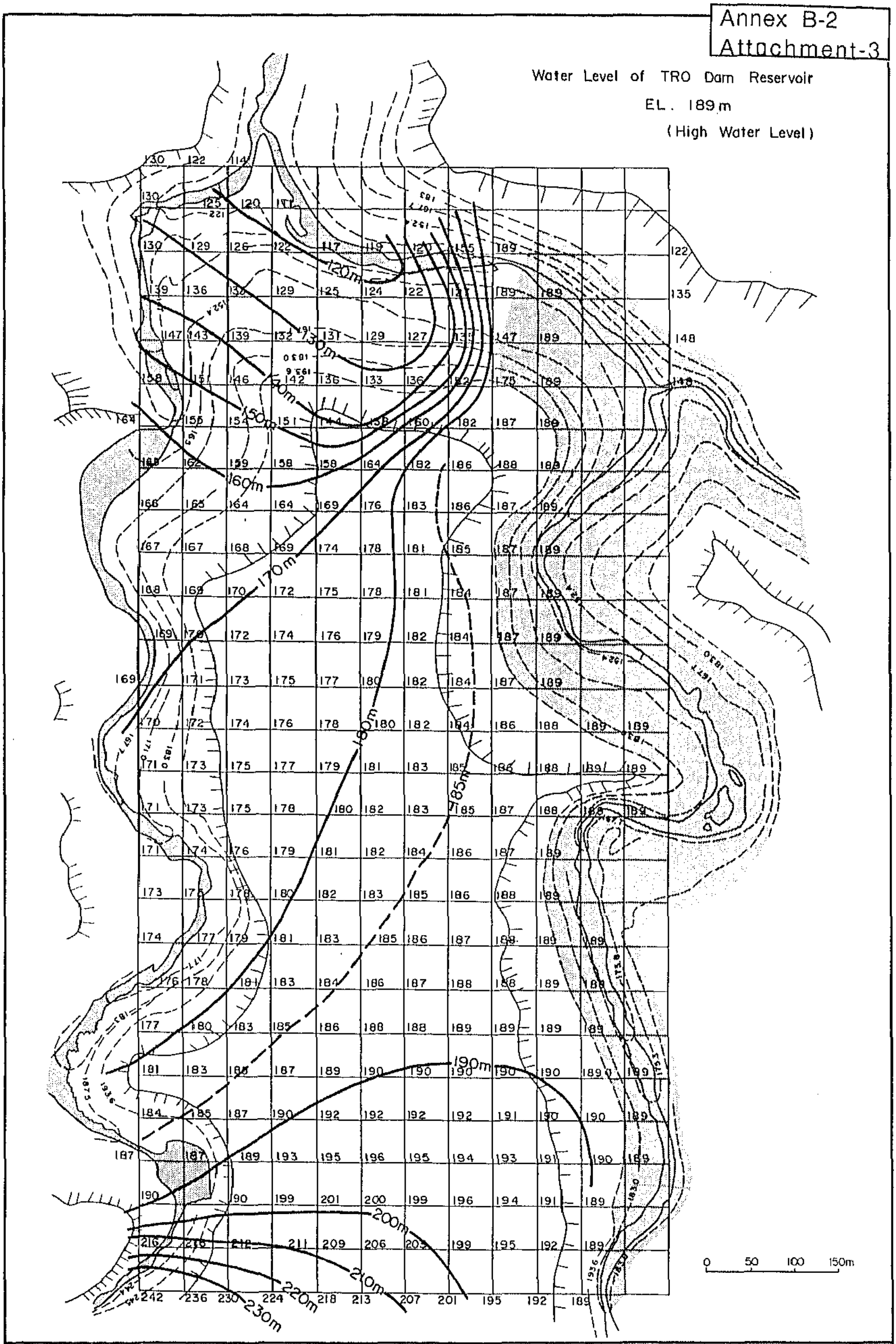
Annex B-2
Attachment-2



CROSS SECTION OF LEFT ABUTMENT ALONG DAM AXIS

CROSS SECTION OF LEFT ABUTMENT ALONG DAM AXIS	GOVERNMENT OF MAURITIUS PORT LOUIS WATER SUPPLY PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY

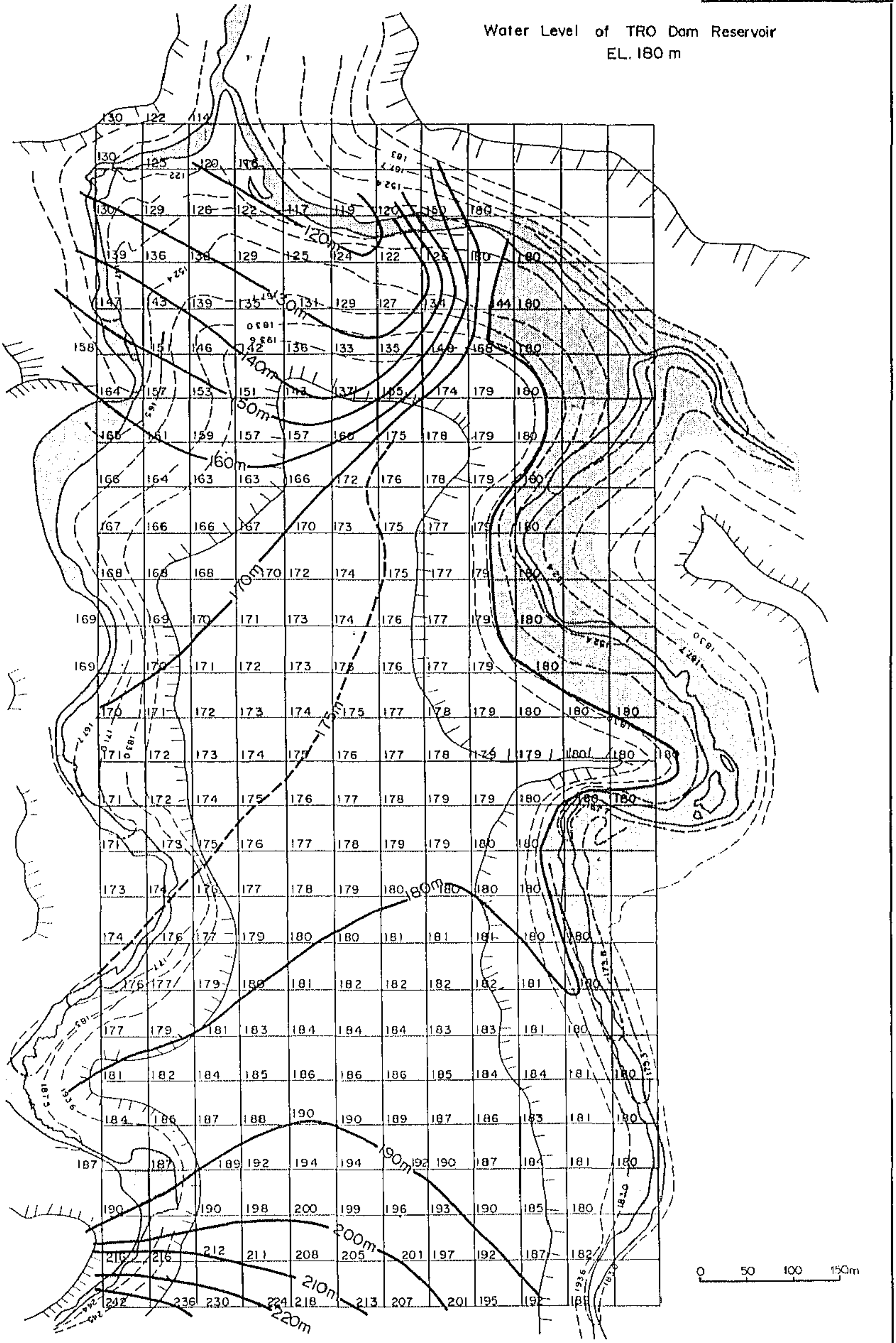
Annex B-2
Attachment-3



GROUND WATER LEVEL
(RESERVOIR WL:EL.189.0m)

