Table D-1(1/2) SOIL LEGEND IN THE STUDY AREA

1. P: PLAINS (elevation less than 60m: slopes generally less than 2%)

PR: Soils formed on recent river alluvium

PRb: Soils with weak profile differentiation and/or stratification

- PRB1 - Caymanas clay loam-loam: Well drained, deep, dark yellowish brown and brown stratified moderately fine textured soil, high in silt with a humic surface layer: calcareous (Typic Haplustolls)
- PRb2 - Dawkins sandy loam: Well drained, deep, yellowish brown stratified medium textured soils high in silt with a humic surface layer: calcareous (Typic Haplustolls)
- PRb3 - Whim clay loam:Well drained, deep, brown and yellowish brown stratified moderately fine textured soils with a humic surface layer (Udic Haplustolls)
- PRb4 - Ferry silty clay: Moderately well drained, deep, dark grayish brown and dark brown stratified fine textured soils high in silt with strong brown mottles: strongly calcareous (Typic Haplustolls)
- PRB4/sa - Ferry silty clay saline- sodic phase: Similar to soils of unit PRb4 but saline and sodic in surface layers (Typic Haplustolls)

PO: Soils formed on old marine alluvium

POc: Soils with moderate profile differentiation

- POc1 - Lodge clay: Moderately well drained, deep, reddish brown cracking clay soils (Typic Chromusterts)
- POc1/sa - Lodge clay, saline - sodic phase: Similar to unit POc1 but saline and sodic in the subsoil (Typic Chromusterts)
- POc2 - Churchpen clay: Imperfectly to moderately well drained, deep, yellowish brown cracking clay soils with few mottles in the subsoil. (Typic Chromusterts)
- POc2/sa - Churchpen clay, saline - sodic phase: Similar to unit POc2 but saline or sodic in the subsoil. (Typic Chromusterts)
- POc3 - Bodles clay:Imperfectly drained, deep, yellowish red and brown distinctly mottled cracking clay soils; moderately saline and in places sodic in the subsoil. (Typic Chromusterts)
- POc4 - Horse Cave clay: Imperfectly drained, deep, yellowish brown cracking clay soils generally saline and sodic throughout but in places with non-saline topsoil. (Entic Chromusterts)
- POc5 - Salt Island clay: Imperfectly drained, deep, dark brown cracking clay soils; strongly saline and sodic throughout. (Typic Chromusterts)
- POc6/sa - Sydenham clay: Imperfectly drained, deep, yellowish brown and brown cracking clay soils with a dark gray gritty surface layer. (Typic Pellusterts)
- POc6 - Sydenham clay, saline-sodic phase: Saline phase - similar to unit POc6 but salaine and sodic in the subsoil. (Typic Pellusterts)
- POc7 - Springfield clay: Poorly drained, deep, yellowish brown and dark brown mottled cracking clay soils, locally saline in the subsoil. (Aquic Chromusterts)

Table D-1 (2/2) SOIL LEGEND IN THE STUDY AREA

POd: Soils with strong profile differentiation

- POd1 - Colbeck clay :Well drained, deep, mixed yellowish red and brown caly soils, non-calcareous ; gently undulating topography (2-5%) (Udertic Paleustalfs)

POA: Association of soils with different degrees of profile differentiation

- POA - Colbeck - Bodles Association: Association of unit POd1 on crests and upper slopes and unit POc3 on lower slopes and depression in a gently undulating landscape (Udertic Paleustalfs/Typic Chromusterts)

2. H: Hills and Hill Remnants:

(Relief intensity 20-200 m; slopes generally 16-50%)

HL: Soils formed on limestone

HLC: Complex of soils with different degrees of profile differentiation

- HLC1 - Rockland-Hellshire complex: Complex of rock-out crops and somewhat excessively drained, shallow, reddish brown stony loam and clay loam with limestone fragments (non-soil/Lithic Ustropepts)
- HLC2 - Union Hill,ustic variant-Hellshire complex:.Complex of somewhat excessively drained, moderately shallow, strong brown gravelly clay and loam and shallow, reddish brown stony loam and clay loam with limestone fragaments (Lithic Ustropepts)

3. T: Tidal Flats and Swamps (regularly flood; slopes less than 1%)

TM: Soils formed on recent marine alluvium

TMX: Undifferentiated soils with very weak or weak profile differentiation

- TMX1 - "Salina" undifferntiated: Poorly drained, deep, strongly saline and sodic soils with varying colours and textures; strong calcareous.(Typic Halaquepts)
- TMX2 - "Mangrove" undifferentiated: Very poorly drained, deep, saline greenish gray clay soils with common mottles; in places with partly decomposed organic material (Hydraquents/Fluvaquents)

4. M: Miscellaneous area

- MB: Beach: Sandy and gravelly shores washed by waves
- MG: Gullied Land: Land cut by recent gullies
- ML: Man-made Land: Areas artificially filled with earth and levelled
- MP: Pits, sandy: Open excavations from which sand is being mined
- MU: Urban Land: Urban areas
- MW: Wet Land: Permanently wet areas

Source: Report of RPPU, Jamaica (1986)

Table D-2 MAIN SOIL CHARACTERISTICS OF THE MAJOR MAPPING UNITS

Map Symbol	Soil Name	Physiographic Position	Family Particle Size Class (25-100cm)	Drainage Class	Available P and K at 0 to 30 cm P	:	K	Inherent Fertility	Major Limitation	Land Capability Classification
PRb1	Caymanas clay loam-loam	level-slightly concave	fine silty	well drained	Medium	:	High	high	none	I
PRb2	Dawkins sandy loam-loam	level towards streams	coarse loamy	well drained	High	:	Medium	high	none	I
PRb3	Whim clay loam	higher terraces	fine loamy	well drained	High	:	Medium	high	none	I
PRb4	Ferry silty clay	slight depressions	fine	moderately well	Medium	:	Medium		wetness	IIw
PRb4/sa	Ferry silty clay,saline-sodic phase	slight depressions	fine	imperfectly	-	:	-	high	sodicity/salinity	IIsa
POc1	Lodge clay	slighty convex	fine	mod. well	Low-Med	:	Low-Med	medium-high	workability/wetness	IIrw
POc1/sa	Lodge clay, saline-sodic phase	lower slopes, depressions	fine	mod. well	Medium	:	Low-Med	medium	salinity/sodicity	IIIsa
POc2	Churchpen clay	level	fine	imperfectly/mod well	Medium	:	Medium	medium-high	workability	IIpw
POc2/sa	Churchpen clay, saline-sodic phase	lower slopes,depressions	fine	imperfectly	Low-High	:	Low-Med	medium	salinity/sodicity	IIsa
POc3	Bodles clay	slightly concave/flat	fine	imperfectly	Low-Med	:	Medium	medium	wetness/workability	IIIwp
POc4	Horse Cave clay	lower slopes	fine	imperfectly	Medium	:	High	medium	salinity/sodicity	IVsa
POc5	Salt Island clay	lower slopes, depressions	fine	imperfectly	Medium	:	Medium	medium	salinity/sodicity	Vsa
POC6	Sydenham clay	slightly concave	fine	imperfectly	Low-Med	:	Low-Med	med-high	workability	IIp
POc6/sa	Sydenham clay, salin-sodic phase	concave/flat	fine	imperfectly	Low-Med	:	Low-Med	medium	salinity/sodicity	IIIsa
POc7	Springfield clay	slight depressions	fine	poorly	Medium	:	Medium	medium	wetness	IIIwp
POd1	Colbeck Clay	upper part low ridges undulating	fine	well	Low	:	Low	medium-low	workability/erosion	IIpe
POA	Colbeck-Bodles complex	undulating landscape	fine	well/imperfectly	-	:	-	medium-low	wetness/workability	IIwp
HLC1	Rockland-Hellshire complex	upper slopes hill tops	fine	somewhat excessively					N/A	VI
HLC2 *)	Union Hill, ustic variant-Fellowship complex	lower slopes of hills	fine	well-somewhat excessively					depth, erosion	Vde

Remarks: Based on CEC, base saturation and amount of exchangeble Ca, Mg, Na, K
*Soils of TM Units: not suitable for cultivation (VI)

Land Capability Class
I : No limitation for cultivation
II : Slightly limitation for cultivation
III: Moderate limitation for cultivation
IV : Strong limitation for cultivation
V : Very strong limitation for cultivation
VI : Not suitable for cultivation

Kind of Limitation
e : erosion
sa salinity/sodicit
p workability
w wetness
d soil depth
- no data

	P (ppm)	K* (ppm)
High	>100	>300
Medium	50-100	150-300
Low	<50	<150

* irrespective of soil texture

Source: Report of RPPD, Jamiaca (1986)

Table D-3 SOIL MAPPING UNITS AND LAND CAPABILITY IN THE STUDY AREA

Map Symbol	Soil Name	Soil Sub-group (USDA)	Area (ha)	Capability Class	
				Upland Crop	Rice
1. Soils formed on recent river alluvium					
PRb1	Caymanas clay loam-loam	Typic Haplustolls	2,660	I	VI
PRb2	Dawkins sandy loam-loam	Typic Haplustolls	1,350	I	VI
PRb3	Whim clay loam	Udic Haplustolls	1,060	I	VI
PRb4	Ferry silty clay	Typic Haplustolls	810	IIw	IIIl
PRb4/sa	Ferry silty clay, saline-sodic phase	Typic Haplustolls	150	IIIsa	IVl
2. Soils formed on old marine alluvium					
POc1	Lodge clay	Typic Chromusterts	1,540	IIpw	IIp
POc1/sa	Lodge clay, saline-sodic phase	Typic Chromusterts	220	IIIsa	IIIps
POc2	Churchpen clay	Typic Chromusterts	5,430	IIpw	IIp
POc2/sa	Churchpen clay, saline-sodic phase	Typic Chromusterts	100	IIIsa	IIIps
POc3	Bodles clay	Typic Chromusterts	490	IIIwp	IIp
POc4	Horse Cave clay	Entic Chromusterts	790	IVsa	IIIps
POc5	Salt Island clay	Typic Chromusterts	2,160	Vsa	Vsa
POc6	Sydenham clay	Typic Pellusterts	1,880	IIpw	IIp
POc6/sa	Sydenham clay, salin-sodic phase	Typic Pellusterts	650	IIIsa	IIIps
POc7	Springfield clay	Aquic Chromusterts	1,470	IIIwp	IIp
POd1	Colbeck Clay	Udertic Paleustalfs	50	IIpe	Vp
POA	Colbeck-Bodles complex	Udertic Paleustalfs/ Typic Chromusterts	230	IIpw	Vp
3. Soils formed on limestone					
HLC1	Rockland-Hellshire complex	Non soil/ Lithic Ustropepts	60	VI	VI
HLC2 *)	Union Hill, ustic variant-Fellowship complex	Lithic Ustropepts	40	Vde	VI
4. Soils formed on recent marine alluvium					
TMX1	"Saline" undifferentiated	Typic Halaquepts	620	VI	VI
TMX2	"Mangrove" undifferenciated	Hydraquents/Fluvaquents	910	VI	VI
5. Miscellaneous areas					
MU	Urban land		4,240		
MW	Wet land		190		
1b,MG,ML,M	Other land		340		
6. Total			27,440		

Source : Soil Survey Unit, Rural Physical Rlanning Division, MOA

Table D-4 SOIL CLASSIFICATION IN THE STUDY AREA BY SOIL TAXONOMY

Order	Sub-order	Great-group	Sub-group	Map Unit Symbol
Mollisols	Ustolls	Haplustolls	Typic Haplustolls	PRb1,PRb2,PRb4,PRb4/sa
Mollisols	Ustolls	Haplustolls	Udic Haplustolls	PRb3
Vertisols	Usterts	Chromusterts	Typic Chromusterts	POc1,POc1/sa,POc2,POc2/sa,POc3,POc4,POc5
Vertisols	Usterts	Pellusterts	Typic Pellusterts	POC6,POC6/sa
Vertisols	Uderts	Chromuderts	Aquie Chromuderts	POC7
Alfisols	Ustaifs	Paleustalfs	Udertic Paleustalfs	POd1
Inceptisols	Tropept	Ustropepts	Lithic Ustropepts	HLC2
Inceptisols	Aquept	Halaquepts	Typic Halaquepts	TMX1
Entisols	Aquept	Hydraquents	Typic Hydraquents	TMX2
Entisols	Aquept	Fluvaquents	Typic Fluvaquents	TMX2

Table D-5 CLASSIFICATION OF THE SOIL SERIES ACCORDING TO SOIL TAXONOMY (USDA) AND CORRELATION WITH FAO/UNESCO SYSTEM

Series	Family (USDA)	Sub-group (USDA)	FAO/UNESCO
Caymanas	fine, silty, mixed, isohyperthermic	Typic Haplustolls	Calcaric Phaeozems
Dawkins	coarse loamy, mixed, isohyperthermic	Typic Haplustolls	Haplic Phaeozems
Whim	fine loamy, mixed, isohyperthermic	Udic Haplustolls	Haplic Phaeozems
Ferry	fine, mixed, isohyperthermic	Typic Haplustolls	Calcaric Phaeozems
Lodge	fine, montmorillonitic, isohyperthermic	Typic Chromusterts	Chromic Vertisols
Churchpen	fine, montmorillonitic, isohyperthermic	Typic Chromusterts	Chromic Vertisols
Bodles	fine, montmorillonitic, isohyperthermic	Typic Chromusterts	Chromic Vertisols
Horse Cave	fine, montmorillonitic, isohyperthermic	Entic Chromusterts	Chromic Vertisols
Salt Island	fine, montmorillonitic, isohyperthermic	Typic Chromusterts	Chromic Vertisols
Sydenham	fine, montmorillonitic, isohyperthermic	Typic Pellusterts	Pellic Vertisols
Springfield	fine, montmorillonitic, isohyperthermic	Aquic Chromusterts	Chromic Vertisols
Colbeck	fine, mixed, isohyperthermic	Udertic Paleustalfs	Vertic Luvisols
Hellshire	loamy-skeletal, mixed, isohyperthermic	Lithic Ustropepts	Lithic Cambisols
Union Hill	clay-skeletal, mixed, isohyperthermic	Lithic Ustropepts	Lithic Cambisols

Source: Report of RPPD, Jamaica (1986)