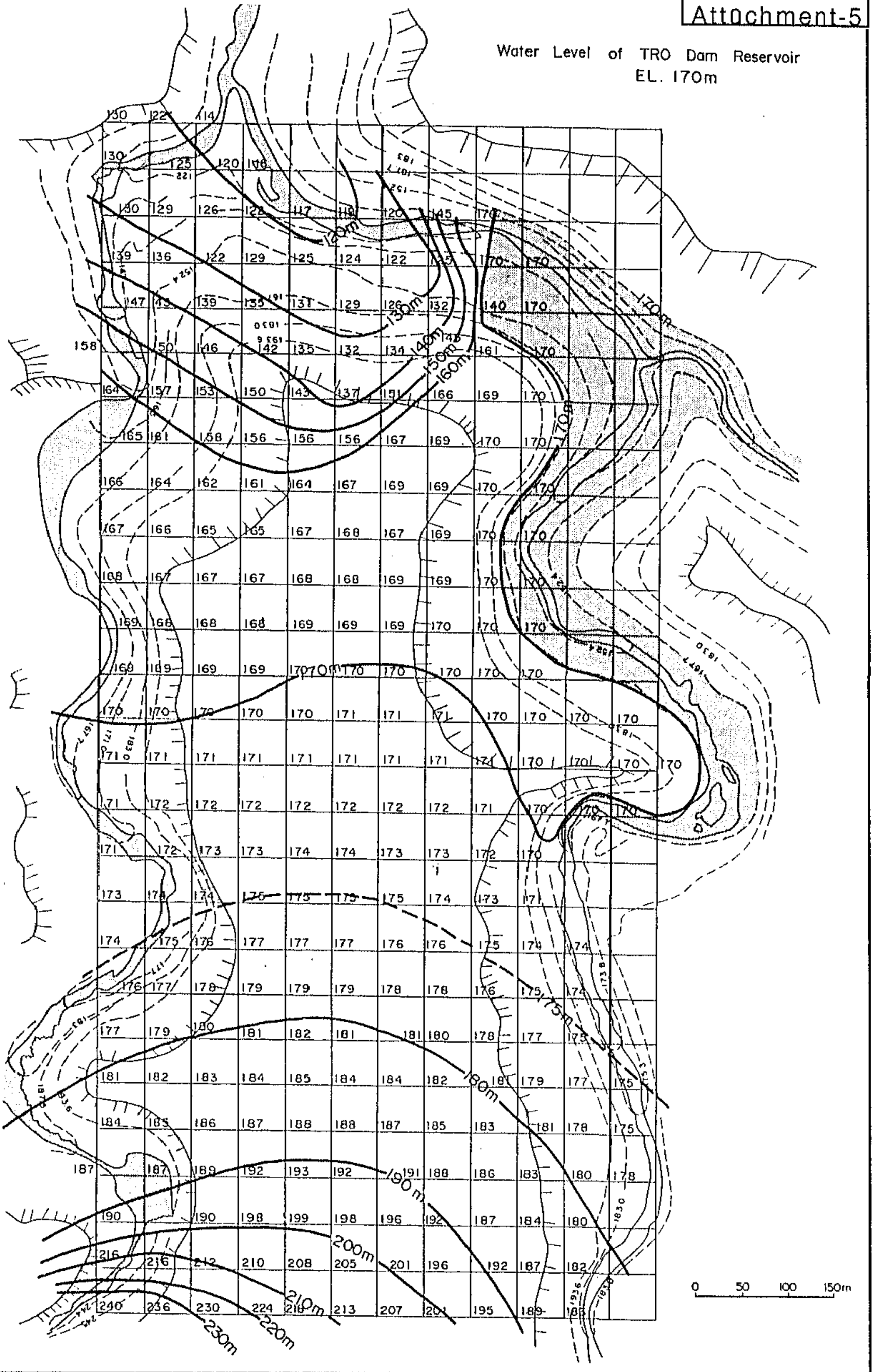
GOVERNMENT OF MAURITIUS
PORT LOUIS WATER SUPPLY PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY



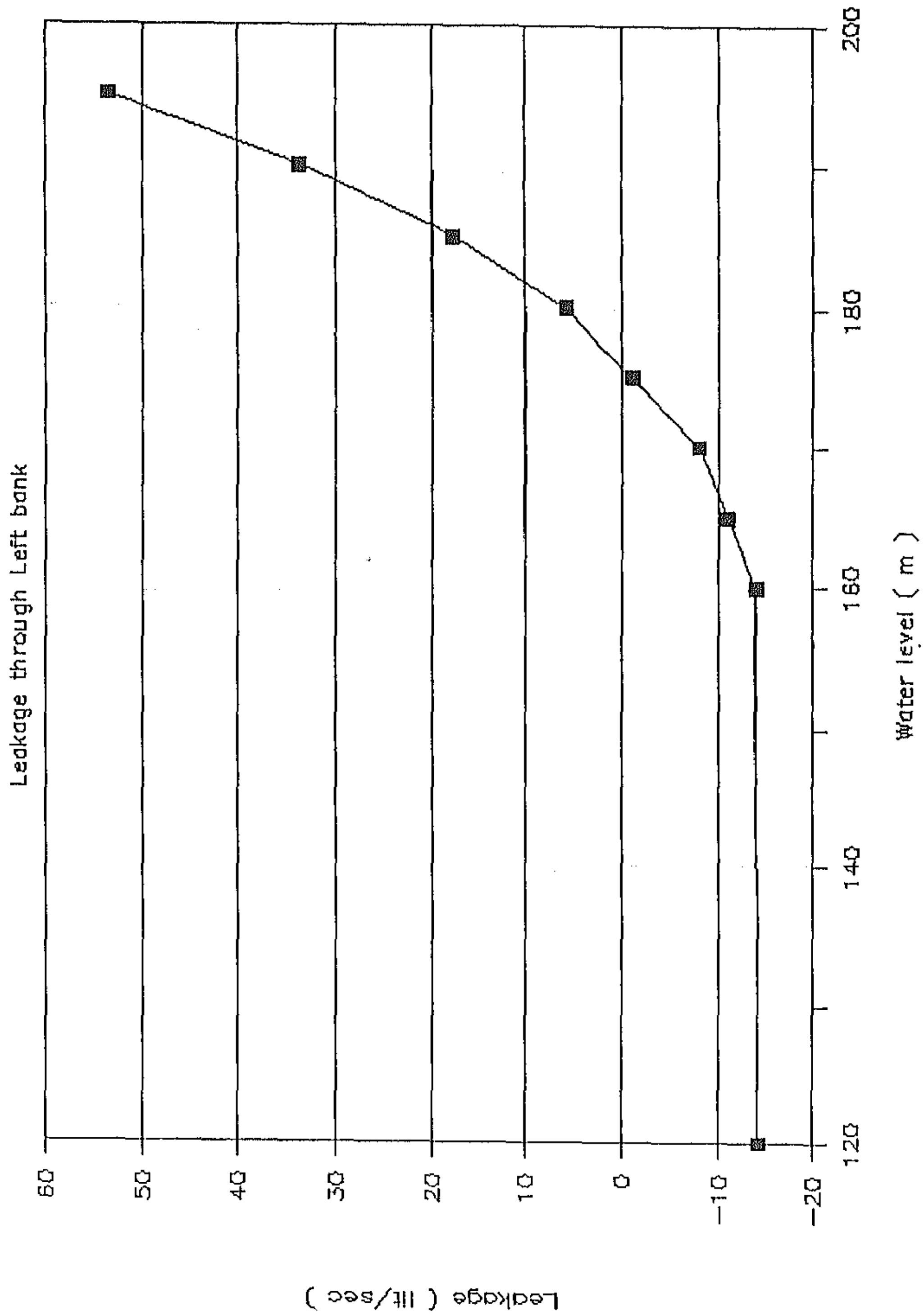
GROUND WATER LEVEL (RESERVOIR WL:EL.180.0m)	GOVERNMENT OF MAURITIUS PORT LOUIS WATER SUPPLY PROJECT
	JAPAN INTERNATIONAL COOPERATION AGENCY

Annex B-2
Attachment-5



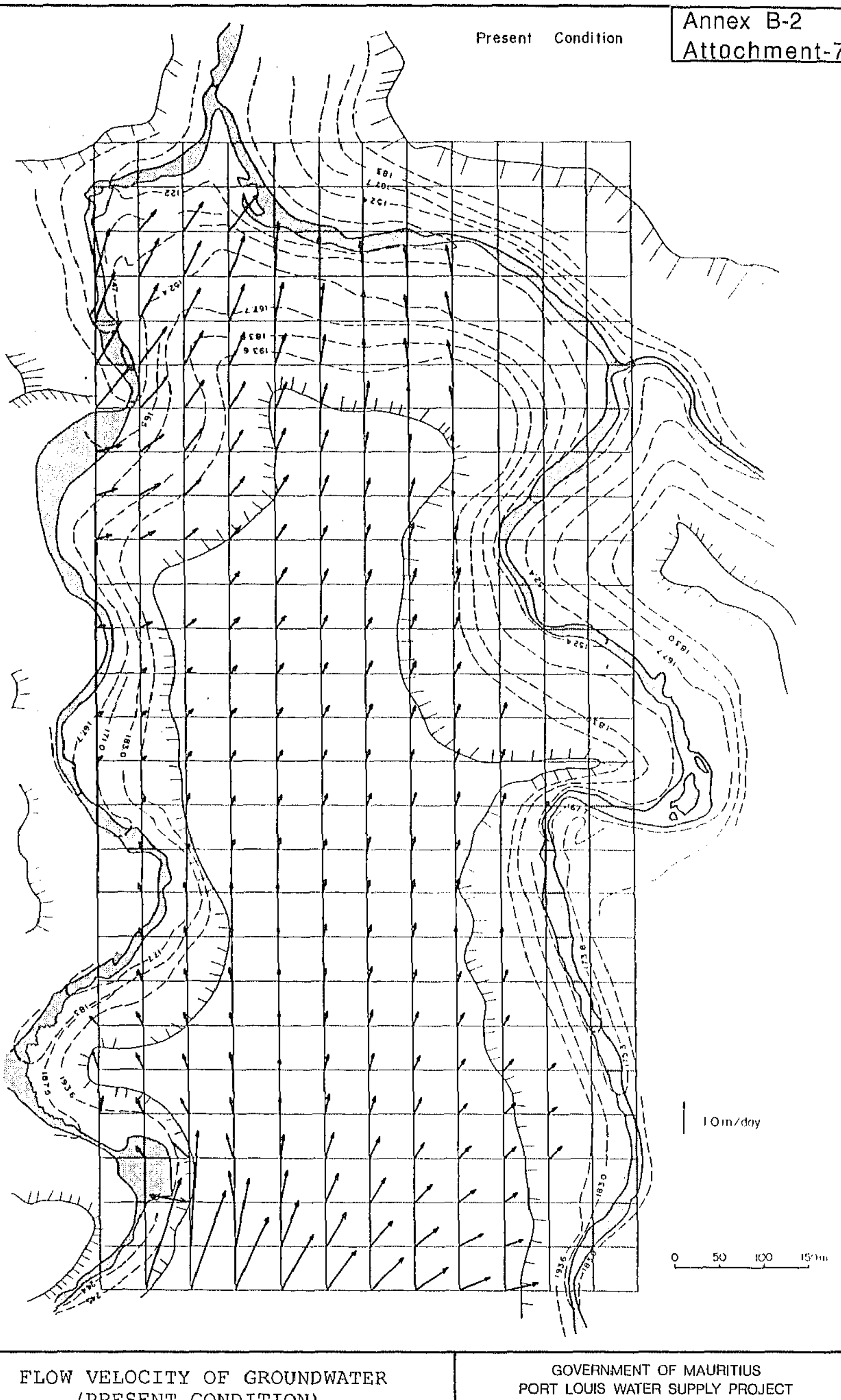
GROUND WATER LEVEL (RESERVOIR WL:EL.170.0m)	GOVERNMENT OF MAURITIUS PORT LOUIS WATER SUPPLY PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY

Annex B-2
Attachment-6



RELATION BETWEEN RESERVOIR
WATER LEVEL AND LEAKAG

Annex B-2
Attachment-7

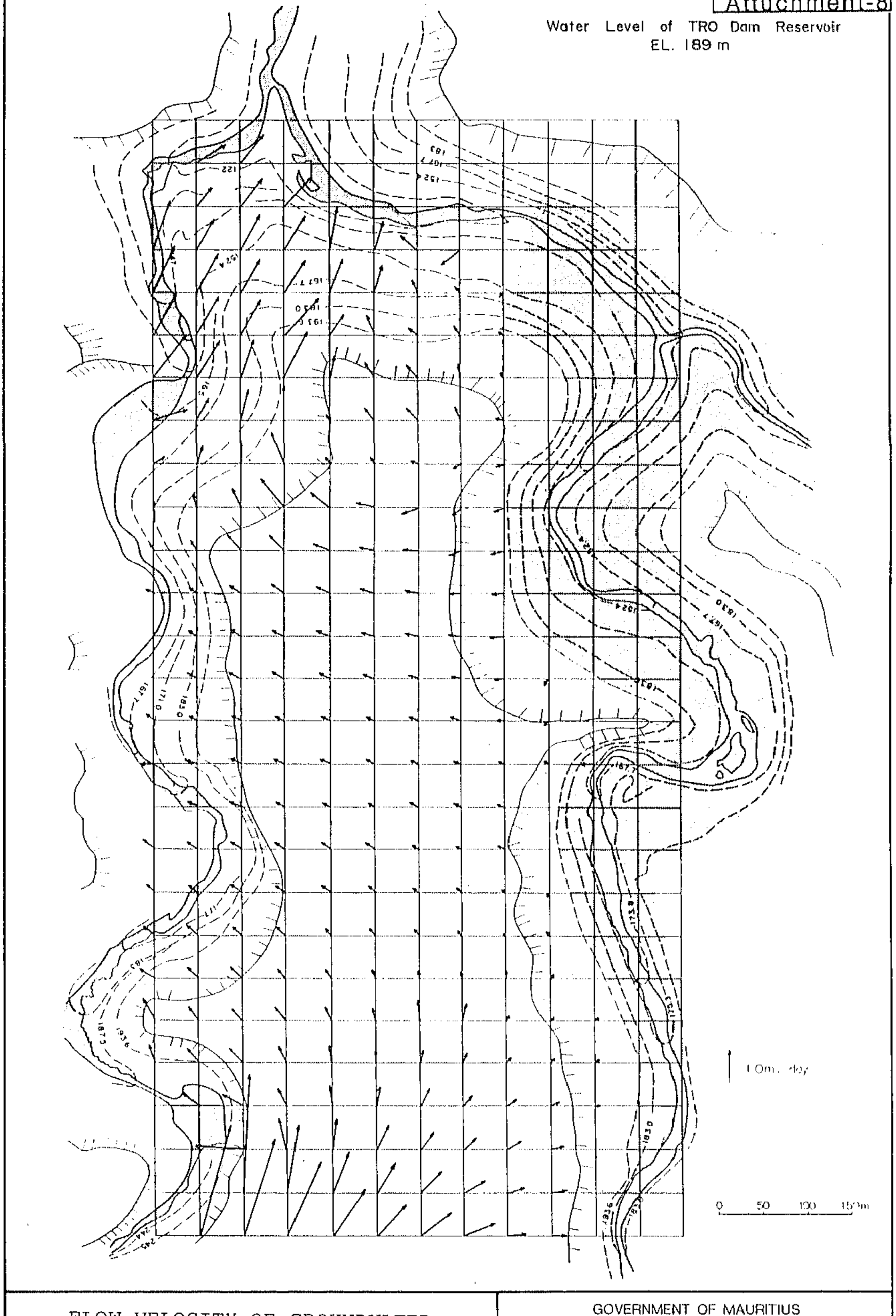


FLOW VELOCITY OF GROUNDWATER
(PRESENT CONDITION)

GOVERNMENT OF MAURITIUS
PORT LOUIS WATER SUPPLY PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

Annex B-2
Attachment-8



FLOW VELOCITY OF GROUNDWATER
(RESERVOIR WL:EL.189.0m)

GOVERNMENT OF MAURITIUS
PORT LOUIS WATER SUPPLY PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

Annex B-2
Attachment-9

AVERAGE WATER BALANCE (1966 - 1986)
(with leakage)

Total Water Requirement : 1.05 m^3/sec
LWL : 139.0 m HWL : 189.0 m
Effective Storage : 6.4 MCM Dead Storage : .275 MCM

SEASON		INFLOW* Resi (MCM)	Dam (MCM)	PIPELINE SUPPLY (MCM)	RELEASE (MCM)	SPILLOUT (MCM)	DEFICIT & NUMBER (MCM)		WATER LEVEL (m)	EVAPORATION (MCM)	LEAKAGE (MCM)
NOV.	1	0.28	0.47	0.18	0.45	0.17	0.00	0	185.2	0.010	0.020
	2	0.24	0.40	0.18	0.50	0.11	0.00	0	184.0	0.010	0.019
	3	0.32	0.51	0.19	0.47	0.23	0.00	0	183.0	0.009	0.017
DEC.	1	0.47	0.68	0.19	0.40	0.30	0.00	0	182.6	0.009	0.015
	2	0.71	0.90	0.20	0.33	0.52	0.00	0	182.4	0.009	0.015
	3	1.32	1.56	0.22	0.29	0.98	0.00	0	184.7	0.009	0.017
JAN.	1	0.69	0.88	0.20	0.21	0.54	0.00	0	185.0	0.010	0.016
	2	1.60	1.82	0.19	0.23	1.53	0.00	0	185.2	0.010	0.018
	3	2.74	2.92	0.24	0.15	2.64	0.00	0	185.6	0.010	0.021
FEB.	1	3.42	3.99	0.24	0.04	3.45	0.00	0	187.8	0.009	0.020
	2	2.95	3.97	0.24	0.06	3.87	0.00	0	187.8	0.009	0.024
	3	2.03	2.44	0.20	0.05	2.34	0.00	0	187.9	0.009	0.020
MAR.	1	2.03	2.55	0.24	0.03	2.38	0.00	0	188.4	0.009	0.024
	2	2.54	2.95	0.24	0.01	2.86	0.00	0	188.6	0.010	0.025
	3	2.13	2.40	0.26	0.05	2.27	0.00	0	188.8	0.009	0.028
APR.	1	1.39	1.59	0.24	0.04	1.48	0.00	0	189.0	0.009	0.026
	2	1.51	2.08	0.24	0.06	1.98	0.00	0	189.0	0.008	0.026
	3	1.20	1.77	0.24	0.06	1.68	0.00	0	189.0	0.008	0.026
MAY.	1	0.96	1.24	0.24	0.07	1.14	0.00	0	189.0	0.007	0.026
	2	0.75	1.00	0.23	0.11	0.87	0.00	0	188.9	0.007	0.026
	3	0.88	1.15	0.25	0.15	1.00	0.00	0	188.8	0.007	0.029
JUN.	1	0.74	1.02	0.23	0.13	0.89	0.00	0	188.7	0.006	0.026
	2	0.68	0.95	0.23	0.12	0.78	0.00	0	188.7	0.006	0.025
	3	0.63	0.91	0.22	0.16	0.71	0.00	0	188.8	0.006	0.025
JUL.	1	0.55	0.81	0.21	0.18	0.61	0.00	0	188.8	0.006	0.026
	2	0.57	0.80	0.22	0.17	0.61	0.00	0	188.8	0.006	0.026
	3	0.71	1.00	0.24	0.17	0.80	0.00	0	188.7	0.007	0.028
AUG.	1	0.63	0.83	0.21	0.15	0.65	0.00	0	188.7	0.007	0.025
	2	0.77	1.13	0.22	0.15	0.96	0.00	0	188.6	0.007	0.025
	3	0.77	1.13	0.24	0.16	0.94	0.00	0	188.6	0.008	0.028
SEP.	1	0.56	0.71	0.21	0.19	0.51	0.00	0	188.5	0.008	0.025
	2	0.49	0.56	0.21	0.22	0.34	0.00	0	188.3	0.008	0.025
	3	0.40	0.49	0.20	0.29	0.23	0.00	0	188.0	0.009	0.025
OCT.	1	0.40	0.58	0.20	0.34	0.29	0.00	0	187.6	0.009	0.024
	2	0.31	0.46	0.20	0.39	0.15	0.00	0	187.0	0.010	0.023
	3	0.29	0.45	0.21	0.48	0.10	0.00	0	186.2	0.010	0.024
		38.69	49.10	7.88	7.06	40.92	0.00	0	-	0.301	0.835