Table D-6 CHEMICAL PROPERTIES OF EACH SERIES

Lab. No. SC	Depth (cm)	Particle Size (%) Sand	Silt	Clay	Texture (USDA)	Moisture Content (Vol. %) pF 2.0	pF 4.2	Organic Carbon (%)	Total Nitrogen (%)	Available P2O5 (ppm)	Available K2O (ppm)	CaCO3 (%)	pH H2O (1:2.5)	pH KCl (1:2.5)	ECe (S/cm)	Extractable Bases, Acidity and CEC (meq/100g soil) Na	K	Ca	Mg	Total	Acidity	CEC	Base Satur. (%)	ESP (%)
1. TYPIC HAPLUSTOLLS; PRb1																								
1631	0-15	30.1	44.0	25.9	loam	-	-	1.41	0.11	400	327	3.73	7.90	6.90	0.14	0.22	0.64	19.90	4.90	25.66	-	20.0	100	1.1
1632	15-34	33.4	41.1	25.6	loam	-	-	0.71	0.07	400	267	3.00	8.00	6.80	0.13	0.21	0.54	20.90	4.40	26.05	-	18.0	100	1.2
1633	34-64	13.6	60.3	26.1	silt loam	-	-	0.22	0.04	114	179	10.30	8.20	7.00	0.13	0.37	0.35	62.00	5.06	67.78	-	18.0	100	2.1
1634	64-122	19.2	55.2	25.6	silt loam	-	-	0.26	0.03	76	132	11.80	8.30	6.90	0.12	0.30	0.23	65.40	4.60	70.53	-	16.0	100	1.5
1635	122-144	6.8	59.1	34.1	silt clay loam	-	-	0.34	0.04	97	141	4.80	8.20	6.80	0.13	0.35	0.37	50.80	6.06	57.78	-	23.2	100	1.5
2. TYPIC HAPLUSTOLLS; PRb2																								
2092	0-40	50.0	34.7	15.3	loam	-	-	1.08	0.05	308	113	0.05	8.15	6.75	0.17	0.17	0.10	16.60	2.86	19.73	-	11.8	100	1.1
2093	40-98	43.3	45.0	11.7	loam	-	-	0.33	0.03	35	63	5.87	8.40	6.90	0.11	0.21	0.10	61.30	2.46	64.07	-	12.0	100	1.5
2094	98-150	48.0	40.3	11.7	loam	-	-	0.31	0.02	40	59	6.75	8.40	6.90	0.15	0.26	0.09	75.00	2.43	77.08	-	13.2	100	2.0
3. Udic HAPLUSTOLLS; PRb3																								
950	0-20/25	42.6	26.0	31.4	clay loam	-	-	1.13	0.10	177	174	0.91	7.53	5.98	0.14	0.70	0.43	21.60	8.33	31.06	0.05	27.2	100	2.6
951	20/25-51	38.6	24.0	37.4	clay loam	-	-	0.57	0.05	234	118	0.64	7.84	5.75	0.17	1.22	0.29	21.60	7.79	30.90	0.05	27.6	100	4.4
952	51-88/90	46.6	24.0	29.4	sandy clay loam	-	-	0.31	0.09	254	99	0.84	8.01	5.74	0.13	1.09	0.24	21.40	6.19	28.92	0.05	24.0	100	4.5
953	88/90-140	46.6	26.0	27.4	sandy clay loam	-	-	0.19	0.03	332	99	0.89	7.95	5.69	0.15	1.13	0.23	20.70	6.36	28.42	0.05	24.4	100	4.6
4. TYPIC HAPLUSTOLLS; PRb4																								
2066	0-20	9.6	48.2	42.2	silty clay	-	-	2.00	0.17	45	169	7.55	7.65	6.95	0.55	0.33	0.41	78.07	3.78	82.59	-	30.0	100	1.1
2067	20-60	10.9	46.5	42.6	silty clay	-	-	1.27	0.13	45	93	8.14	8.20	6.95	0.29	1.62	0.22	73.12	7.60	82.62	-	28.0	100	5.8
2068	10 cm	90.7	4.4	5.0	sand	-	-	0.10	0.01	50	37	2.57	8.55	7.50	0.09	0.13	0.00	22.11	0.68	22.92	-	4.0	100	3.3
2069	60-90	2.8	67.4	29.8	silty clay loam	-	-	0.46	0.04	30	68	7.21	8.35	7.00	0.43	1.86	0.13	68.75	6.15	76.89	-	21.6	100	8.6
2070	90-140	0.4	65.1	34.5	silty clay loam	-	-	1.17	0.16	35	76	11.39	7.75	7.05	1.22	1.18	0.11	80.10	8.62	90.03	-	26.4	100	4.5
2071	140-154	4.1	61.5	34.5	silty clay loam	-	-	2.02	0.19	43	59	60.78	7.75	7.30	1.50	0.32	0.06	73.41	6.07	79.86	-	14.4	100	2.2
5.TYPIC CHROMUSTERTS;POc1																								
2040	0-22/33	34.4	27.6	38.0	clay loam	-	-	0.87	0.08	58	146	0.27	0.27	5.80	0.18		0.38	17.64	12.34	30.56	-	30.8	99.7	0.0
2041	22/33-41/53	30.4	29.6	40.0	clay	-	-	0.24	0.04	42	81	0.19	7.75	6.20	0.43	2.02	0.27	19.00	14.33	35.62	-	30.8	100	6.6
2042	41/53/90	32.4	29.6	38.0	clay loam	-	-	0.30	0.01	34	54	0.23	7.80	6.45	0.63	3.01	0.21	17.94	14.36	35.52	-	33.2	100	9.1
2043	90-145	38.4	27.6	34.0	clay loam	-	-	0.14	0.02	50	45	0.23	7.75	6.55	1.35	1.99	0.20	16.69	12.67	31.55	-	30.4	100	6.5
6. TYPIC CHROMUSTERTS;POc2																								
1919	0-32	29.1	22.0	48.9	clay	-	-	1.26	0.18	66	257	0.76	8.25	6.50	0.14	0.44	0.82	36.99	10.72	48.97	-	47.2	100	0.9
1920	32-106	25.1	22.0	52.9	clay	-	-	0.49	0.08	42	155	0.48	8.20	6.70	0.20	1.92	0.57	32.99	13.65	49.13	-	45.2	100	4.2
1921	106-150	26.4	12.7	60.9	clay	-	-	0.12	0.03	84	109		8.40	6.70	0.69	7.42	0.59	29.13	17.08	54.04	-	46.8	100	15.5
7. TYPIC CHROMUSTERTS;I																								
2025	0-15/25	24.0	43.2	32.8	clat loam	-	-	1.50	0.17	67	257	0.73	7.95	6.65	0.32	0.62	0.69	21.13	10.74	33.18	-	28.0	100	2.2
2026	15/27-52	6.9	52.4	40.7	silty clay	-	-	0.68	0.08	36	141	0.30	7.35	6.60	0.88	2.30	0.45	18.54	14.46	35.75	-	32.4	100	7.1
2027	52-59/64	17.3	37.2	45.5	clay	-	-	0.47	0.11	42	86	0.36	7.05	5.95	1.53	3.61	0.38	14.06	16.93	34.98	-	28.4	100	12.7
2028	59/64-74/81	19.5	38.6	41.8	clay	-	-	0.43	0.04	24	41	1.02	6.50	5.40	1.99		0.19	14.20	14.60	28.99	-	32.4	89.5	
2029	74/81-94	31.4	36.1	32.5	clay loam	-	-	0.27	0.02	36	59	0.40	6.30	5.20	1.71		0.17	11.46	13.23	24.86	-	26.0	95.6	
2030	94-140	43.0	37.0	20.0	loam?	-	-	0.12		39	28	1.39	6.23	4.55	1.16	1.54	0.08	6.91	10.21	19.74	-	18.0	100	14.1
8.ENTIC CHROMUSTERTERTS;POc4																								
1887	0-15/18	25.1	22.0	52.9	clay	46.9 #	38.8	2.01	0.11	108	395	1.43	7.70	6.00	0.12	1.19	1.10	31.16	12.97	46.42	-	46.0	100	2.6
1888	15/18-57	23.1	16.0	60.9	clay	49.8	44.9	0.49	0.03	69	228	1.25	8.40	6.50	0.45	5.27	0.78	25.61	18.05	49.71	-	46.4	100	11.4
1889	57-120	23.1	16.0	60.9	clay	48.9 #	40.9	0.41	0.02	76	150	1.37	7.90	6.70	1.27	4.05	0.68	25.70	15.21	45.64	-	46.8	98	8.7
1890	120-150+	23.1	20.9	56.0	clay			0.20	0.01	151	150	1.36	7.50	6.50	3.99	2.93	0.62	25.30	17.10	45.95	-	44.4	100	6.6
9.TYPIC CHROMUSTERTS;POc5																								
853	0-35	30.5	24.0	45.5	clay	-	-	1.40	0.04	54	179	1.11	7.80	6.70	0.28	15.23	0.64	27.90	21.65	65.42	-	48.8	100	31.2
854	35-93	26.5	20.0	53.5	clay	-	-	0.39	0.06	34	81	1.55	7.90	6.80	4.53	16.98	0.34	22.26	27.70	67.28	-	47.2	100	36.0
855	93-140+	25.8	28.0	46.2	clay	-	-	0.18	0.03	23	118	6.59	8.30	7.40	4.90	13.50	0.58	45.84	21.70	81.62	-	42.8	100	31.5
10.TYPIC PELLUSTERTS;POc6																								
1823	0-30/35	39.1	16.0	44.4	clay	-	-	0.89	0.16	82	164	3.59	8.40	6.75	0.20	1.10	0.45	28.10	8.96	38.61	-	32.4	100	3.4
1824	30/35-65	35.1	14.0	50.9	clay	-	-	0.30	0.03	26	136	0.82	8.45	6.60	0.26	2.70	0.45	23.80	11.42	38.37	-	32.8	100	8.2
1825	65-105	37.1	10.0	52.9	clay	-	-	0.30	0.03	28	104	1.00	7.85	6.20	0.48	2.13	0.32	17.76	11.45	31.66	-	32.0	99	6.7
1826	105-125	49.1	18.0	32.9	sandy clay loam	-	-	0.16	0.02	121	90	1.25	7.10	6.10	0.96	1.64	0.25	23.71	9.24	34.84	-	30.4	100	5.4
1827	125+	69.1	12.0	18.9	sandy loam	-	-	0.05	0.02	200	72	1.71	7.30	5.40	0.42	0.88	0.17	9.12	6.11	16.28	-	14.0	100	6.3
11.LAQUIC CHROMUSTERTS;POc7																								
1734	0-30	24.4	28.7	46.9	clay	-	-	2.25	0.13	20	136	3.05	8.10	6.95	0.19	0.37	0.29	46.34	12.64	59.64	-	46.0	100	0.8
1735	30-70	24.7	52.7	52.9	clay	-	-	0.50	0.05	25	90	1.71	8.20	6.85	0.39	2.13	0.28	26.92	21.40	50.73	-	39.6	100	5.4
1736	70-125	24.4	24.7	50.9	clay	-	-	0.08	0.01	14	90	5.00	8.35	7.10	0.65	1.44	0.30	33.33	26.35	61.42	-	36.0	100	4.0
12.UDERTIC PALEUSTALFS;POd1																								
2095	0-11	22.0	45.3	32.7	clay loam	-	-	2.02	0.35	25	37	-	5.17	3.91	0.06	0.28	0.14	4.50	3.30	8.22	-	14.4	57.1	1.9
2096	11/22/30	13.1	37.2	49.8	clay	-	-	0.94	0.22	15	54	-	4.65	3.41	0.06	0.58	0.21	3.20	3.50	7.49	-	21.6	34.7	2.7
2097	22/30-62/72	12.3	41.8	45.9	silty clay	-	-	0.52	0.16	11	63	-	4.39	2.97	0.10	2.09	0.33	3.50	4.10	10.02	-	26.4	38	7.9
2098	62/72-120+	10.6	43.3	46.1	silty clay	-	-	0.46	0.17	17	37	-	3.85	2.82	0.36	4.61	0.25	4.50	5.76	15.12	-	28.8	52.5	16.0

Table D-7 PHYSICAL PROPERTIES OF MAJOR SOIL SERIES

Soil Series (Map Symbol)	Location	Sampling Depth (cm)	Thickness of Soil Layer (cm)	Bulk Density (g/cm3)	Solid Phase (%)	Void Ratio (%)	Field Moisture		pF 2.0		pF 4.2		Available Water (mm)	
							wt %	vol %	wt %	vol %	wt %	vol %	Per soil layer	Accumu-lation
1 Caymanas clay loam	Caymanas Estate	10	0 -20	1.17	44.2	55.8	-	-	34.2	40.0	4.7	5.5	69.0	69.0
(PRb1)	Horticulture Centre	30	20-40	1.05	39.6	60.4	-	-	39.2	41.2	5.9	6.2	70.0	139.0
		50	40-60	1.09	41.1	58.9	-	-	43.9	47.9	5.6	6.1	83.6	222.6
2 Dawkins clay loam	Bernard Lodge Estate	10	0 -20	1.42	53.6	46.4	-	-	28.0	40.0	3.4	4.8	70.4	70.4
(PRb2)		30	20-40	1.29	48.7	51.3	-	-	22.4	28.9	3.2	4.1	49.6	120.0
		50	40-60	1.43	54.0	46.0	-	-	27.2	38.9	3.3	4.7	68.4	188.4
3 Whim clay loam	Spring Village	10	0 -20	1.25	47.2	52.8	4.3	5.4	31.1	38.9	4.3	5.4	67.0	67.0
(PRb3)		30	20-40	1.30	49.1	50.9	17.5	22.8	35.0	45.5	4.3	5.6	79.8	146.8
		50	40-60	1.34	50.9	49.1	23.4	31.4	38.8	52.0	5.1	6.8	90.4	237.2
4 Lodge clay	Brompton Farm	10	0 -20	1.29	48.7	51.3	13.8	17.8	37.3	48.1	23.7	30.6	35.0	35.0
(POc1)		30	20-40	1.25	47.2	52.8	9.3	11.6	33.9	42.4	19.4	24.3	36.2	71.2
		50	40-60	1.56	58.9	41.1	11.2	17.5	38.3	59.8	27.7	43.2	33.2	105.4
5 Churchpen clay	Innswood Estate	10	0 -20	1.20	45.3	54.7	9.7	11.6	38.8	46.6	7.2	8.6	76.0	76.0
(POc2)		30	20-40	1.39	52.5	47.5	32.8	45.6	47.1	65.5	11.6	16.1	98.8	174.8
		50	40-60	1.39	52.5	47.5	29.8	41.4	45.9	63.8	15.9	22.1	83.4	258.2
6 Bodles clay	Bodles Agriculture	10	0 -20	1.18	44.5	55.5	14.9	17.6	35.5	41.9	29.5	34.8	14.2	14.2
(POc3)	Station	30	20-40	1.44	54.3	45.7	15.8	22.6	43.0	61.9	38.7	55.7	12.4	26.6
		50	40-60	1.56	58.9	41.1	10.9	17.0	40.4	63.2	34.5	53.8	18.8	45.4
7 Salt Island clays	Amity Hall	10	0 -20	0.96	36.2	63.8	27.6	26.5	42.5	40.8	31.3	30.1	21.4	21.4
(POc5)		30	20-40	1.28	48.3	51.7	29.3	37.5	48.5	62.1	42.9	54.9	14.4	35.8
8 Sydenham clay	McCooks Pen	10	0 -20	1.34	50.6	49.4	20.1	26.9	46.1	61.8	36.9	49.5	24.6	24.6
(POc6)		30	20-40	1.32	49.8	50.2	30.1	39.7	47.9	63.2	36.8	48.6	29.2	53.8
		50	40-60	1.29	48.7	51.3	30.9	39.9	48.8	63.0	39.9	51.5	23.0	76.8
9 Whim clay loam	Colbeck	10	0 -20	1.36	51.3	48.7	8.5	11.6	32.5	44.2	14.1	19.2	50.0	50.0
(PRb3)		30	20-40	1.35	50.9	49.1	8.1	10.9	33.1	44.7	15.2	20.5	48.4	98.4

TABLE D-8 INTAKE OF MAJOR SOIL SERIES UNDER VARIOUS LAND USE

Site No.	Soil Series (Map symbols)	Land Use	D = C x T^n (mm)	I = C x nT^(n-1) (mm/min)	IB (mm/hr)	Measured Soil Layer	Infiltra-tion
2	Caymanas clay loam (PRb1)	Ornamental trees	D1=32T0.656	I1=21T-0.344	202.00	Surface	very rapid
			D2=15T0.776	I2=11.6T-0.224	233.00	Surface	
			D3=18.5T0.744	I3=13.8T-0.256	227.00	Surface	
				Average	221.00	(Surface)	
1	Dawkins clay loam (PRb2)	Vegetable	D1=9.4T0.292	I1=2.56T-0.728	1.80	Surface	rapid
			D2=14.4T0.368	I2=5.30T-0.632	7.50	Surface	
			D3=20.0T0.472	I3=9.44T-0.528	2,271.00	Surface	
				Average	12.00	(Surface)	
3	Whim clay loam (PRb3)	Vegetable	D1=8.9T0.40	I1=3.56T-0.60	6.20	Surface	moderate
			D2=12T0.40	I2=4.80T-0.60	8.40	Surface	
			D3=7.9T0.32	I3=2.53T-0.68	2.60	Surface	
				Average	5.70	(Surface)	
7	Lodge clay (POc1)	Mango	D1=3.6T0.36	I1=1.3T-0.64	1.70	Surface	moderate
			D2=2.6T0.496	I2=1.3T-0.504	4.40	Surface	
			D3=1.1T0.656	I3=0.72T-0.344	7.00	Surface	
				Average	4.40	(Surface)	
4	Churchpen clay (POc2)	Sugar cane	D1=26.5T0.704	I1=1.87T-0.296	24.00	Surface	rapid
			D2=12T0.60	I2=7.2T-0.4	48.00	Surface	
			D3=2.1T0.40	I3=0.84T-0.6	1.50	subsurface	slow
				Average	38.00	(Surface)	
6	Bodles clay (POc3)	Improved pasture	D1=8.2T0.528	I1=4.33T-0.472	18.00	Surface	rapid
			D2=12T0.520	I2=6.24T-0.48	25.00	Surface	
			D3=3.7T0.36	I3=1.331-0.64	1.80	subsurface	slow
				Average	21.00	(Surface)	
5	Salt Island clay (POc5)	Rice paddy	D1=1.0T0.152	I1=0.152T-0.848	0.05	Surface	very slow
			D2=2.4T0.192	I2=0.46T-0.808	0.18	Surface	
			D3=3.0T0.312	I3=0.94T-0.688	0.90	Surface	
				Average	0.40	(Surface)	
8	Sydenham clay (POc6)	Sugar cane	D1=1.05T0.416	I1=0.44T-0.584	0.86	Surface	very slow
			D2=2.1T0.216	I2=0.50T-0.784	0.24	Surface	
			D3=2.1T0.256	I3=0.54T-0.744	0.40	Surface	
				Average	0.40	(Surface)	

Table D-9 AREAS OF EACH LAND CAPABILITY CLASS IN THE STUDY AREA

For Upland Crops		For Rice	
Classes	Extent (ha)	Classes	Extent (ha)
1. Arable Land		1. Arable Land	
I	5,070	IIp	10,810
IIw	810	IIIl	810
IIpw	9,080	IIIps	1,760
IIpe	50	IVl	150
IIIwp	1,960	Sub-total	13,530
IIIsa	1,120	2. Limited Arable Land	
IVsa	790	VI	5,070
Sub-total	18,880	Vsa	2,160
2. Limited Arable Land		Vp	280
Vsa	2,160	Sub-total	7,510
Vde	40	3. Non-arable Land	
Sub-total	2,200	VI	6,400
3. Non-arable Land			
VI	6,360		
4. Total	27,440	4. Total	27,440

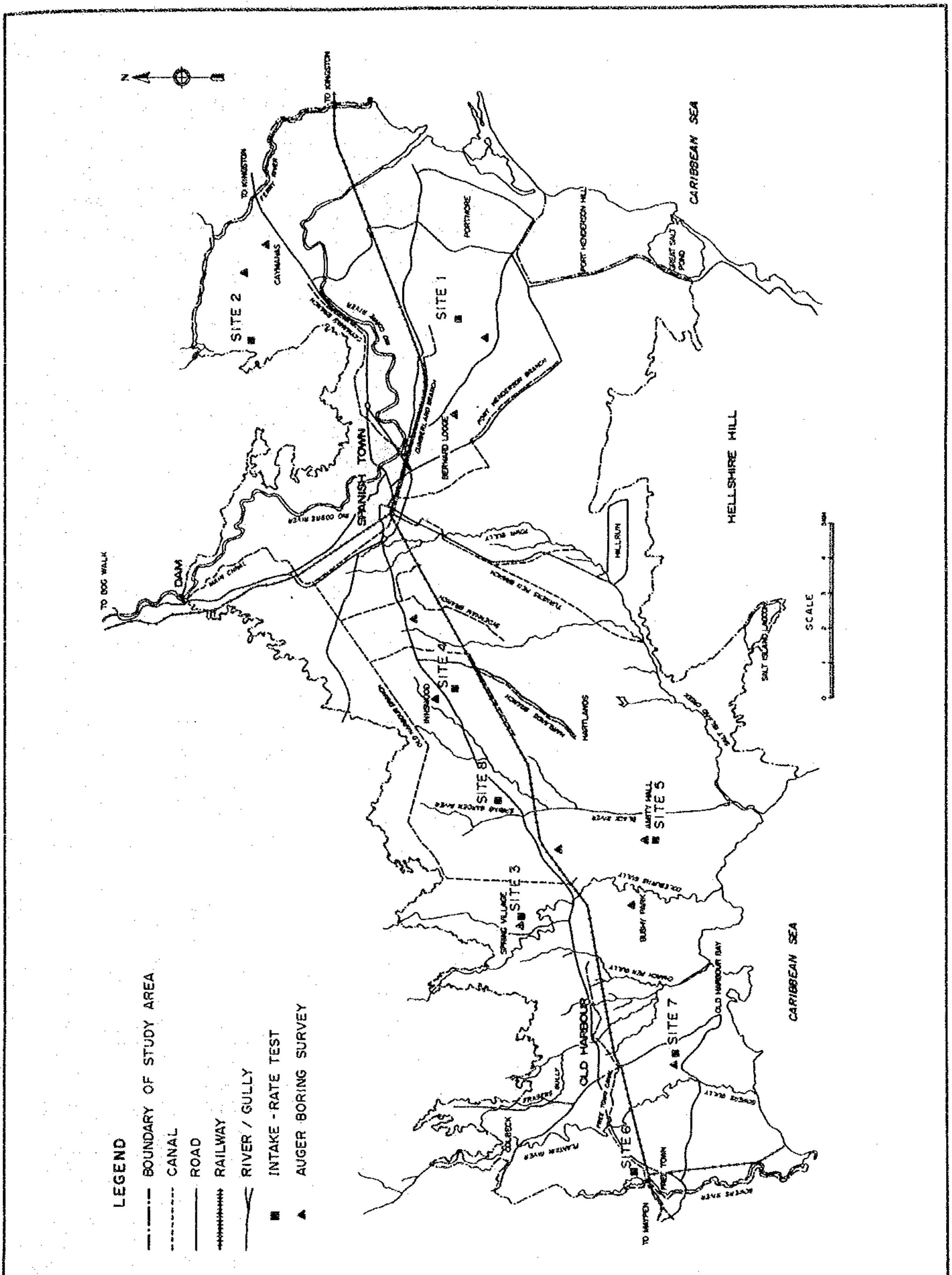
Table D-10 SUITABILITY RATINGS OF THE VARIOUS MAPPING UNITS FOR THE PRODUCTION OF IRRIGATED CROPS FOR ST. CATHERINE COASTAL PLAIN

Map Symbol	Soil Name	Area (ha)	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Physiographic Position	Family Particle Size Class (25-100cm)	Drainage Class	Inherent Fertility	Major Limitation	Land Capability Classification
1. Soils formed on recent river alluvium																							
PRb1	Caymanas clay loam-loam	2,660	1	1	1	3	1	1	1	2	1	1	1	1	1	2	1	level slightly concave	fine silty	well drained	high	none	I
PRb2	Dawkins sandy loam-loam	1,350	1	1	1	3	1	1	1	1	1	2	1	1	1	3	1	level towards sharp	coarse loamy	well drained	high	none	I
PRb3	Whim clay loam	1,060	1	1	1	3	1	1	1	2	1	1	1	1	1	2	1	higher terraces	fine clayey	well drained	high	none	I
PRb4	Ferry silty clay	810	1	1	1	2	1	1	1	3	1	1	1	1	1	1	1	lower slopes	fine clayey	moderately well	high	wetness	IIw
PRb4/sa	Ferry silty clay,																						
	saline-sodic phase	150	2	1	1	3	1	2	1	4	2	1	1-2	2	1	1	2	lower slopes	fine clayey	imperfectly	high	sodicity/salinity	IIIsa
2. Soils formed on old marine alluvium																							
POc1	Lodge clay	1,540	1	1	1	1	1	2	1	3	2	1	1	2	1	1	2	slighty concave	fine clayey	imperfectly,well	medium-high	workability	IIpw
POc1/sa	Lodge clay,																						
	saline-sodic phase	220	2	2	1	2	1	3	1	4	2	1	1-2	2	1	1	2	lower slopes,	fine clayey	imperfectly,well	medium	salinity/sodicity	IIIsa
POc2	Churchpen clay	5,430	1	1	1	1	1	2	1	3	2	1	1	2	1	1	2	level	fine clayey	imperfectly	medium-high	workability	IIpw
POc2/sa	Churchpen clay,																						
	saline-sodic phase	100	2	1	1	2	1	3	1	4	2	1	1-2	2	1	1	3	lower slopes	fine clayey	imperfectly	medium	salinity/sodicity	IIIsa
POc3	Bodies clay	490	2	1	1	1	1	2	1	3	1	1	1	2	1	1	2	slightly concave	fine clayey	imperfectly	medium	wetness	IIIwp
POc4	Horse Cave clay	790	3	2	2	2	2	3	3	4	3	2	2	3	2	2	3	lower slopes	fine clayey	imperfectly	medium	salinity/sodicity	IVsa
POc5	Salt Island clay	2,160	3-4	4	2-3	3	3	4	3-4	4	4	3	3	4	3-4	2-3	4	lower slopes,	fine clayey	imperfectly	medium	salinity/sodicity	Vse
POc6	Sydenham clay	1,880	1	1	1	1	1	2	1	3	2	1	1	2	1	1	2	slightly concave	fine clayey	imperfectly	med-high	workability	IIpw
POc6/sa	Sydenham clay,																						
	salin-sodic phase	650	2	1	1	2	1	3	1-2	4	2	1	1	2	1	1	3	concave	fine clayey	imperfectly	medium	salinity/sodicity	IIIsa
POc7	Springfield clay	1,470	2	2	1	1	1	3	1	4	2	1	2	2	3	1	3	slight depressions	fine clayey	well	medium	wetness	IIIwp
POd1	Colbeck Clay	50	2	1	1	3	1	2	1	3	1	2	1	2	1	3	1	upper part low ridges	fine clayey	well	medium-low	workability/erosion	IIpe
POA	Colbeck-Bodles complex	230	2	1	1	3	1	2	1	3	2	2	1	2	2	3	2	undulating	fine clayey	imperfectly	medium-low	wetness/workability	IIpw
3. Soils formed on limestone																							
HLC1	Rockland-Hellshire complex	60	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	Upper part	loamy skeletal	excessively		N/A	VI
HLC2	Union Hill, ustic variant-	40	3	4	4	4	3	3	2	4	3	3	2	2-3	2	4	4	Upper part	clayey skeletal	somewhat			
*)	Fellowship complex																			excessively		depth/erosion	Vde
4. Soils formed on recent marine alluvium																							
TMX1	"Saline" undifferentiated	620	4	4	3-4	4	4	4	4	4	4	4	4	4	4	4	4	flat					VI
TMX2	"Mangrove" undifferenciated	910	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	flat					VI

Remarks: A : Sugarcane, B : Bananas, C : Coconut, D : Rice, E : Sorghum, F : Groundnuts, G : Cassava, H : Virginia Tobacco, I : Sunflower, J : Cotton, K : Improved Pressure, L : Vegetables, M : Sisal, N : Fish Farming, O : Soyabean, maize

Crop Suitability Ratings; 1 : highly suitable 2 : moderately suitable 3 : marginally suitable 4 : not suitable

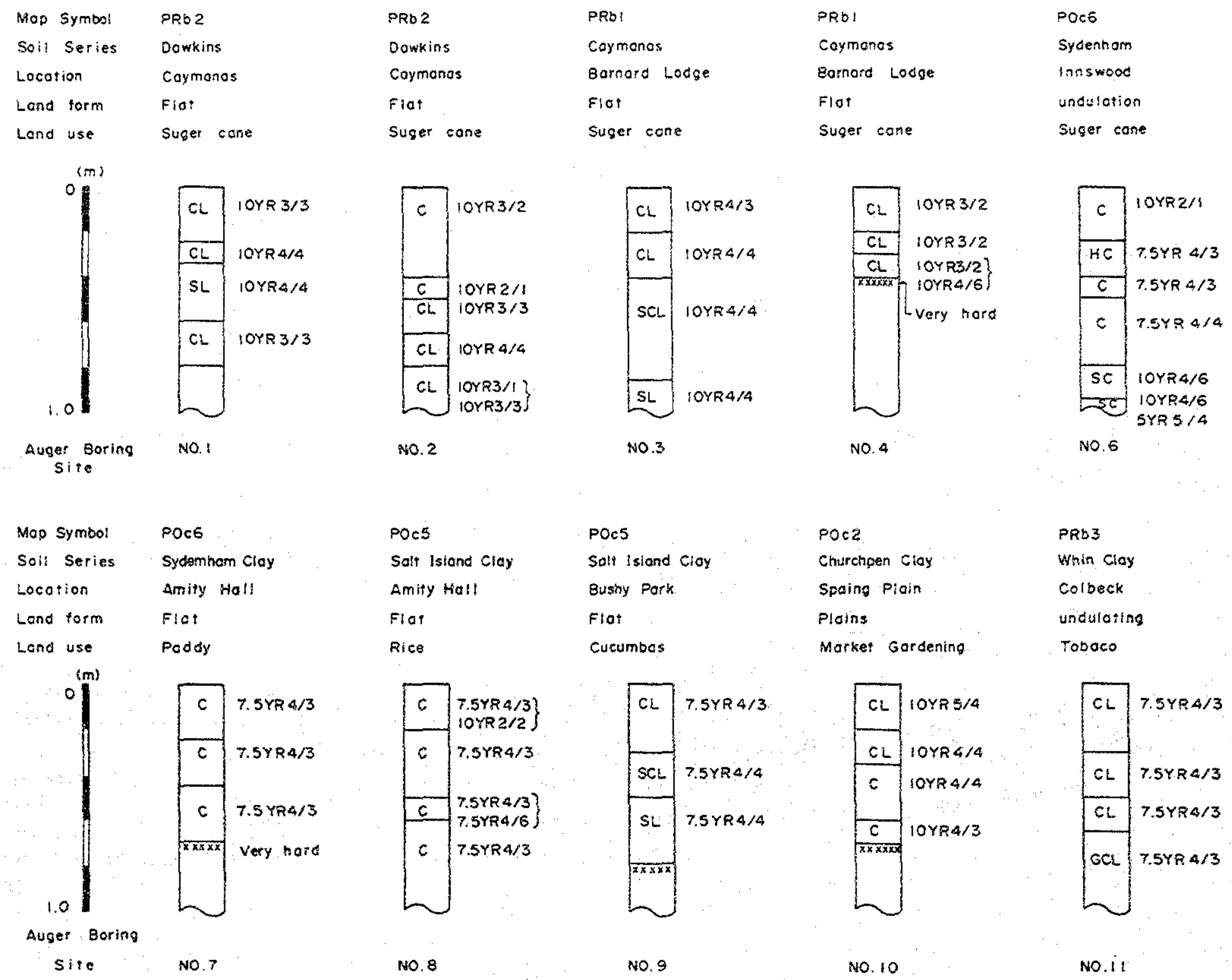
Source : Land Capability Classification in St. Catherine Plains, Soil Survey Unit, Rural Physical Planning Division, MOA, JAMAICA



THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

Fig. D-1
LOCATION OF SURVEY SITES OF INTAKE-RATE TEST

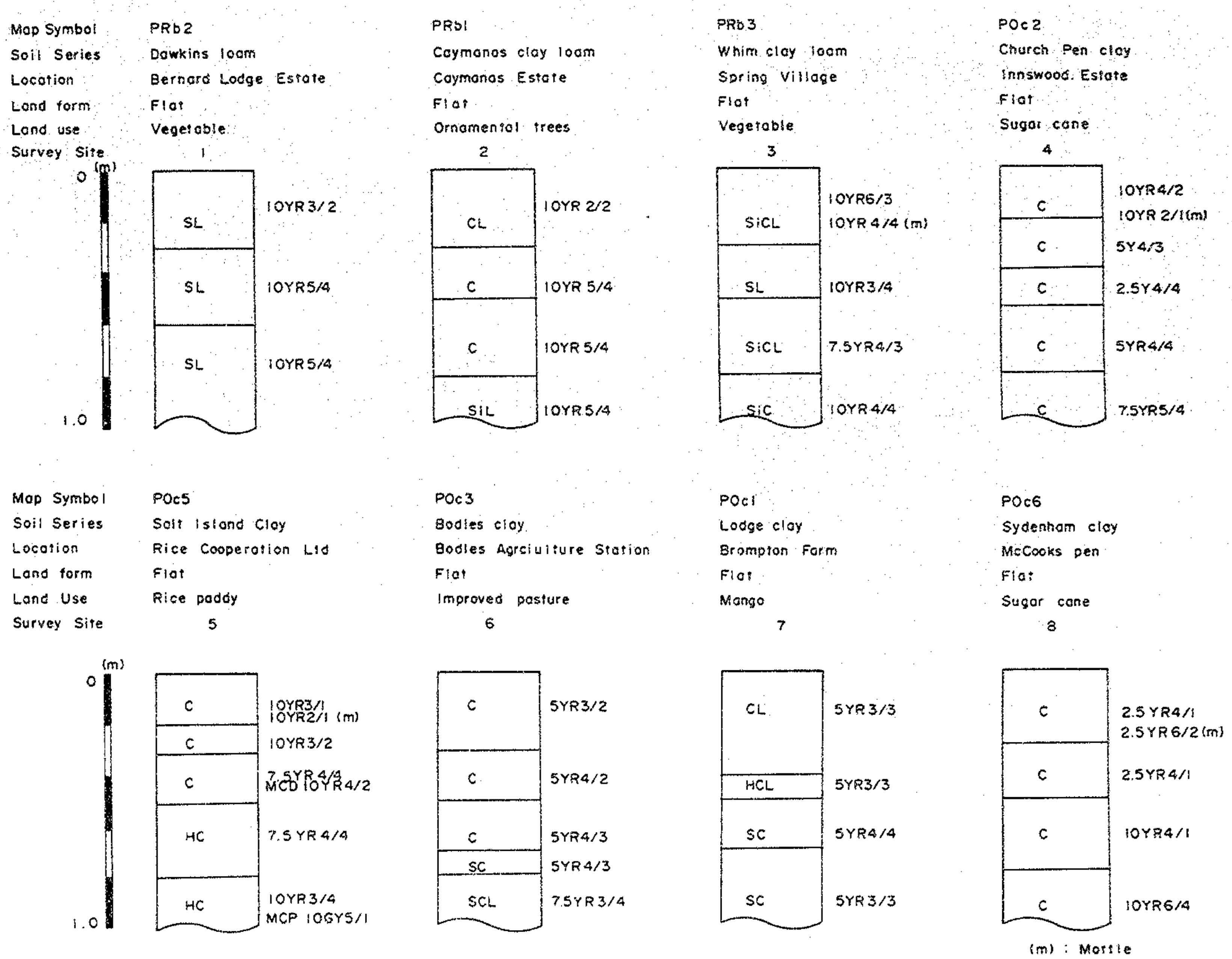
JAPAN INTERNATIONAL COOPERATION AGENCY



THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

Fig. D-2
SOIL PROFILE DIAGRAM OF THE STUDY AREA

JAPAN INTERNATIONAL COOPERATION AGENCY



THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

Fig. D-3
SOIL PROFILE DIAGRAM AT THE SURVEY SITES OF INTAKE-RATE TEST

JAPAN INTERNATIONAL COOPERATION AGENCY

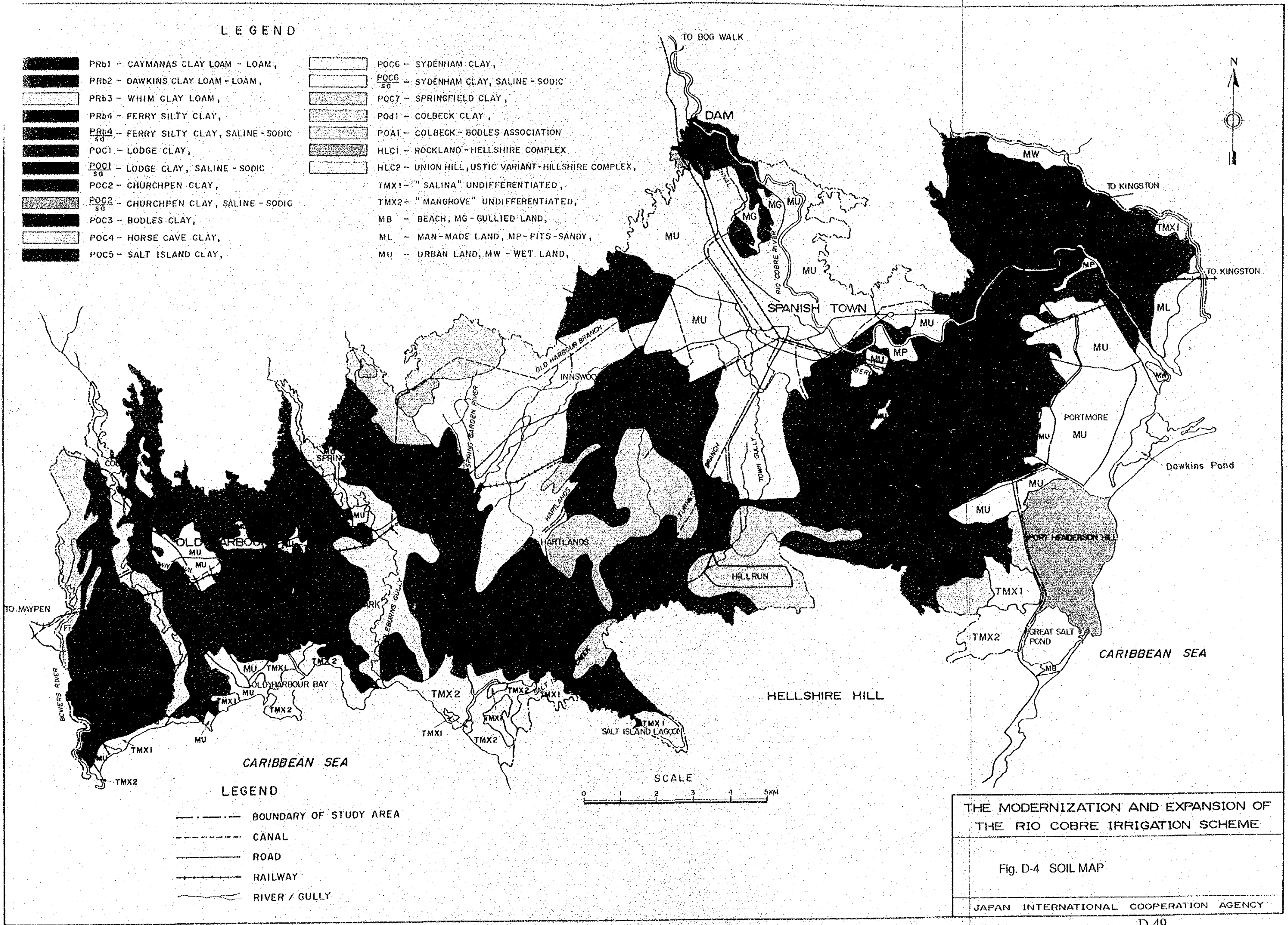
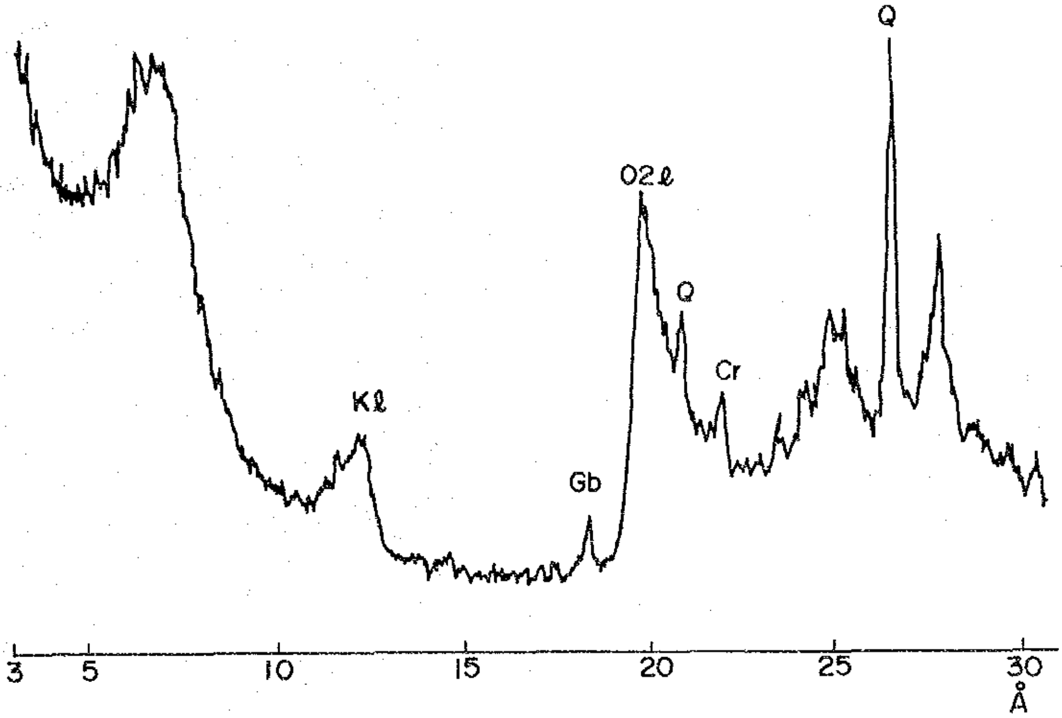
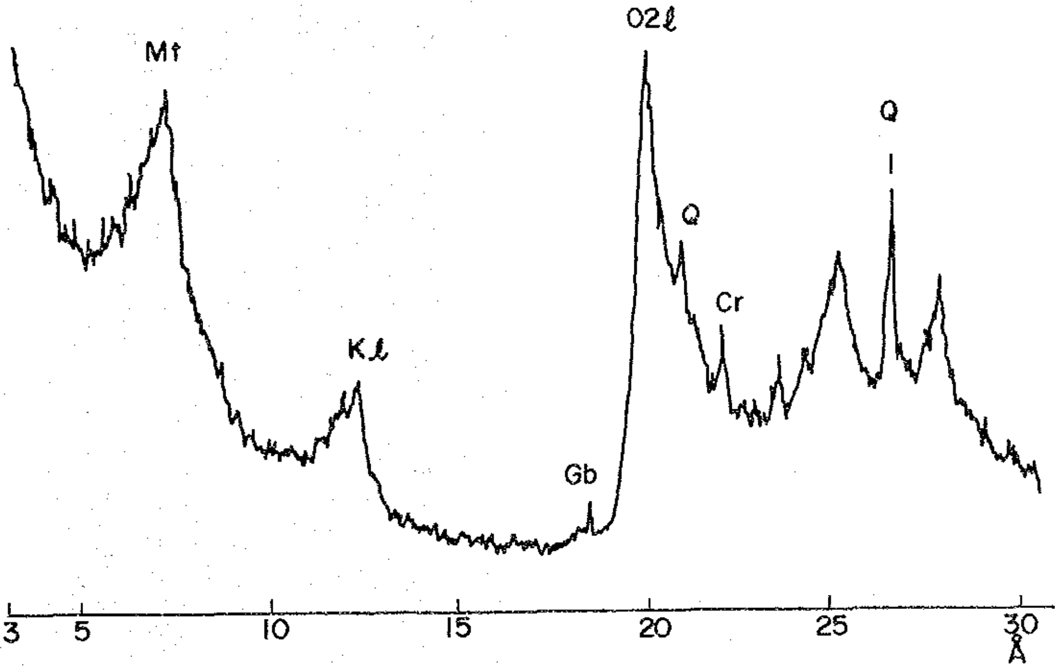


Fig. D-4 SOIL MAP

(1) Caymanas Loam Soils (PRb1)



(2) Paddy Soils in Amity Hall (POc5)



REGEND

Mt : Montomorillonite

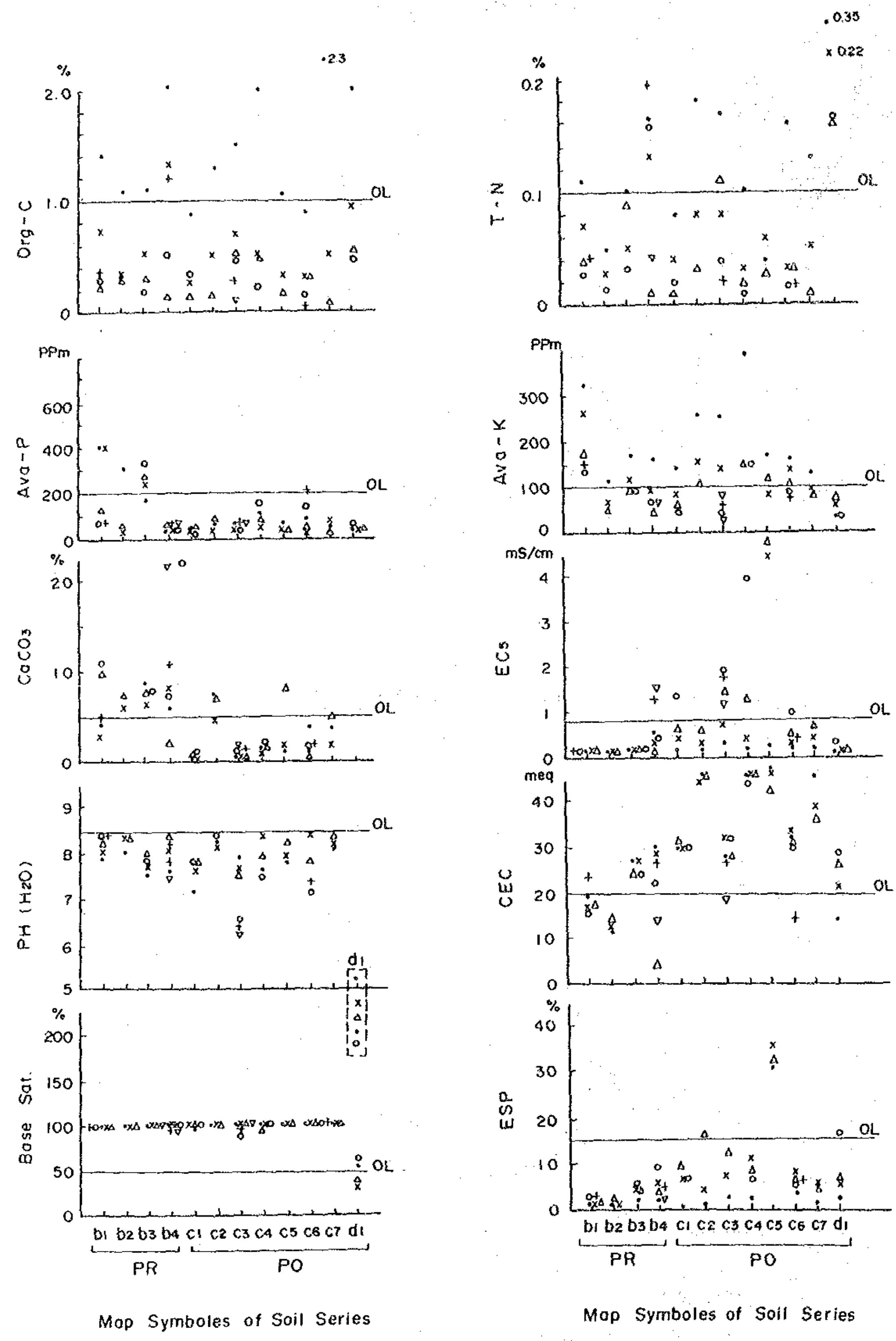
Kℓ : Kaolinite

Gb : Gibbsite

Q : Quartz

Cr : Cristballite

THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME
Fig. D-5 X-RAY DIFFRACTION PATTERNS OF THE SOILS
JAPAN INTERNATIONAL COOPERATION AGENCY



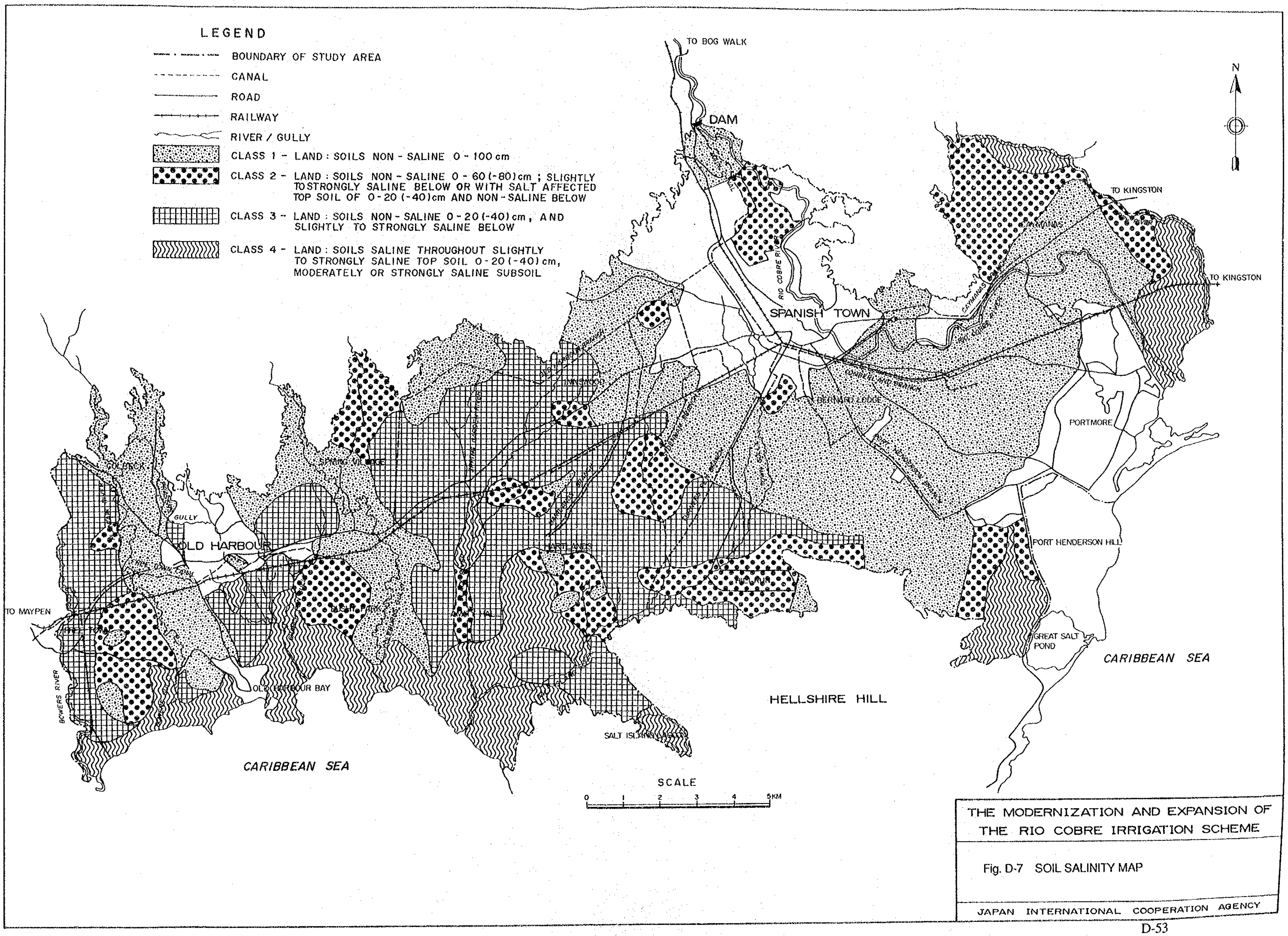
Legend

- • 1st Layer
- x 2nd "
- Δ 3rd "
- o 4th "
- \+ 5th "
- ▽ 6th "
- OL Optimum Level

THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

Fig. D-6
SOIL CHEMICAL PROPERTIES OF TYPICAL SOIL SERIES IN THE STUDY AREA

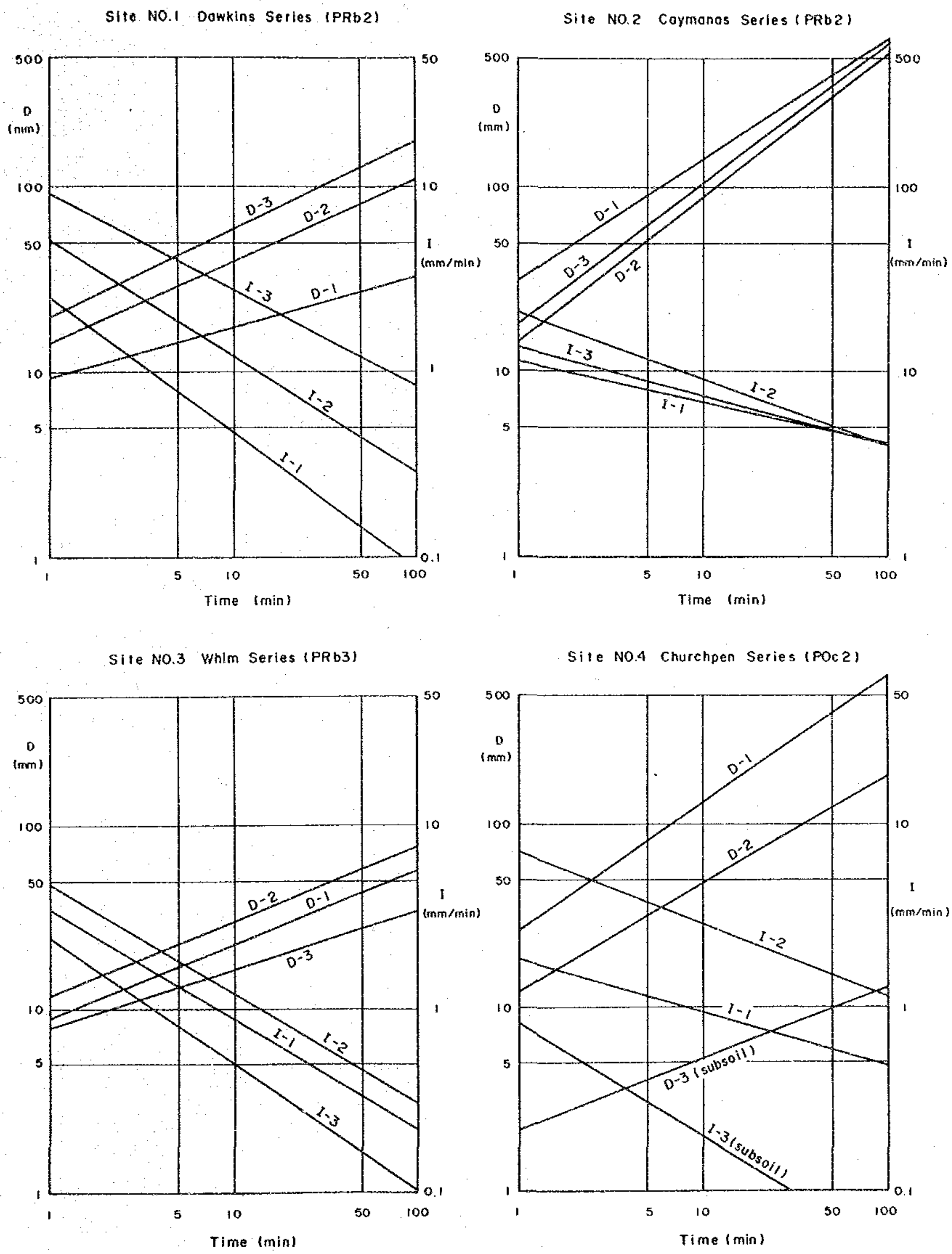
JAPAN INTERNATIONAL COOPERATION AGENCY



THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

Fig. D-7 SOIL SALINITY MAP

JAPAN INTERNATIONAL COOPERATION AGENCY



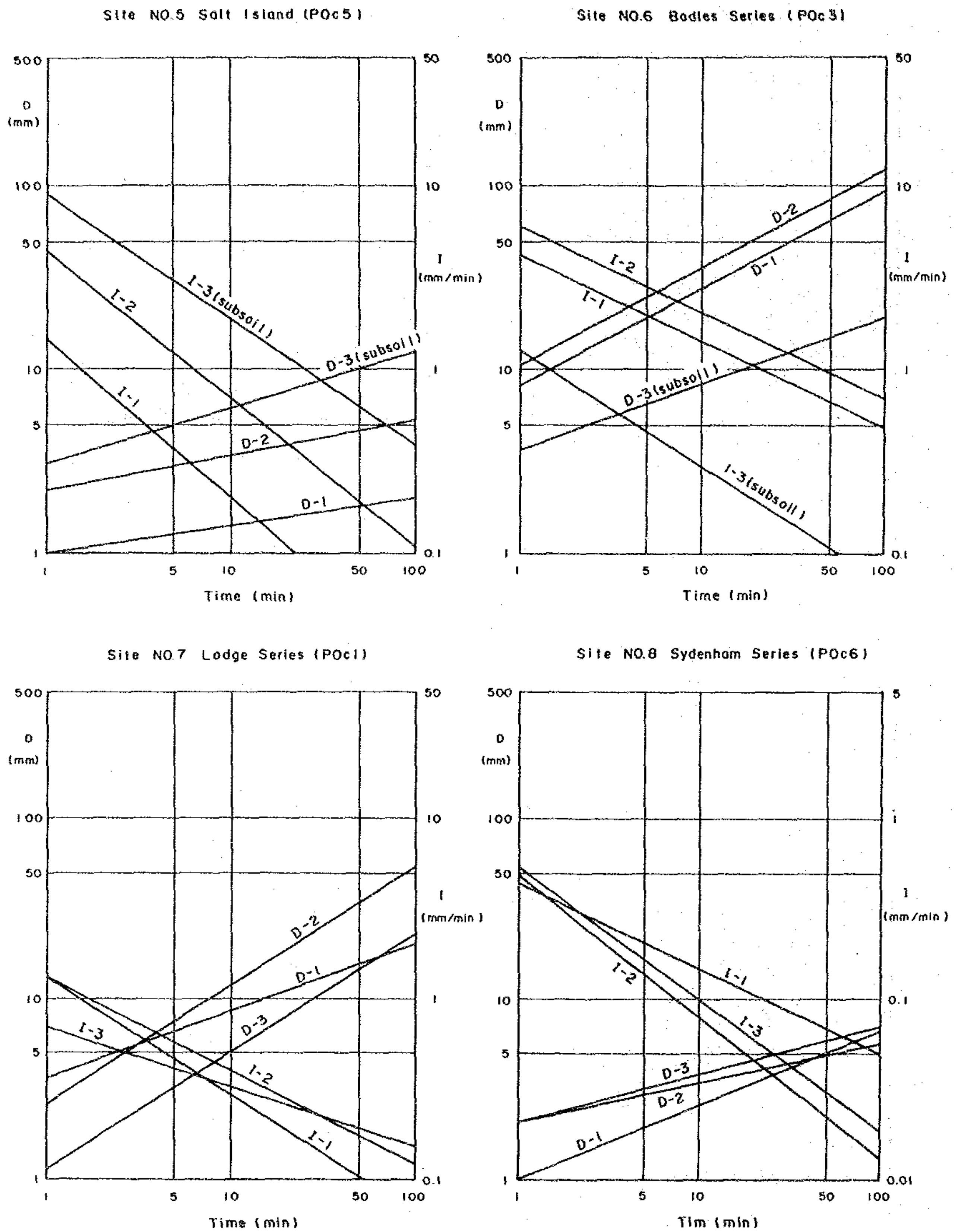
D: Cumulatively infiltration (mm)

I: Intake-rate (mm/min)

THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

Fig. D-8 (1/2)
INTAKE-RATE OF THE SOILS

JAPAN INTERNATIONAL COOPERATION AGENCY



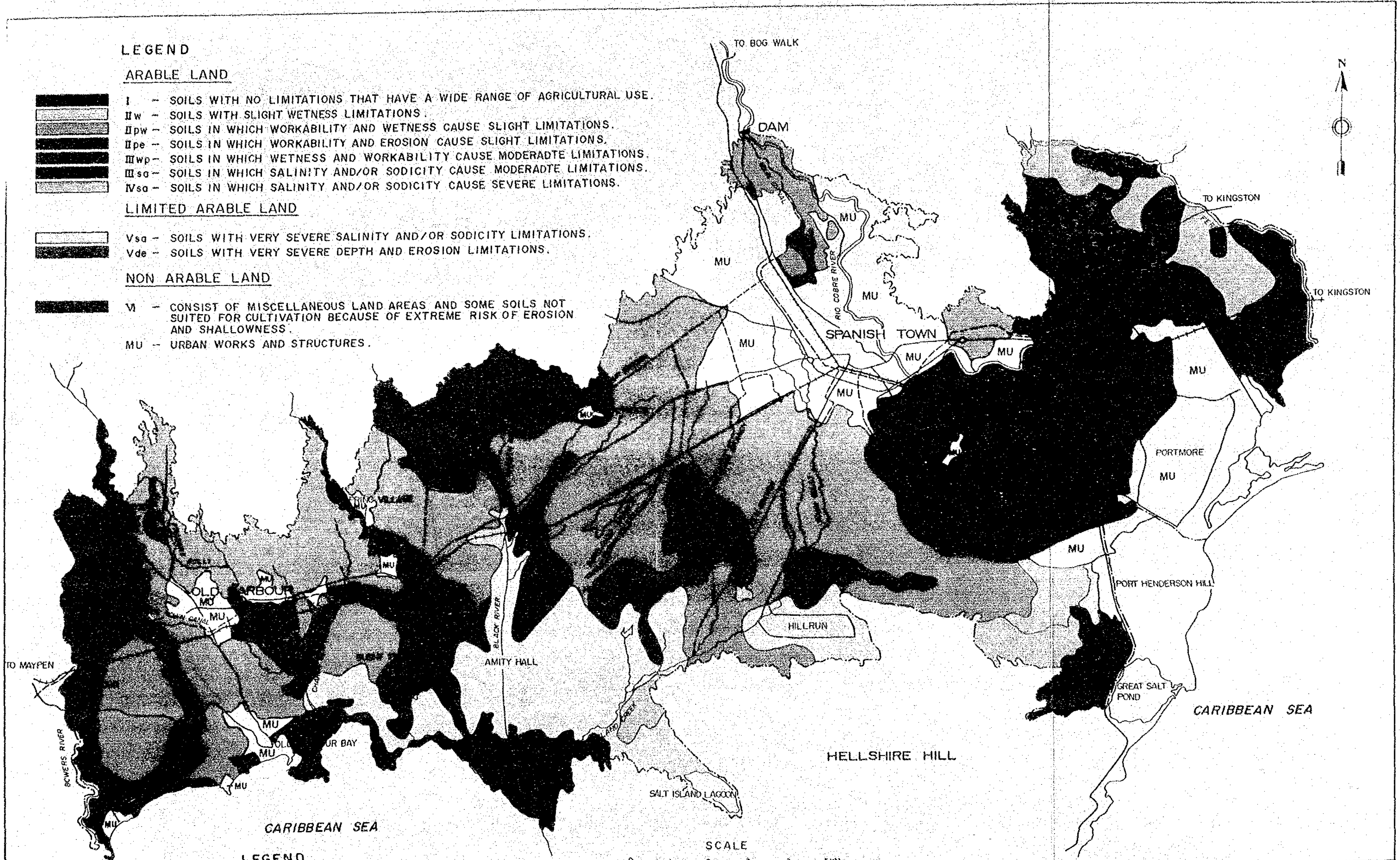
D: Cumulatively infiltration (mm)

I: Intake-rate (mm/min)

THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

Fig. D-8 (2/2)
INTAKE-RATE OF THE SOILS

JAPAN INTERNATIONAL COOPERATION AGENCY



THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

Fig. D-9
LAND CAPABILITY MAP FOR UPLAND CROPS

JAPAN INTERNATIONAL COOPERATION AGENCY

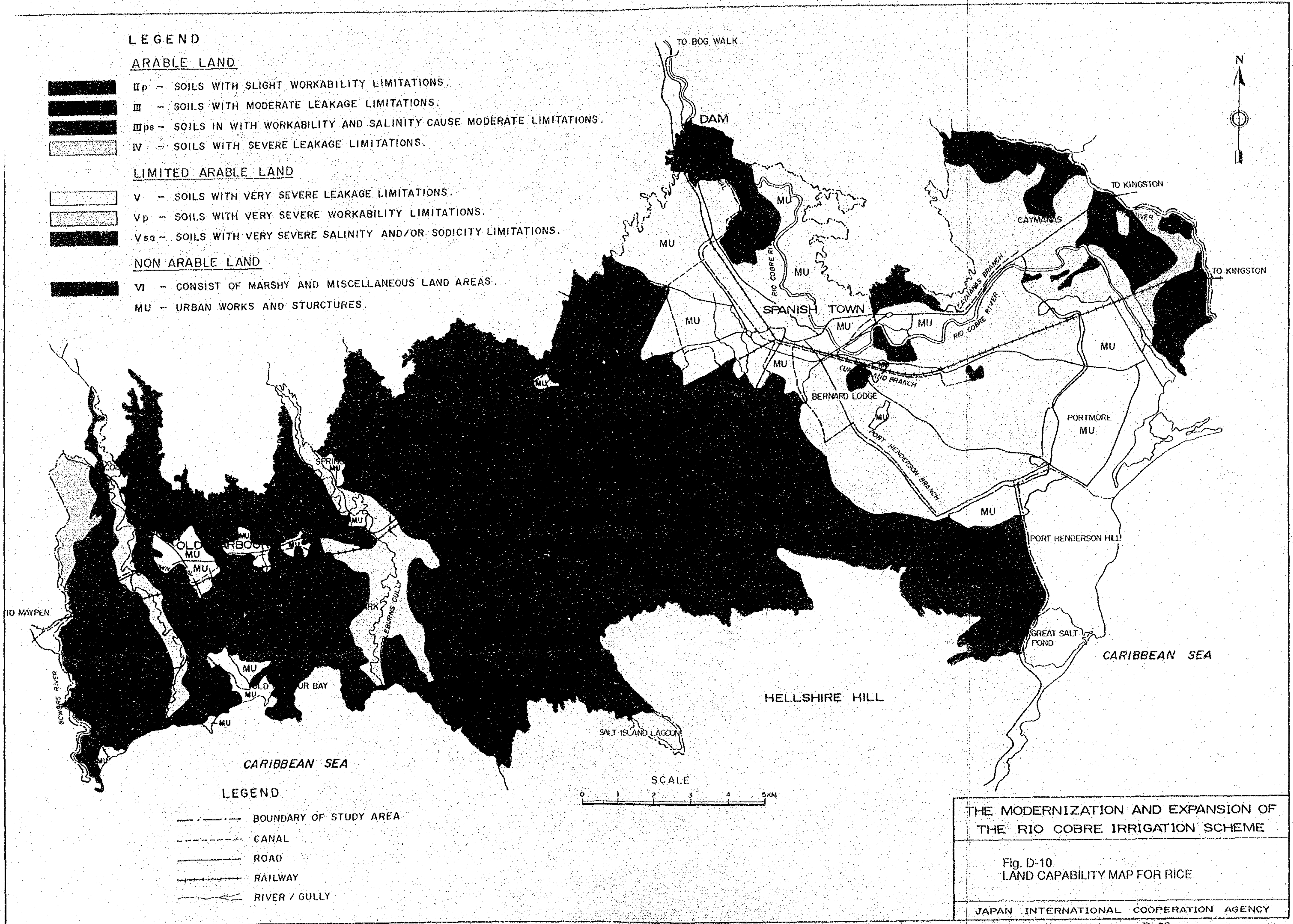


Fig. D-10
LAND CAPABILITY MAP FOR RICE

ANNEX - E

SOIL MECHANICS

ANNEX-E

SOIL MECHANICS

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LIST OF FIGURES

1. GENERAL

In the soil mechanical survey of the project area, four physiographic units were observed in the Rio Cobre Basin: Central inlier, Limestone uplands, Inland basins and coastal plains.

(1) The Central inlier covers the uplands underlain by shales, conglomerates and volcanics along the north-east section of the basin and the strongly undulated rocks in this area. The north-west ridges of the area are underlain by and esitic volcanics of Cretaceous age which during inundation periods have been supplying the Bowers Gully with raw materials forming aggregates.

(2) The Limestone uplands is the largest single physiographic unit in the basin enfolding interior basins and extending from the central plateau to north of the coastal plains of the basin.

(3) The Inland basins comprise two major interior basins, St. Thomas and Lluidas Vale which are surrounded by limestone hills of 150 to 600 m in height above the basins.

(4) The coastal plains in which most of the study area is located, vary from sea level to some 40 m in elevation at the northern parts. The area comprise two distinct zones.

    (a) The old alluvial area, found mostly in the western parts of the plains from Spanish Town to Old Harbour area, has been deposited on a base of karstified limestone stratum. Therefore, there are considerable variations in thickness from a few to several hundred feet. In profile it consists of coarse and fine sand, silt, clay, and these mixed texture.

    (b) The recent alluvial area, found in the eastern parts of the plains, includes soils developed over the recent gravelly alluvium. Due to intermittent sedimentation from the Rio Cobre, surface soils in this area are of loamy to sandy texture and excessively well drained.

2. PROGRAMME OF WORKS

Investigation of materials and foundations for the construction of structures of the project such as earth, concrete, reservoir dikes, etc., were conducted in the field and at laboratories in Kingston from August to October in 1986. At the stage of reconnaissance survey, proposed quarry sites, borrow areas and reservoirs, where possible within the study area, were given priority for evaluation, Fig. E-1 and E-2 show the location of the proposed sites and of the field investigations.

(1) Foundation of reservoirs

Two proposed reservoirs were selected for examination of foundations and soil materials. These were Town Gully Reservoir in Bernard Lodge Estate and Black river Reservoir in Innswood Estate. The investigation was carried out in the following ways.

(a) Town gully reservoir

- Five (5) Bore holes of 15 m depth with standard penetration tests every 1.5 m
- Five (5) Test pits of 2 m depth for sampling
- Insitu permeability tests at two (2) pits selected from the above five

(b) Black river reservoir

- Three (3) Bore holes of 10 m depth with standard penetration tests every 1.5 m
- Five (5) Test pits of 2 m depth for sampling
- Insitu permeability test at two (2) pits selected from the above five

(2) Aggregates

Four locations were selected as proposed quarry sites, one inside and the others outside of the study area. These are:

(a) Plantain river at Colbeck in St. Dorothy
(b) Rio Minho river at May Pen
(c) Hope river at Kingston
(d) Rio Cobre river near Spanish Town

The items subjected to laboratory tests were: (i) Gradation, (ii) Specific Gravity, (iii) Durability, (iv) Abrasion, (v) Dry rodded density, and (vi) Shore hardness to limestone.

(3) Soil material

Soil materials for embankments of canals and reservoirs investigated were as follows:

(a) Location of borrow pits

- Angels Pen
- Bellevue Heights
- Thetford Hill
- White Marl
- Rhodens Pen
- Mount Gotham
- Town Gully Reservoir
- Black river Reservoir

(b) Items of laboratory test

- Specific gravity
- Field moisture
- Unit density
- Grain size analysis
- Consistency
- Permeability
- Compaction
- Compression
- Consolidation

3. INVESTIGATIONS AND LABORATORY TESTS

3.1 Foundation of Reservoirs

3.1.1 Town gully reservoir

(1) Location and dimension of reservoir

The proposed reservoir is located adjacent to Spanish Town between the Town Gully and the Port Henderson branch and to be constructed as a type of square pond encircled by a levee or dike on a flat plain with the following dimensions:

Dam height	:	10.0 to 4.2 m
Reservoir area	:	200 ha (2.0 km^2)
Storage capacity	:	9.6 (million m^3)

The area belongs to the Rio Cobre alluvial fan sloping rather steeply at more or less 1/500. The depth of the alluvium varies from a few to several hundred feet in depth and consists of layers of gravels, coarse to fine sand, silt and clay or a mixture of these materials in a sort of unity or interbeded caused by the position and flow conditions of previous stream channels. There are two (2) distinct subsoil strata in the Rio Cobre alluvium the old alluvium and the recent alluvium, of which the former has rather impervious subsoils and the latter previous. The boundary of these subsoil strata is considered to be located along the Port Henderson branch with the recent alluvium to eastward and the old alluvium to westwards. The reservoir is sited on the old alluvium side in order to avoid excessive seepage losses through the bed of the reservoir.