* Dam : inflow into TRO dam reservoir
Resi: river flow of residual basin

PERMIABILITY (after improvement)

Unit : cm/sec

	1		2		3		4		5		6		7
14	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-05	1E-05	1E-06	1E-04	1E-04	1E-04
	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-05	1E-06	1E-06	1E-04	1E-04	1E-04
13	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-05	1E-06	1E-06	1E-04	1E-04	1E-04
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	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04
4	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04
	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04
3	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04
	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04
2	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04
	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04
1	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04)
	1		2		3		4		5		6		7

Ref: 1) Original permiability is set to be 10^{-4} cm/sec at each node.

2) Dam core : 10^{-6} cm/sec

Curtain grout or other improved area : 10^{-5} cm/sec

Others : 10^{-4} cm/sec

GROUND WATER ELEVATION (Present condition)

	1		2		3		4		5		6		7	River bed (Terre Rouge)	Section 4-5 Flux(lit/sec)
14	130	122	114	-	-	-	-	-	-	-	-	-	-	-	-
	130	125	120	116	-	-	-	-	-	-	-	-	-	-	
13	130	129	126	122	117	119	120	121	122	-	-	-	122	122	-0.03
	139	136	133	129	127	126	126	127	127	129	-	129	135	135	-0.31
12	147	143	139	136	134	132	132	132	133	134	135	139	148	148	-0.42
	156	150	146	142	140	138	137	137	137	138	140	143	148	148	-0.16
11	164	156	151	148	145	143	142	142	142	142	144	146	148	148	-0.01
	165	160	155	152	149	147	146	145	145	145	146	148	-	148	0.03
10	166	162	158	155	153	151	150	149	148	148	148	-	-	148	-0.02
	167	164	161	158	156	154	153	152	151	151	150	-	-	150	-0.06
9	168	165	163	161	159	157	156	155	154	153	152	-	-	152	-0.10
	169	166	164	163	161	160	158	157	156	155	154	153	-	153	-0.19
8	169	168	166	165	163	162	161	160	159	158	157	156	154	154	-0.26
	170	169	167	166	165	164	163	162	161	161	160	159	158	158	-0.20
7	171	170	169	168	167	166	166	165	164	163	162	162	161	161	-0.13
	171	171	170	170	169	169	168	167	167	166	165	165	164	164	-0.10
6	171	172	172	172	171	171	170	170	169	169	168	168	167	167	-0.07
	173	173	173	173	173	173	173	172	172	171	171	171	-	171	-0.04
5	174	175	175	176	176	176	175	175	174	174	174	-	-	174	-0.01
	176	177	177	178	178	178	178	177	177	176	175	174	-	174	-0.09
4	177	179	180	181	181	181	181	180	179	178	177	176	175	175	-0.23
	181	182	183	184	184	184	184	183	181	180	178	177	175	175	-0.47
3	184	185	186	187	188	188	187	186	184	182	180	178	175	175	-0.86
	-	187	189	192	193	193	191	189	187	184	182	180	178	178	-1.24
2	-	-	190	198	199	198	196	193	190	186	183	182	181	180	-1.84
	-	216	212	210	208	205	201	197	192	188	184	182	-	182	-2.94
1	242	236	230	224	218	213	207	201	195	189	183	-	-	183	-4.50
	1		2		3		4		5		6		7	Total	-14.23

GROUND WATER ELEVATION

Water Level of TRO Dam reservoir : 189 m Unit : meter

	1		2		3		4		5		6		7	River bed (Terre Rouge)	Section 4-5 Flux(lit/sec)
14	130	122	114	-	-	-	-	-	-	-	-	-	-	-	-
	130	125	120	116	-	-	-	-	-	-	-	-	-	-	
13	130	129	126	122	117	119	120	155	189	-	-	-	122	122	4.72
	139	136	133	129	125	124	122	127	189	189	-	-	135	135	3.91
12	147	143	139	135	131	129	127	135	147	189	-	-	148	148	-0.21
	156	151	146	142	136	133	136	152	175	189	-	-	148	148	0.98
11	164	157	154	151	144	138	160	182	187	189	-	-	148	148	0.98
	165	162	159	158	158	164	182	186	188	189	-	-	-	148	2.34
10	166	165	164	164	169	176	183	186	187	189	-	-	-	148	2.61
	167	167	168	169	174	178	181	185	187	189	-	-	-	150	4.12
9	168	169	170	172	175	178	181	184	187	189	-	-	-	152	4.14
	169	170	172	174	176	179	182	184	187	189	-	-	-	153	3.95
8	169	171	173	175	177	180	182	184	187	189	-	-	-	154	3.60
	170	172	174	176	178	180	182	184	186	188	189	189	-	158	2.71
7	171	173	175	177	179	181	183	185	186	188	189	189	189	161	2.10
	171	173	175	178	180	182	183	185	187	188	189	189	-	164	1.75
6	171	174	176	179	181	182	184	186	187	189	-	-	-	167	1.52
	173	175	178	180	182	183	185	186	188	189	-	-	-	171	1.09
5	174	177	179	181	183	185	186	187	188	189	189	-	-	174	0.64
	176	178	181	183	184	186	187	188	188	189	189	-	-	174	0.42
4	177	180	183	185	186	188	188	189	189	189	189	-	-	175	0.16
	181	183	185	187	189	190	190	190	190	190	189	189	-	175	-0.16
3	184	185	187	190	192	192	192	192	191	190	190	189	-	175	-0.63
	-	187	189	193	195	196	195	194	192	191	190	189	-	178	-1.19
2	-	-	190	199	201	200	199	196	194	191	189	-	-	180	-1.89
	-	216	212	211	209	206	203	199	195	192	189	-	-	182	-2.94
1	242	236	230	224	218	213	207	201	195	192	189	-	-	183	-4.50
	1		2		3		4		5		6		7	Total	30.22

Annex B-2
Attachment-13

GROUND WATER ELEVATION

Water Level of TRO Dam reservoir : 180 m

Unit : meter

	1		2		3		4		5		6		7	River bed (Terre Rouge)	Section 4-5 Flux(lit/sec)
14	130	122	114	-	-	-	-	-	-	-	-	-	-	-	-
	130	125	120	116	-	-	-	-	-	-	-	-	-	-	
13	130	129	126	122	117	119	120	150	180	-	-	-	122	122	3.55
	139	136	132	129	125	124	122	126	180	180	-	-	135	135	2.67
12	147	143	139	135	131	129	127	134	144	180	-	-	148	148	-0.24
	156	151	146	142	136	133	135	148	168	180	-	-	148	148	0.56
11	164	157	153	151	143	137	155	174	179	180	-	-	148	148	0.63
	165	161	159	157	157	160	175	178	179	180	-	-	-	148	1.27
10	166	164	163	163	166	172	176	178	179	180	-	-	-	148	1.30
	167	166	166	167	170	173	175	177	179	180	-	-	-	150	1.96
9	168	168	168	170	172	174	175	177	179	180	-	-	-	152	1.90
	169	169	170	171	173	174	176	177	179	180	-	-	-	153	1.73
8	169	170	171	172	173	175	176	177	179	180	-	-	-	154	1.49
	170	171	172	173	174	175	177	178	179	180	180	180	-	158	1.02
7	171	172	173	174	175	176	177	178	179	179	180	180	180	161	0.68
	171	172	174	175	176	177	178	179	179	180	180	180	-	164	0.45
6	171	173	175	176	177	178	179	179	180	180	-	-	-	167	0.26
	173	174	176	177	178	179	180	180	180	180	-	-	-	171	0.07
5	174	176	177	179	180	180	181	181	181	180	180	-	-	174	-0.04
	176	177	179	180	181	182	182	182	182	181	180	-	-	174	-0.17
4	177	179	181	183	184	184	184	183	183	181	180	-	-	175	-0.36
	181	182	184	185	186	186	186	185	184	182	181	180	-	175	-0.63
3	184	185	187	188	190	190	189	187	186	183	181	180	-	175	-1.07
	-	187	189	192	194	194	192	190	187	184	181	180	-	178	-1.51
2	-	-	190	198	200	199	196	193	190	185	180	-	-	180	-2.12
	-	216	212	211	208	205	201	197	192	187	182	-	-	182	-3.13
1	242	236	230	224	218	213	207	201	195	189	183	-	-	183	-4.50
	1		2		3		4		5		6		7		Total 5.76

Annex B-2
Attachment-14

GROUND WATER ELEVATION

Water Level of TRO Dam reservoir : 170 m　　　　Unit : meter

	1		2		3		4		5		6		7	River bed (Terre Rouge)	Section 4-5 Flux(lit/sec)
14	130	122	114	-	-	-	-	-	-	-	-	-	-	-	-
	130	125	120	116	-	-	-	-	-	-	-	-	-	-	
13	130	129	126	122	117	119	120	145	170	-	-	-	122	122	2.44
	139	136	132	129	125	124	122	125	170	170	-	-	135	135	1.56
12	147	143	139	135	131	129	126	132	140	170	-	-	148	148	-0.25
	156	150	146	142	135	132	134	145	161	170	-	-	148	148	0.21
11	164	157	153	150	143	137	151	166	169	170	-	-	148	148	0.33
	165	161	158	156	156	156	167	169	170	170	-	-	-	148	0.43
10	166	164	162	161	164	167	169	169	170	170	-	-	-	148	0.31
	167	166	165	165	167	168	169	169	170	170	-	-	-	150	0.36
9	168	167	167	167	168	168	169	169	170	170	-	-	-	152	0.27
	169	168	168	168	169	169	169	170	170	170	-	-	-	153	0.15
8	169	169	169	169	170	170	170	170	170	170	-	-	-	154	0.01
	170	170	170	170	170	171	171	171	170	170	170	170	-	158	-0.10
7	171	171	171	171	171	171	171	171	171	170	170	170	170	161	-0.18
	171	172	172	172	172	172	172	172	171	170	170	170	-	164	-0.24
6	171	172	173	173	174	174	173	173	172	170	-	-	-	167	-0.26
	173	174	174	175	175	175	175	174	173	171	-	-	-	171	-0.16
5	174	175	176	177	177	177	176	176	175	174	174	-	-	174	-0.06
	176	177	178	179	179	179	178	178	176	175	174	-	-	174	-0.15
4	177	179	180	181	182	181	181	180	178	177	175	-	-	175	-0.31
	181	182	183	184	185	184	184	182	181	179	177	175	-	175	-0.56
3	184	185	186	187	188	188	187	185	183	181	178	175	-	175	-0.98
	-	187	189	192	193	192	191	188	186	183	180	178	-	178	-1.35
2	-	-	190	198	199	198	196	192	189	184	180	-	-	180	-1.93
	-	216	212	210	208	205	201	196	192	187	182	-	-	182	-3.01
1	242	236	230	224	218	213	207	201	195	189	183	-	-	183	-4.50
	1		2		3		4		5		6		7	Total	-7.99

ANNEX (B-3)

JUSTIFICATION FOR DEPTH OF FOUNDATION EXCAVATION FOR SPILLWAY AND EARTH DAM AT MO4 AND TR9

1. General

In the design of dam for M04 and TR9 schemes, the spillway is founded on the weathered rock surface situated at around 15 m depth from the ground surface. The impervious cut-off trench is also excavated down to the weathered rock surface to secure the safety of dam.

the above design is based on the following consideration:

2. Foundation for spillway

(1) The spillway (a heavy concrete structure) founded on the clay materials should be considered to cause a differential settlement due to the so-called consolidation of clay materials (The consolidation of clay occurs because the water contained in the clay discharges out due to the weight of concrete structure); that is, the foundation of the concrete structure will move.

As a result, many troubles are considered to arise in the concrete structure itself. Besides that, the earth dam will be subject to serious damages in the contact portion with the concrete structure due to the movement of concrete structure, resulting in a fatal damage of whole dam.

Therefore, the Team considers the spillway, in principle, is forced to be founded on the weathered rock situated at about 15 m depth where the consolidation will not occur.

(2) The spillway is a concrete gravity dam which should followed the dam design criteria accepted widely.

According to the dam design criteria, the foundation of dam has to have the safety factor more than 4 times at least in both sliding and bearing strength.

It will be difficult to secure the above necessary safety factor on the foundation of clay as seen in the attached paper (attach.-1) which shows a stability analysis of a concrete structure on the clay material.

In the case of this example, the safety factor for sliding is calculated at 0.83 which is much less than 4.0. The bearing stress is calculated at 24.83 t/m^2, while the bearing strength of clay materials will be about 5.0 to 15 t/m^2.

Thus, it is considered that such an important concrete structure as the spillway of dam should not be founded on the clayey materials which tend to cause various troubles.

3. Foundation for earth dam

(1) Impervious cut-off trench

The securement of a sufficient impermeability in the dam foundation is the most important factor for the safety of a fill type dam.

As for measures to secure the sufficient impermeability of dam foundation, there are three(3) widely accepted measures as shown in Attachment-2. One of them is usually applied in accordance with the thickness of pervious foundation.

Case (a) in Attachment-2, in which the cut-off trench reaches the impervious stratum, is most reliable technically, and therefore, it is recommended to apply the Case (A),if the thickness of pervious layer is not so deep or if there is no large difference in the cost.

Attachment-3 presents a preliminary cost comparison on the above three (3) treatment measures.