(2) Results of investigations and laboratory tests

Five (5) bore holes were drilled in the reservoir area. Four (4) holes at the corners and one (1) hole at the centre each 15 m deep with Standard Penetration Tests at 1.5 m intervals. The bore hole logs show that the substrata of the reservoir consist of layers from medium to fine sand, silt and clay or a mixture of ununiformed thickness. On the whole, clay layers dominate the subsoils occupying about 70%, the remaining 30% being sandy soil. There is a tendency towards increasing sandy layers in the subsoils as they gets close to the border with the recent alluvium for bore hole B1 log and test pit P1 profile show 50% content of each layer. (see Fig. E-3 to E-5) About the density of the subsoils though the specific gravities of the soils range from 2.38 to 2.62 which are slightly below normal, the dry densities range from 1,331 to 1,879 g/cc averaging 1,570 g/cc which is a comparatively high density. (see Table E-1) Concerning the bearing strength of the subsoils, the N values of Standard Penetration Tests range from 13 to 27 in sandy soils and from 13 to 22 in clayey soils which, as represented by Dr. Terzaghi, shows that the sandy soils are medium dense having 35° to 40° of internal friction angle and the clayey soils are stiff having about 26 ton/m^2 of allowable bearing capacity. (see Table E-3 and E-4) The increased stress in the substrata caused by the new embankment of the 10 m high dam will be approximately $q = 17$ ton/m^2 at 5 m depth,

$q = 15$ ton/m^2 at 10 m depth, $q = 10$ ton/m^2 at 30 m depth so that there will be no problem with the bearing capacity of the substrata of the reservoir.

Concerning the permeability of the substratum, insitu permeability tests were applied at test pit P1 at 1.0 m depth, and P5 at 2.0 m depth with a hole of 0.6 m diameter, 0.6 m depth. The measured permeability coefficients were $k = 5.0 \times 10^{-2}$ cm/sec at P1 and negligibly small at P5. Laboratory permeability tests with undisturbed samples taken at 2.0 m depth were applied to the test pits P1, P3 and P4. The measured permeability coefficient k values were $k = 2 \times 10^{-5}$ cm/sec, 4×10^{-9} cm/sec, 1×10^{-4} cm/sec respectively.

Another simple method of permeability test by low constant head with undisturbed samples of 5 cm diameter x 5 cm length taken from every test pits at the depth of 0.5, 1.0 and 2.0 m was carried out at the laboratory of MOA. The result shows that the permeability coefficient were $k = 10.69$ m/day (1.2×10^{-2} cm/sec) at (test pit P1) 0.5 m depth, $k = 8.31$ m/day (9.6×10^{-3} cm/sec) at test pit P1 of 1.0 m depth and at the other pits were very or rather negligible. (see Table E-6) According to the degree of permeability of soil suggested by Creager relating to D20 (20% size passing) in the subsoils of the reservoir were $k = 3 \times 10^{-3}$ cm/sec order of the sandy soils and $k = 3 \times 10^{-6}$ cm/sec of the clayey soils. (see Table E-5) Judging from above tests and analyses, the reservoir foundation is covered with enough thick and impervious clayey layers. Generally, however, it would be desirable to site the reservoir as far as possible from eastern edge of the area close to the well drained recent alluvium.

3.1.2 Black river reservoir

(1) Location and dimensions of the reservoir

The reservoir is proposed in the upper part of the Black river where it flows from north to south in the farm land of the Innswood Estate. Its dimensions are as follows:

Dam height	:	8.8 to 4.8 m
Reservoir	:	80 ha (0.8 km^2)
Storage capacity	:	3.8 million m^3

The river is a small stream, 8 km long, collecting drainage mainly from inside the farm area. The reservoir would be sited were upstream with its catchment in the old aluminum.

(2) Results of field investigations and laboratory test

Three (3) bore holes and five (5) test pits were executed in and out of the reservoir in the same manner applied at the Town Gully reservoir as shown in Fig. E-1 to E-2. According to bore hole logs and soil profiles of the test pits, the subsoils of the reservoir area consist mainly of clayey layers with some sandy layers. There is however a tendency of increasing sandy layers towards the south-east of the area. (see Fig. E-3) The bore holes of B6, B7 and the test pits of P6, P7, P8, P10 have subsoils of clayey materials but B8 and P9 which were located in the south-east part of the area have rather sandy soils. According to the results of laboratory tests, the specific gravities range between 2.30 to 2.62 averaging 2.50 and a dry density range from 1.471 to 1.890 g/cc averaging 1.665 g/cc. (see Table E-2)

The N values of Standard Penetration Tests were 8 to 15 with sandy soils and 13 to 15 with clayey soils which as represented by Dr. Terzaghi's method, shows that the sandy soils are medium dense having about 35o of internal friction angle and the clayey soils are stiff and have qu = 2.0 kg/cm^2 of unconfined compressing strength and qa = 26 ton/m^2 of allowable bearing strength. (see Table E-3 to E-4) The increased stress in the substrata from the new built 9 m high dam will be less than 17 ton/m^2 so that there will be no problem with the bearing capacity of the foundation.

Concerning the permeability of substrata, several kinds of permeability test were applied such as insitu permeability test, laboratory test with undisturbed sample, etc. Permeability coefficients by the insitu permeability test were k = 5.5 x 10^{-3} cm/sec at test pit P9 and negligibly small at P8. The values by the laboratory test with undisturbed samples from test pits P6, P8, P9 at 2.0 m depth were k = 2 x 10^{-8} cm/sec at P6, k = 6 x 10^{-9} cm/sec at P8, k = 1 x 10^{-9} cm/sec at P9. (see Table E-2)

Another simple permeability tests applied to all test pits were conducted at the laboratory of MOA. This shows that k values of P8 at 1.0 m depth and P9 at 2.0 m depth were 2 x 10^{-8} cm/sec for both and negligibly small at other test pits. (see Table E--6)

Judging from the results above, there will be no particular problems of seepage in the foundation of the reservoir. But attention should be paid to the south-east corner of the reservoir where there is the possibility of sandy layers in the substrata. (see bore hole log B8)

3.1.3 Conclusion

(1) Town Gully reservoir

There are two most important aspects to be considered in the design of the dam foundations at this site. These are the permeability and the bearing capacity of the foundation. From these point of view the reservoir would be constructed on the Rio Cobre old alluvium which will have 1,570 g/cc of dry dense, 35° to 40° of internal friction angle and 26 ton/m^2 of allowable bearing capacity which will be ample to support a 10 m high dam.

Concerning water-tightness, clayey soils occupy about 70% of the substrata and occur widely in the upper part of the subsoil over the reservoir area with impervious k values of the order of 10^{-5} to 10^{-8} cm/sec. There should therefore be no particular problems with the reservoir foundation, however the following precautions should be taken into consideration when designing the dam: (a) the reservoir should be constructed as far distance as possible from the recent alluvium, (b) the clay soils upstream of dam toe should be confirmed for at least 150 m as a natural blanket, if not, an additional artificial blanket would be necessary, (c) dam embankment materials should be collected from the area more than 150 m from the dam toe.

(2) Black river reservoir

Conditions are similar to those of the Town Gully reservoir described above in respect of the bearing capacity of the foundation. Concerning the permeability of the foundation, the subsoils of the reservoir, as a whole, are finer than those of the Town Gully reservoir so that there should be no question of the leakage through the foundations. Even so, attention should be paid to the southeast corner of the reservoir to confirm the possible existence of sandy soil in the subsoil which might have close connection with the sand which appears in B8 bore hole logs.

3.2 Aggregates

The purpose of aggregate investigations was to find raw materials in and around the study area.

Three major rivers which have been transporting river sediments into the study area from the outside are the Rio Cobre, the Coleburns Gully and the Plantain River of Bowers Gully. River sediments of the Rio Cobre and Coleburns Gully have few volcanic gravels because most parts of the upstream catchments are covered by limestone strata, but the Plantain river has a considerable quantity of volcanic sediments at Colbeck area.

The locations of the aggregate investigation were as follows:

(1) Plantain river at Colbeck St. Dorothy	:	Gravel and sand
(2) Rio Minho river at May pen	:	Gravel and sand
(3) Hope river at King stem	:	Gravel and sand
(4) Rio Cobre river near Spanish Town	:	Sand

3.2.1 Plantain river

This river upstream of Bowers Gully, located 4 km north of Old Harbour town, is considered to be an intermittent river. At Colbeck, it meanders over a width of from 5 to 20 m. There are volcanic sediments in the river bed over about 3 km. Being an intermittent river, the supply of sediment from upstream occur only during flood periods. There has therefore been no collection of raw materials from this river.

Samplings were conducted at two points, upstream and in the middle as regards river deposits and limestone boulders for laboratory testing. Results of the investigations and laboratory test are given below:

(a) Quantity of raw materials

While the extent of the river sediments is 3 km, the actual extent available of raw materials is about 2.5 km and the depth of sediments to be collected should be about 0.5 m on average from the point of view of river conservation. Thus the available quantity of raw materials will be about 7,500 m^3.

(b) Gradation

The materials of the river bed consist of various sizes of granular materials from one foot boulders to fine sand, and the average boulder content, over 40 mm in size, was 50% in terms of weight. About grain-size distribution, the Fineness Modulus of the coarse aggregate under 40 mm was 7.0 and of the fine aggregate 3.0. Both figures are within ASTM limitations. (American Society of Testing Materials) (see Fig. E-7 and Table E-8)

(c) Specific gravity

Specific gravities of gravels, sand and limestone boulder range from 2.55 to 2.65 which are within the normal for aggregate materials. (see Table E-7)

(d) Durability test (soundness in sodium sulphate)

The weight losses recorded in the test were 12 to 20% for the gravel, 20 to 30% for the sand and 1 to 2% for the limestone boulders. ASTM limitations for losses are 10% for sand and 18% for gravel (see Table E-7), but there is an exception to these limitations. If there is evidence of concrete made from similar aggregates to the samples having been placed under similar climatic conditions and if the concrete has been standing for a long time under weathering condition similar to those of the study area, the aggregate can be used. The Rio Cobre dam of headworks has been stable for more than 100 years with concrete made from similar aggregate.

(e) Abrasion test

The weight losses by Los Angeles Abrasion test were measured to be 16 to 23% which is within 50%, the limitation of ASTM. (see Table E-7)

(f) River deposits

The samples of river deposits collected from an outcrop (Colbeck Gully) on of the river bank contain excessive fine materials (clay and silt) 26 to 40% by weight and are not usable for concrete. (see Table E-7)

3.2.2 Rio Minho river

The Rio Minho river is the largest in the country and the eastern part of its drainage is adjacent to the western border of the Rio Cobre Basin. Its upstream catchments are covered with metamorphic and volcanic strata of cretaceous age and, therefore, have the same sequence of geological structure as the upstream of Plantain river.

An enterprise, Shaw's Aggregate Ltd., has been operating an aggregate business beside this river at May Pen, 35 km from Spanish Town. Sample materials of two graded gravels and a sand were collected from the stockyard of the company.

According to the results of laboratory test, the qualities of aggregate are similar to those of the Plantain river with 2.60 to 2.62 Specific gravity, 4 to 19% Durability, and 20 to 28% Abrasion. (see Table E-7)

3.2.3 Hope river

The Hope river flows into Hunt's Bay east of Kingston. The upstream area of the river is covered with igneous and metamorphic rocks with steep slopes that would supply a large quantities of raw materials to the downstream.

Two enterprises have been operating aggregate businesses with materials from the Hope river for all sorts of concrete in and out of the Kingstone area. Samples of raw material from the river were collected at the quarry site of Jamaica Premix Ltd.

From the results of laboratory test, the records of the test were 2.56 to 2.59 Specific gravity, 20% Durability, and 28% Abrasion, which are considered similar to those of Plantain river and Hope river. (see Table E-7)

3.2.4 Rio Cobre river

There are no gravels available along the Rio Cobre river other than sands of limestone origin. A few companies are collecting sand along this river after floods. Apart from the sand in the river bed, there are sandy deposits in the recent alluvium along the river, but this sand has not been used in important structures. The sample of sand was collected in the river near Spanish Town.

Based on the results of laboratory test, the records of the test are 2.52 Specific gravity, 3.4% Absorption, 20% Durability, and 1.94 for F.M.

The qualities are, therefore, not largely different from the sands of three above rivers except for the Fineness Modulus of 1.94 which is extremely low and consisted of very fine sand, compared to the standard value of F.M (=2.70). (see Fig. E-6 and E-7)

3.2.5 Conclusion

As a whole, aggregates from four above locations are considered usable for concrete works of the project under strict quality control. A concrete mixing test would be necessary prior to concrete works in the field, especially for concrete-works requiring high strength.

(1) Plantain river

Materials from the river bed are considered usable for concrete-works of the project, but from the view point of river conservation the volume of raw materials to be collected will be limited to about 7,500 m^3.

The river deposits outcropping in the river, are not adequate for concrete works because of their substantially silty and clayey characteristics.

A crushing plant, therefore, will be considered necessary for processing the boulders in the river.

(2) Rio Minho and Hope river

Production of aggregates is taking place at both locations. The quality and quantity of aggregates are considered sufficient and adequate for the project so that they could be used with technical specifications for the purpose.

(3) Rio Cobre river

It would be necessary to control the grading of sand from this river bed, and raw materials from this river deposit will not be used for concrete-works of the project because of their high clay content.

3.3 Soil Materials

3.3.1 Borrow pits

Soil materials for embankments of main and branch canals and for the construction of dams were investigated along these canals and the proposed sites of the reservoirs as shown in Fig. E-1 and E-2. Six locations were selected along these canals as proposed borrow pits and samples for laboratory tests were collected from four locations out of the six and two reservoir sites accordingly. Three types of soils were selected along the canal areas for laboratory tests. These were alluvial soil, bauxitic soil and white marl.

(1) Angels pen

This soil is located along the main canal at Angels pen and its type is of recent alluvium. Its granular texture, therefore varies largely in the soil layer. Its available volume was estimated at approximately 60,000 m^3.

(2) Bellevue heights

This is located at a northern hill area of the Innswood Estate, and the soil type is bauxitic soil so that the soil texture is generally homogeneous. The available volume was estimated to be approximately 120,000 m^3.

(3) Thetford hill

This is located in the northern mountain area of Old Harbour Town, and its soil type is white marl. A private company has been operating its production at the borrow pit and the available volume was estimated at approximately 200,000 m^3.

(4) White marl

This is located on the side of the highway between Spanish Town and Kingston. Its estimated volume is approximately 30,000 m^3.

(5) Rhodens pen

This is located beside the Rio Cobre river, south of Spanish Town. This soil type is river sediment. Its granular texture, therefore, varies largely in the soil layer. Its available volume was estimated at approximately 270,000 m^3.

(6) Mount Gotham

This is located in the mountain area, north of Caymanas Estate, its soil type is bauxitic soil. The available volume was estimated at approximately 80,000 m^3.

(7) Town Gully reservoir and Black river reservoir

Soil materials of the dam embankment were examined with the samples collected from test pits described in the Section 3.3.1 (Foundation of reservoirs). This soil type is alluvial soil.

3.3.2 Results of investigation and laboratory tests

(1) Angels pen

The material has 2.47 Specific Gravity which is slightly low. This soil belongs to ML group and consists mostly of fine grained soil, 40% of silt and 23% of clay. A compaction test shows that the maximum dry density is 1.722 g/cm^3 with 17% of moisture and a permeability coefficient of $k = 2.5 \times 10^{-6}$ cm/sec. A compression test shows that it has 39o of angle of shear and 0.4 kg/cm^3 of cohesive strength. (see Table E-9)

(2) Bellevue heights

This soil belongs to ML group and has 2.60 Specific Gravity. It consists of 80% of silt. The results of a compaction test were 1,500 g/cm^3 for dry density with 26% moisture and $k = 1.2 \times 10^{-7}$ cm/sec for permeability. (see Table E-9)

(3) Thetford Hill and white marl

These soils belong to GM group and have 2.47 to 2.53 of specific gravities. They consist of mostly gravel (42 to 59%) and sand (18 to 35%) with a slight content of silt and clay. The results of compaction tests were 1.909 to 1.911 g/cm^3 for dry densities with 13% of moisture. Permeability coefficients of $k = 3.5 \times 10^{-3}$ to 1.2×10^{-6} cm/sec were measured. (see Table E-9)

(4) Town Gully reservoir

Soil materials from test pits P1, P3 and P4 at 2.0 m depth were sampled for laboratory tests. The specific gravities measured were 2.40 to 2.61 and the compositions of the soils was silt (29 to 48%) and clay (28 to 45%). (see Table E-1) The results of compaction tests were 1.597 to 1.789 g/cm^3 for dry densities with 13.5 to 25.0% of moistures and $k = 1.0 \times 10^{-5}$ to 2.3×10^{-8} cm/sec for permeabilities. The records of compression test were 33° to 42° of angle of shear and 0.23 to 0.40 kg/cm^2 of cohesive strength. (see Table E-9)

(5) Black river reservoir

Soil materials from test pits P6, P8 and P10 at 2.0 m depth were sampled for laboratory tests. The specific gravities measured were 2.45 to 2.62, and the compositions of the soils were silt (28 to 55%) and clay (23 to 54%). (see Table E-2) The results of compaction tests were 1.493 to 1.602 g/cm^3 for dry densities with 18 to 24% of moistures and $k = 4.1 \times 10^{-6}$ to 5.9×10^{-8} cm/sec for permeabilities.

The records of compression tests were 24° to 47° of angle of shear and 0.16 to 0.08 kg/cm^2 of Cohesive strength. (see Table E-9)

3.3.3 Conclusion

(1) Angels pen

This soil can be used for both canal and road embankments.

(2) Bellevue heights

This soil can be used for road construction but if it is used for canal construction, concrete lining will be necessary to reduce leakage.

(3) Thetford hill and White marl

These materials consist mostly of gravel and sand. They, therefore have a weak cohesive characteristic but a high bulk density. These soils should be used for road construction and dam embankment in a random zone.

(4) Town Gully and Black river reservoir

The soil materials in the reservoir area can be used for the dam construction. Since there are various soil textures in the area, borrow pits should be selected to meet the needs of the dam body or the dam body should be designed according to the materials available at nearest borrow pits.

Since construction materials are largely clayey at the fitter of these reservoirs special attention must be given to avoiding cracks in the dam body.

(a) Filter sand

The sand material from Rhodens Pen borrow pit could be used as filter material for the dam bodies.

(b) Rip rap material

For slope protection of the dams, a riprap will be necessary. For this the limestone outcropping at Bernard Lodge and Innswood mountain area will be quite suitable. Its solubility however needs to be tested in a laboratory.

Table E-1 MECHANICAL ANALYSIS OF BORE HOLE LOGS AND TEST PITS

Location: TOWN GULLY RESERVOIR

	Hole		B1			B2			P1		P3	P4
	Sample No.		1	2	5	2	5	8-A	1	1	3	4
	Depth (feet)	Unit	5	10	25	10	25	40	2	7	7	7
1	Specific Gravity	g/cm3	2.45	2.58	2.62	2.49	2.38	2.49	2.61	2.51	2.40	2.61
2	Field Moisture	%	21.12	6.95	26.89	21.44	29.75	30.26	-	22.52	23.61	13.77
3	Unit Density	gm/cc	1.454	1.727	1.719	1.686	1.879	1.426	-	1.492	1.419	1.331
4	Consistency											
4	a) Liquid Limit	%	47.0	sand	-	42.0	61.1	39.3	sand	44.2	81.0	36.0
	b) Plastic Limit	%	15.5	-	-	12.6	28.9	25.5	-	32.8	37.6	15.8
5	Grain Size Analysis											
	Components											
	Clay (<0.005mm)	%	57	0	25	50	52	-	0	33	45	28
	Silt (<0.074mm)	%	20	16	21	39	43	-	6	29	48	41
	Sand (<2.0mm)	%	21	80	54	11	5	-	83	35	4	30
	Gravel (>2.0mm)	%	2	4	0	0	0	-	11	3	3	1
	Classification		CL	SM	SC	CL	CH		S	CL	CH	ML
6	Permeability											
	Creager's Method	cm/s	3x10^-6	3x10^-3	3x10^-6	3x10^-6	3x10^-6	-	3x10^-3	3x10^-6	3x10^-6	3x10^-6
	Laboratory Test	cm/s	-	-	-	-	-	-	-	2x10^-5	4x10^-9	1x10^-4
7	Consolidation											
	Preconsolidation of Pressure	kg/cm2	-	-	-	-	-	-	-	2.4	2.9	3.8
	Compression Index		-	-	-	-	-	-	-	0.002	0.007	0.02
	Coefficient of Compressibility	cm2/kg	-	-	-	-	-	-	-	0.003	0.005	0.014

Table E-2 MECHANICAL ANALYSIS OF BORE HOLE LOGS AND TEST PITS

Location: BLACK RIVER RESERVOIR

Hole		B6			B8			P6		P8	P10
Sample No.		2	3	6	1	2	3	6	6	8	8
Depth (feet)	Unit	10	15	30	5	10	15	2	7	2	7
1 Specific Gravity	g/cm3	2.47	2.62	2.48	2.44	2.33	2.48	2.45	2.51	2.59	2.62
2 Field Moisture	%	24	-	21.86	26.93	26.67	-	-	-	-	-
3 Unit Density	gm/cc	2	1.890	1.882	1.523	1.471	1.478	-	-	-	-
4 Consistency											
a) Liquid Limit	%	45.0	sand	61.5	53.6	84.4	sand	42.5	49.2	49.0	75.2
b) Plastic Limit	%	23.3	-	18.2	21.9	29.0	-	26.6	19.0	24.1	36.2
5 Grain Size Analysis		24.0	16	49	39	56	0				
Components											
Clay(<0.005mm)	%	24	16	49	39	56	0	23	53	39	54
Silt(<0.074mm)	%	25	37	40	61	14	13	55	28	41	29
Sand(<2.0mm)	%	21	47	7	0	23	79	18	17	14	10
Gravel(>2.0mm)	%	30	0	4	0	7	8	4	2	6	7
Classification		GC	SM	CH	MH	CH	GM	ML	CH	MH	CH
6 Permeability											
Creager's Method	cm/s	3X10^-6	3X10^-5	3X10^-6	3X10^-6	3X10^-6	3X10^-3	3X10^-5	3X10^-6	3X10^-6	3X10^-6
Laboratory Test	cm/s	-	-	-	-	-	-	-	2X10^-8	6X10-9	1X10^-9
7 Consolidation											
Preconsolidation of Pressure	kg/cm2	-	-	-	-	-	-	-	2.7	3.9	2.2
8 Compression Index		-	-	-	-	-	-	-	0.01	0.02	0.01
Coefficient of Compressibility	cm2/kg	-	-	-	-	-	-	-	0.015	0.013	0.006

Table E-3 SOIL CLASSIFICATION AND S.P.T VALUES

Bore hole No.	Top Gally Reservoir					Black River Reservoir		
	B1	B2	B3	B4	B5	B6	B7	B8
1 Log Records (m)								
Sandy	7.0	2.7	4.8	0.8	2.5	2.0	0	12
Clayey	8.0	12.0	12.5	14.0	10.0	9.2	10	4.8
2 N value								
Sandy	13	17	27	22	13	15	-	8
Clayey	13	22	22	22	21	15	13	15

Remarks: Figures in log record are accumulation of each category.
N values are average in each category.
S.P.T. (Standard Penetration Test)

Table B-4 CORRELATION BETWEEN N AGAINST ø AND qu

Sand soil	by Meyerh of Method		Clay soil	by Terzaghi-Pech Method		
Soil Condition	N	ø deg	Soil consition	N	qu(kg/cm2)	qa(kg/cm2)
very loose	< 4	< 30	very soft	<2	<0.25	<0.32
loose	4 - 10	30 - 35	soft	2 - 4	0.25 - 0.5	0.32 - 0.65
medium	10 - 30	35 - 40	medium	4 - 8	0.5 - 1.0	0.65 - 1.30
dense	30 - 50	40 - 45	stiff	8 - 15	1.0 - 2.0	1.30 - 2.60
very dense	> 50	> 45	very stiff	15 - 30	2.0 - 4.0	2.60 - 5.20
			very hard	>30	>4.0	>5.20

Remarks: qu; means unconfined compressive strength
qa; means allowable bearing strength by safety facter of 2

Table E-5 PERMEABILITY COEFFICIENT K AND D 20 SIZE BY CREAGERS METHOD

D20(mm)	K (cm/sec)	Soil type
0.005	3 x10^-6	Clay
0.01	1.05 x10^-5	Fine Silt
0.02	4.00 x10^-5	Coarse Silt
0.03	8.50 x10^-5	Coarse Silt
0.04	1.75 x10^-4	Coarse Silt
0.05	2.80 x10^-4	Coarse Silt
0.06	4.60 x10^-4	Very Fine Sand
0.07	6.50 x10^-4	Very Fine Sand
0.08	9.00 x10^-4	Very Fine Sand
0.09	1.40 x10^-4	Very Fine Sand
0.10	1.75 x10^-3	Very Fine Sand
0.12	2.60 x10^-3	Fine Sand
0.14	3.80 x10^-3	Fine Sand
0.16	5.10 x10^-3	Fine Sand
0.18	6.85 x10^-3	Fine Sand
0.20	8.90 x10^-3	Fine Sand
0.25	1.40 x10^-3	Fine Sand
0.30	2.20 x10^-2	Medium Sand
0.35	3.20 x10^-2	Medium Sand
0.40	5.80 x10^-2	Medium Sand
0.50	7.50 x10^-2	Medium Sand
0.6	1.10 x10^-2	Coarse Sand
0.7	1.60 x10^-1	Coarse Sand
0.8	2.15 x10^-1	Coarse Sand
0.9	2.80 x10^-1	Coarse Sand
1.0	3.60 x10^-1	Coarse Sand
2.0	1.80	Fine Gravels

Remarks: i.e. 20% of the sample is smaller than the size

Table E-6 PERMEABILITY TEST RECORD

	Soil No.	Core Ring No.	Depth (m)	Location	Bulk Density (g/cm3)	Permeability (m/day)
SC	979	P1	0.5	Towns Gully	1.42	10.69
SC	980	P1	1.0	Towns Gully	1.27	8.31
SC	981	P1	2.0	Towns Gully	1.56	0.00
SC	982	P2	1.0	Towns Gully	1.64	0.00
SC	983	P2	2.0	Towns Gully	1.58	1.91
SC	984	P3	0.5	Towns Gully	1.50	0.00
SC	985	P3	1.0	Towns Gully	1.46	0.00
SC	986	P3	2.0	Towns Gully	1.62	0.00
SC	987	P4	0.5	Towns Gully	1.52	0.00
SC	988	P4	1.0	Towns Gully	1.67	0.00
SC	989	P4	2.0	Towns Gully	1.55	0.02
SC	990	P5	1.0	Towns Gully	1.60	0.00
SC	991	P5	2.0	Towns Gully	1.58	0.00
SC	992	P7	1.0	Black River	1.39	0.00
SC	993	P7	2.0	Black River	1.48	0.00
SC	994	P8	1.0	Black River	1.47	2.08
SC	995	P8	2.0	Black River	1.43	0.00
SC	996	P9	1.0	Black River	1.28	0.00
SC	997	P9	2.1	Black River	1.46	1.66
SC	998	P10	1.0	Black River	1.54	0.00
SC	999	P10	2.0	Black River	1.41	0.06

Table E-7 AGGREGATE TEST RECORD

Location: Source/Area		Plantain River Gully						Rio Minho		Hope		Rio Cobre
		Upstream River Bed			Middle Part River Bed			Shaw's Plant		Jamaica Premix		Spanish Town
Pit No.		2			3			7		8		9
	Unit	C. Agg.	F. Agg.	Lime Stone	C. Agg.	F. Agg.	Lime Stone	C. Agg.	F. Agg.	20mm C. Agg.	F. Agg.	Sand
A. LOS ANGLES ABRASION												
1. Percent loss (100 Revs.)	%	3.90	-	3.80	5.85	-	4.78	4.57a	-	8.95	-	-
2. Percent loss (500 Revs.)	%	19.05	-	15.77	22.91	-	21.04	19.90a	-	27.85	-	-
3. Coeff. of uniformity	-	0.204	-	0.240	0.255	-	0.227	0.229a	-	0.299	-	-
B. SPECIFIC GRAVITY AND ABSORPTION												
1. SSD Specific Gravity	-	2.55	2.62	2.65	2.65	2.61	2.55	2.63b	2.60	2.56	2.59	2.52
2. Water Absorption	%	5.10	3.88	1.20	3.52	5.10	2.66	1.79b	3.34	2.33	3.69	3.40
C. SOUNDNESS IN SODIUM SULPHATE												
1. Percent Wt. Loss after 5 cycles	%	19.89	20.63	2.04	12.16	33.38	1.27	4.28c	16.88	19.18	20.87	19.80
D. DRY RODDED UNIT WEIGHT	pcf	120.0	102.90	-	120.2	104.30	-	101.0d	106.80	95.50	106.00	101.80
E. UNCONFINED COMPRESSIVE STRENGTH												
1. Specimen 'A'												
a) Compressive Strength	psi	-	-	-	-	-	-	-	-	-	-	-
b) Unit weight	psf	-	-	162.7	-	-	156.4	-	-	-	-	-
2. Specimen 'B'												
a) Compressive strength	psi	-	-	-	-	-	-	-	-	-	-	-
b) Unit weight	pcf	-	-	164.9	-	-	157.5	-	-	-	-	-

Notes:
a - Blends of 314" & 112" size
b - 3/4" sizes
c - Blends of 3/4", 112 and 3/4" sizes
d - Blended 60% - 3/4" and 40% - 1/2" sizes
e - Washed Material

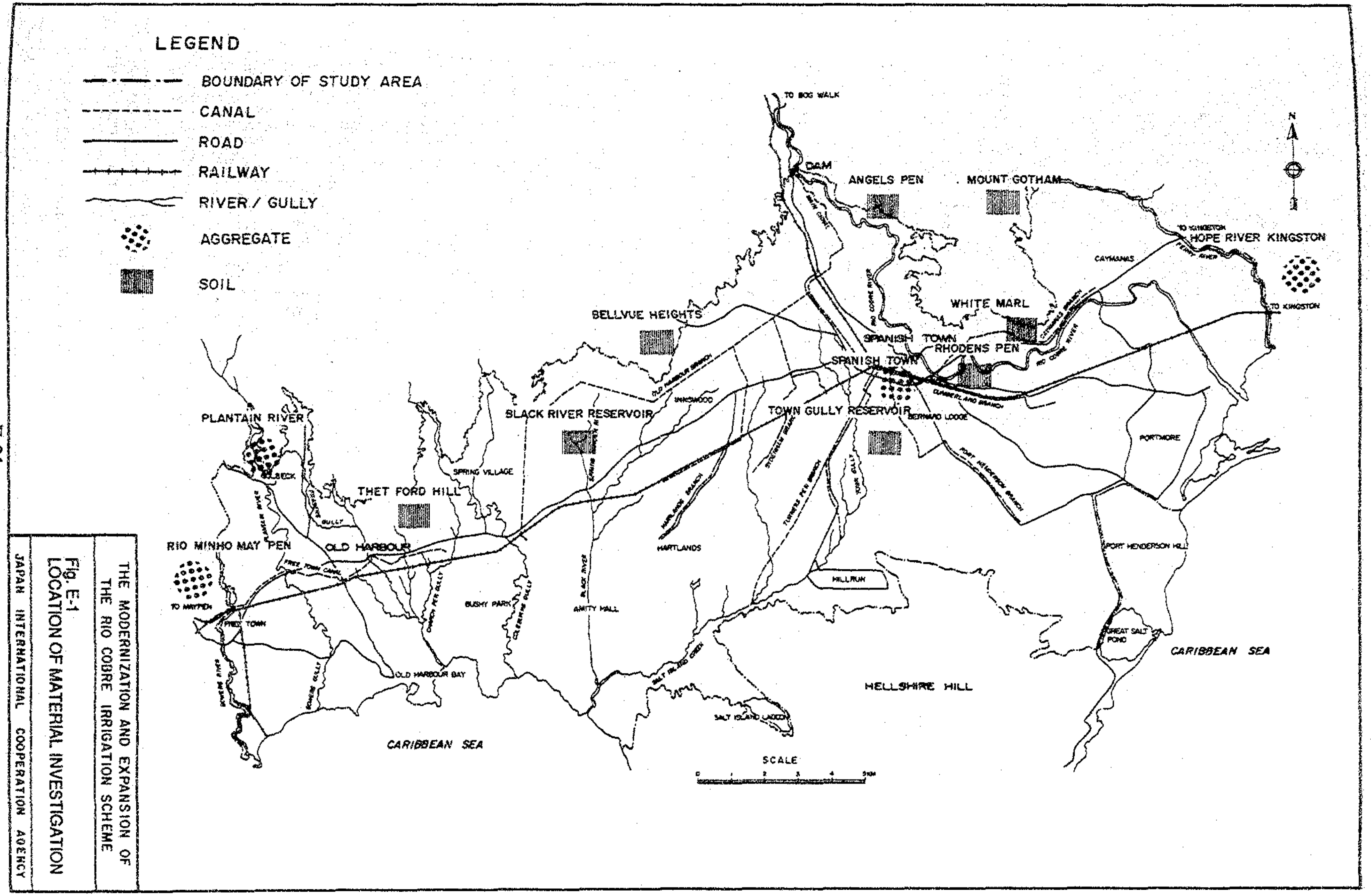
Table E-8 AGGREGATE TEST RECORD GRAIN SIZE ANALYSIS

Location	Plantain River						Colbeck Gully				Rio Minho		Hope		Rio Cobre
Source	Upstream River Bed			Middle Part River Bed			Upstream Sidebank		Downstream Sidebank		Shaw's Plant		Jamaica Premix		Spanish Town
Pit No.	2			3			4		6		7		8		9
	-40mm C. Agg	-5mm F. Agg	+5mm C. Agg	-40mm C. Agg	-5mm F. Agg	+5mm C. Agg	-40mm C. Agg	-5mm F. Agg	-40mm C. Agg	-5mm F. Agg	3/4" C.Agg.	F. Agg.	3/4" C. Agg.	F. Agg.	F. Agg.
2"(50mm)	-	-	-	-	-	-	-	-	100	-	100.0	-	100.0	-	-
1.5"(37.5mm)	100.0	-	100.0	100.0	-	100.0	100.0	-	93.1	-	83.4	-	82.3	-	-
1"(25mm)	86.1	-	77.8	78.4	-	78.8	71.4	-	76.8	-	61.3	-	62.7	-	-
3/4"(20mm)	72.4	-	64.3	75.3	-	67.7	64.5	-	65.6	-	42.6	-	34.5	-	-
1/2"(13mm)	61.1	-	47.5	66.9	-	53.0	55.0	-	49.0	-	28.3	100.0	18.0	100.0	100.0
3/8"(10mm)	54.7	100.0	34.2	58.8	100.0	41.5	43.6	100	37.8	-	13.6	97.1	0.9	99.7	99.9
#4 (4.75)	45.7	99.7	3.3	43.0	99.5	9.4	8.0	99.7	12.1	100	1.4	75.2	0.4	75.0	95.2
#10 (2.0)	34.7	74.1	1.2	30.3	68.4	5.1	5.1	70.1	10.6	81.6	0.8	46.7	-	52.1	84.9
#20 (0.8)	18.8	38.8	1.1	19.7	44.5	5.0	4.8	50.5	10.2	65.2	-	21.1	-	14.0	75.2
#40 (0.4)	8.6	15.3	0.9	12.9	26.4	4.7	4.4	40.3	9.6	55.6	-	8.0	-	8.5	43.2
#100 (0.15)	3.5	5.1	0.5	5.5	10.0	4.0	4.1	30.4	8.4	45.3	-	2.8	-	5.8	8.3
#200 (0.07)	2.9	3.8	0.3	4.3	7.0	3.2	3.4	26.4	7.4	39.6	-	1.0	-	4.2	2.1

Remark: 1. These numbers are cumulative percent passing
2.+40mm over size 52% at Pit No.2 ,56% at Pit No.3