The result is as follows:

Case (A): US$ 3,780,000
Case (B): US$ 6,300,000 (concrete wall)
US$ 3,900,000 (cement grout)
Case (c): US$ 3,660,000

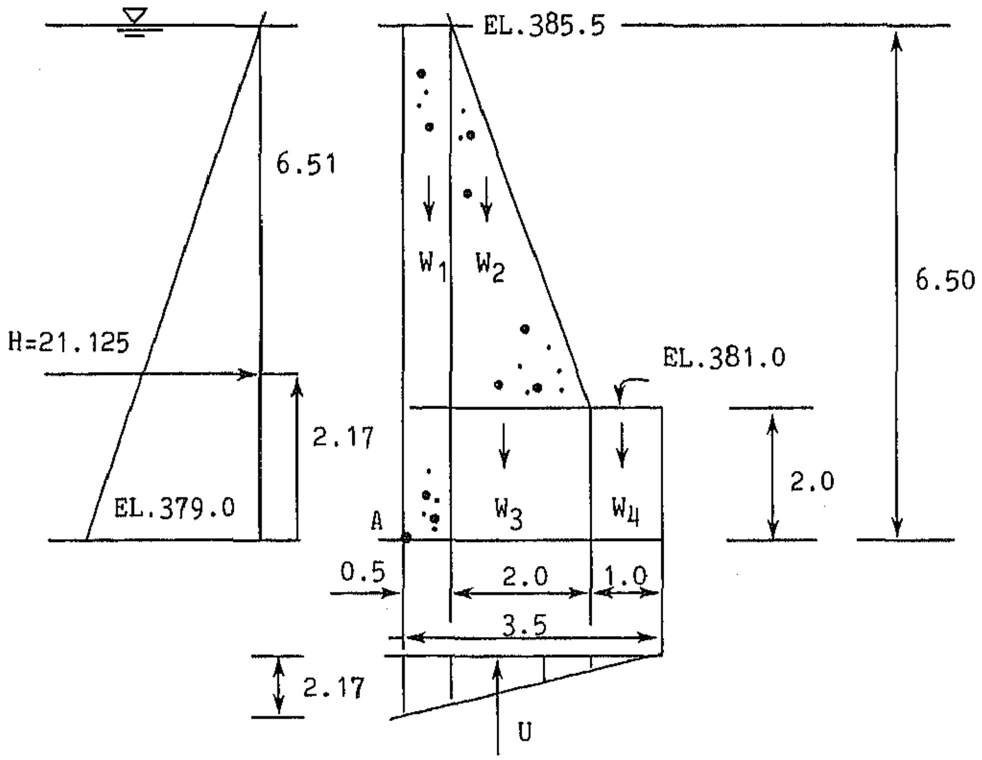
As seen,the cost difference is negligibly small among three measures. In such a case, application of the most reliable and complete measure (Case(A)),in principal, is recommendable.

(2) Foundation for earth dam

The foundation of a fill type dam is prohibited to contain any organic or harmful materials. Furthermore, very loose residual soil materials should be removed to avoid probable troubles to be caused by consolidation of loose soil materials or the collapse of dam body along a weak sliding circle which appears through the weak foundation.

Based on the field investigations at MO4 or TR9, it is judged the stripping of about 3.0 m depth at least will be required.

Examination of Stability for A Concrete Structure on Clayey Material



	FORCE	H	V	ARM	MONENT
H	$\frac{1}{2}\times 6.5\times 6.5=21.125$	21.125	—	2.17	45.84
W_1	$6.5\times 0.5\times 2.4=7.8$	—	7.8	0.25	1.95
W_2	$\frac{1}{2}\times 4.5\times 2.0\times 2.4=10.8$	—	10.8	1.17	12.64
W_3	$2.0\times 2.0\times 2.4=9.6$	—	9.6	1.5	14.40
W_4	$1.0\times 2.0\times 2.4=4.8$	—	4.8	3.0	14.40
U	$\frac{1}{2}\times 2.17\times 3.5=3.80$	—	-3.80	1.17	-4.45

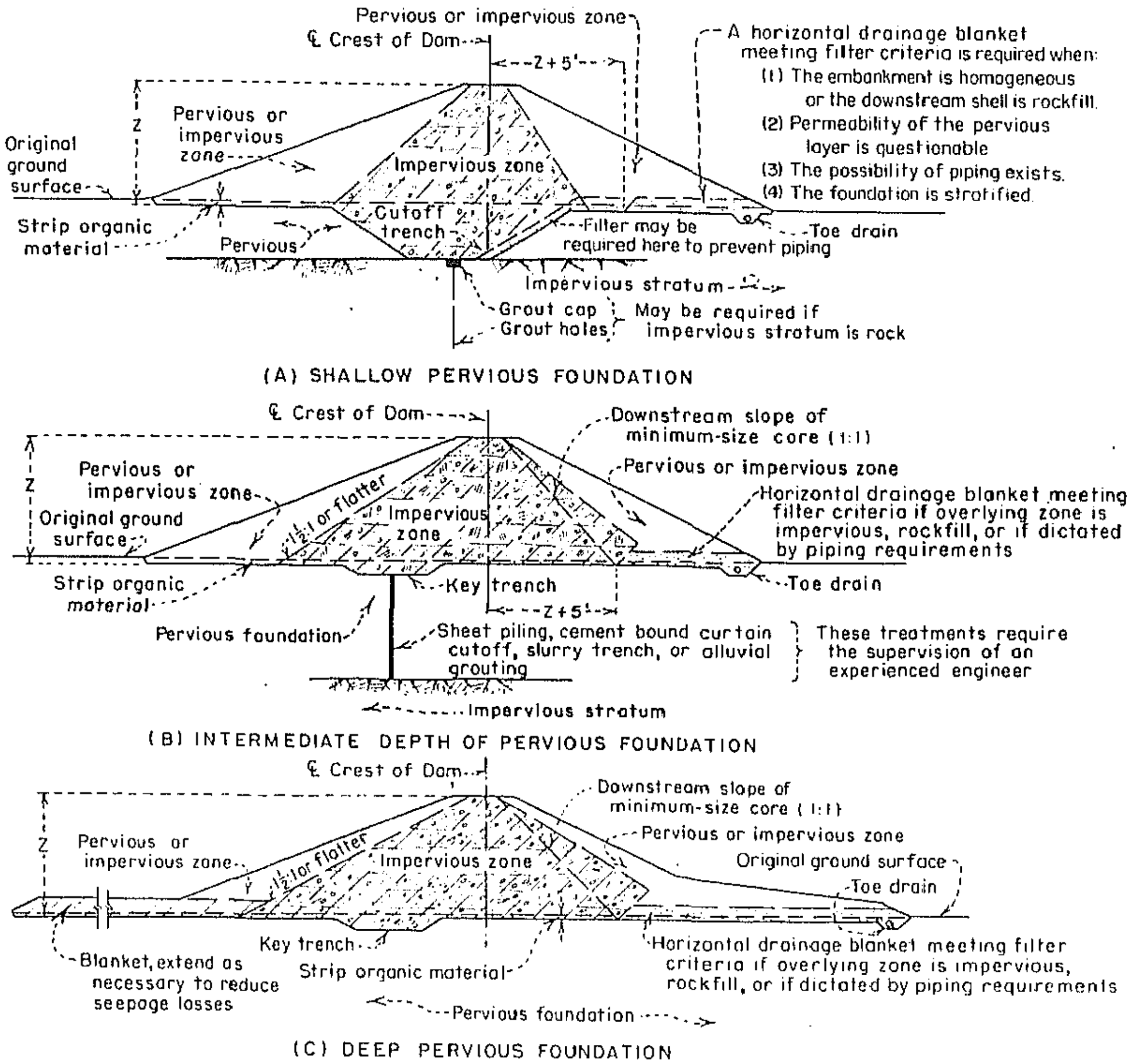
$\Sigma H = 21.125$ $\Sigma V = 29.2$ $\Sigma M = 84.78$

$$S.F=\frac{\tau.\ell+f.\Sigma V}{\Sigma H}=\frac{2.0\times 3.5+0.364\times 29.2}{21.125}$$

$$=\frac{17.63}{21.125}=0.83$$

$$\sigma=\frac{\Sigma V}{\ell}(1\pm\frac{6\times e}{\ell})=\frac{29.2}{3.5}(1\pm\frac{6\times 1.153}{3.5})=\begin{cases}24.83\ t/m^2\\ -8.15\ t/m^2\end{cases}$$

$$e=\frac{\Sigma M}{\Sigma V}-\frac{\ell}{2}=\frac{84.78}{29.2}-\frac{3.5}{2}=1.153$$

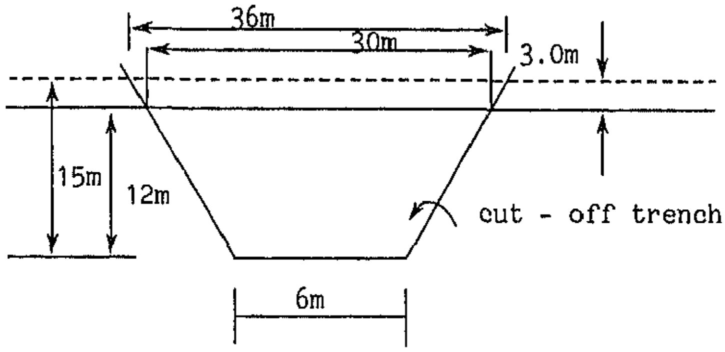


Source : DESIGN OF SMALL DAMS, USBR, 1977

TYPICAL FOUNDATION TREATMENTS

Preliminary Cost Comparison of Foundation Treatments

(1) Case (A)



$A = \frac{15}{2}(30+6) = 270m^2$

$L \fallingdotseq 1.000m$

$V = 270,000m^3$

$Cost \fallingdotseq 270,000 \times (\$4.0 + \&10.0)$
$= US\$\ 3,780,000$

(2) Case (B)

(1) Concrete Cut - off wall :

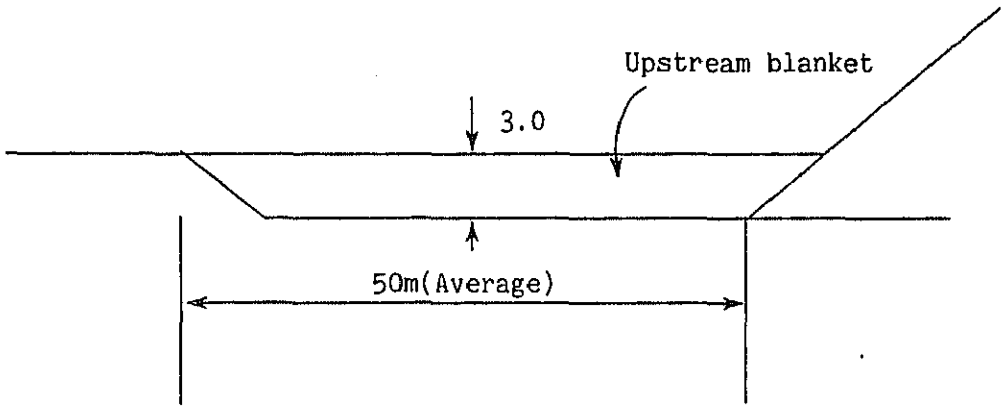
$A = 15m \times 1.000m = 15.000m^2$
$Cost \fallingdotseq 15.000m^2 \times \$420/m^2 =$ <u>US$6,300,000</u>

(ii) Sheet pile :
The effect by sheet pile is poor, and the sheet pile is not used recently. Its cost is also higher.

(iii) Cement grout :
$15m \times \frac{1.000m}{0.5m} \times \$130/m =$ <u>US$ 3,900,000</u>

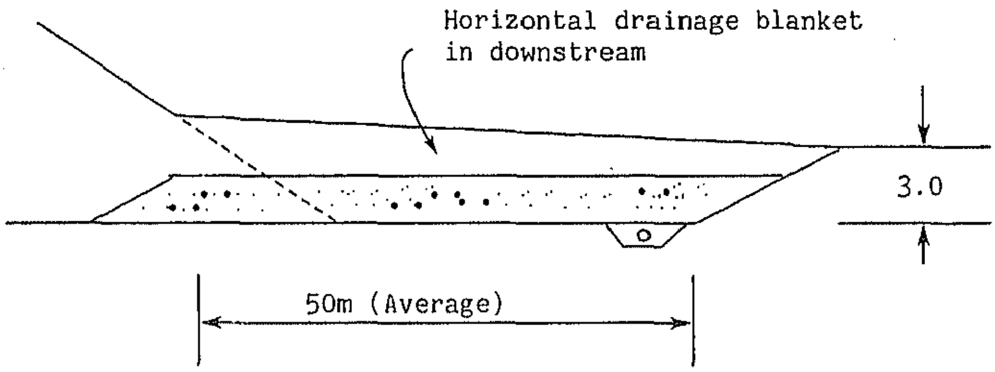
Note : Cement grouting in five grained pervious layer is not recommendable because of its poor technical reliability.

(3) Case (C)



Excavation : $A = 3.0m \times 50m = 150m^2$
$V = 150m^2 \times 1.000m = 150.000m^3$
$Cost = 150.000m^3 \times \$4/m^3$ = US$ 600,000

Embankment : $A = 3.0m \times 50m = 150m^2$
$V = 150m^2 \times 1.000m = 150.000m^3$
$Cost = 150.000m^3 \times \$10/m^3$ = US$ 1,500,000



Excavation : $A \fallingdotseq 3.0m \times 30m = 90m^2$
$V = 90m^2 \times 1.000m = 90.000m^3$
$Cost = 90.000m^3 \times \$4.0/m^3$ = US$ 360,000

Embankment : $A \fallingdotseq 3.0m \times 40m = 120m^2$
$V = 120m^2 \times 1.000m = 120.000m^3$
$Cost = 120.000m^3 \times \$10.0/m^3$ = US$ 1,200,000

Grand Total of Cost = US$ 3,660,000