Table E-9 RECORDS OF SOIL MECHANICAL ANALYSIS

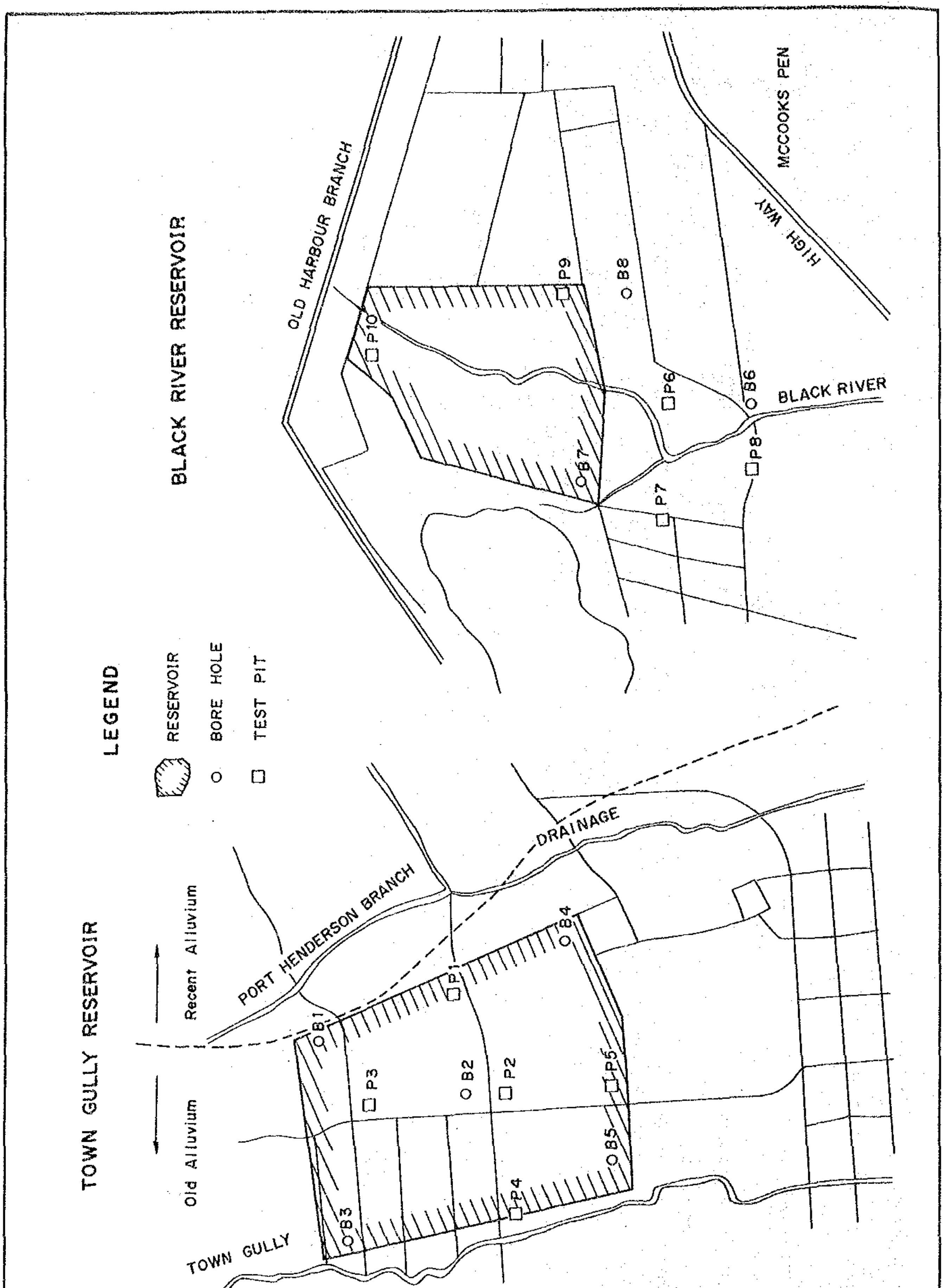
			Reservoirs						Borrow Pits			
	Location		Town gully			Black River			Angels Pen	Bellvue Hights	Thetford Hill	White Marl
	Pit No.		1	3	4	6	8	10	1	2	3	4
	Soil type								Alluvium	Bauxite	White Marl	White Marl
	Depth (feet)	Unit	7	7	7	7	7	7				
1	Specific Gravity	g/cm3	2.51	2.40	2.61	2.51	2.59	2.62	2.54	2.60	2.47	2.53
2	Grain Size Analysis											
	Components											
	Clay(<0.005mm)	%	33	45	28	53	39	54	22	9	9	9
	Silt(<0.074mm)	%	29	48	41	28	41	29	51	79	14	14
	Sand(<2.0mm)	%	35	4	30	17	14	10	27	12	18	35
	Gravel(>2.0mm)	%	3	3	1	2	6	7	0	0	59	42
	Liquid Limit	%	44.2	81.0	36.0	49.2	49.0	75.1	34.15	38.70	22.85	22.80
	Plastic Limit	%	32.8	37.6	15.8	19.0	24.1	36.2	21.55	25.17	15.83	18.44
	Classification		CL	CH	ML	CH	MH	CH	ML	ML	GM	GM
3	Compaction											
	Maximum dry density	gm/cc	1.698	1.597	1.789	1.602	1.528	1.493	1.722	1.501	1.909	1.911
	Optimum moisture	%	13.5	25.0	14.0	18.0	20.8	24.0	17.0	26.0	12.5	12.5
	Permeability	cm/s	1.0x10^-5	2.5x10^7	2.3x10^-8	4.1x10^-6	8.3x10^-7	5.9x10^-8	2.5x10^-6	1.2x10^-7	3.5x10^-3	1.2x10^-6
4	Compression											
	Peak stress	kg/cm2	1.43	1.32	1.04	0.39	0.28	0.49	1.65	0.79	-	-
	Angle of shear	deg	29.5	33.5	42.0	47.0	35.0	24.0	39.0	30.0	-	-
	Cohesion	kg/cm2	0.40	0.35	0.23	0.08	0.07	0.16	0.4	0.23	-	-



THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

Fig. E-1
LOCATION OF MATERIAL INVESTIGATION

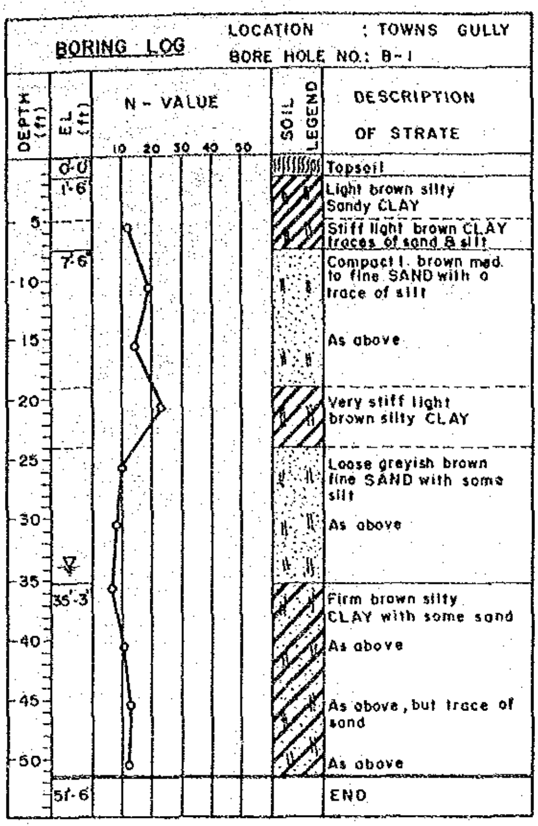
JAPAN INTERNATIONAL COOPERATION AGENCY

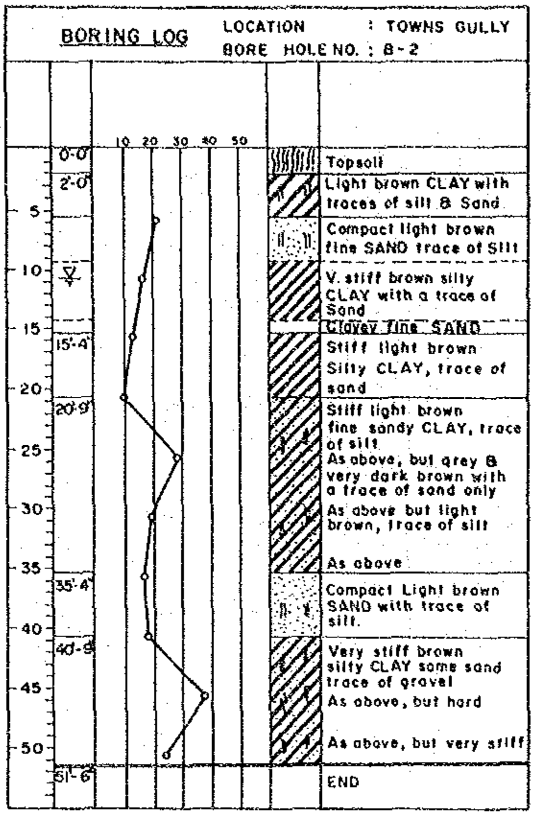


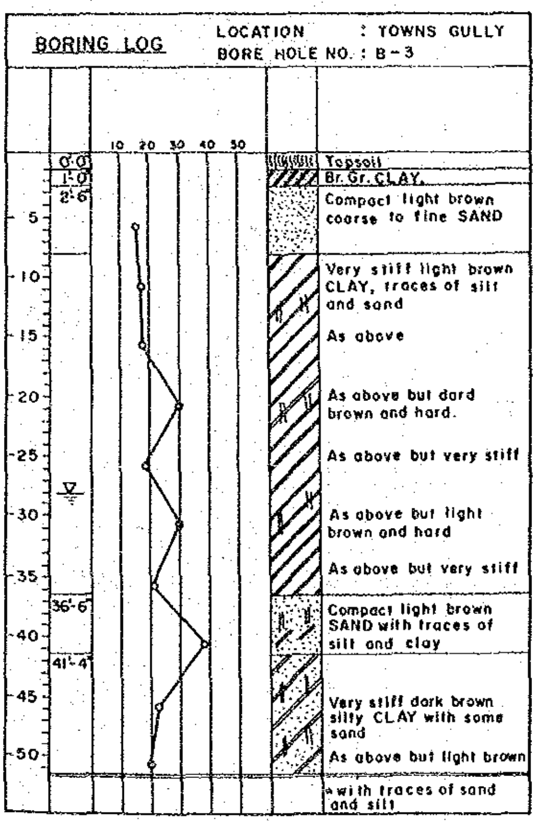
THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

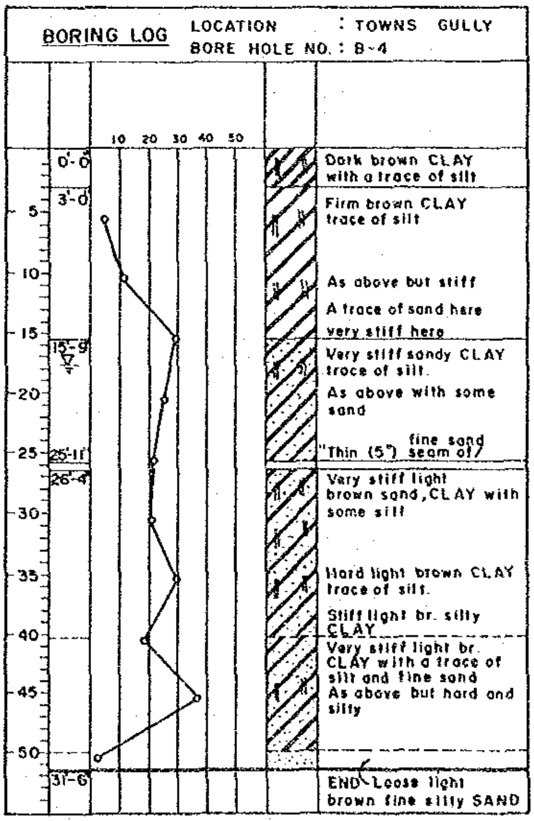
Fig. E-2
INVESTIGATION OF RESERVOIRS

JAPAN INTERNATIONAL COOPERATION AGENCY





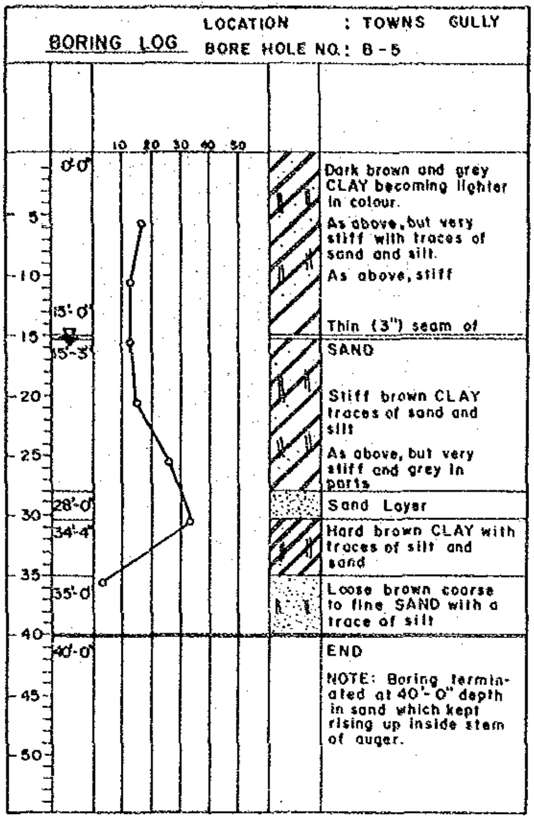


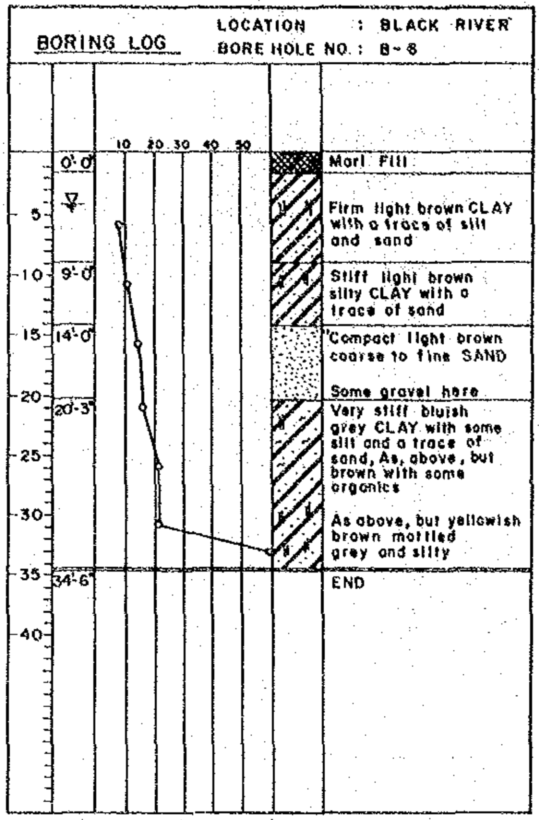


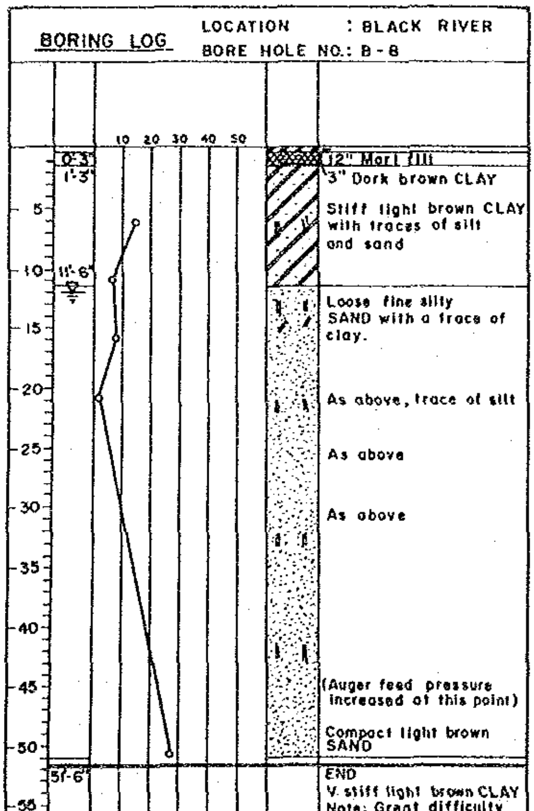
THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

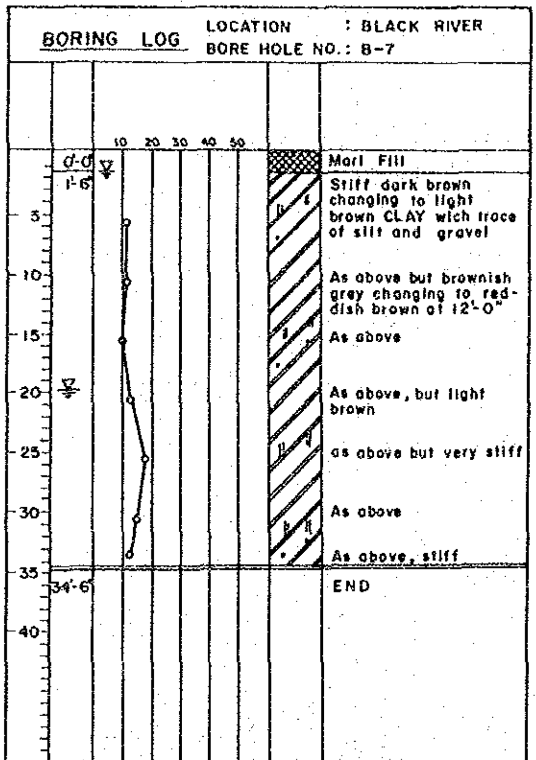
Fig. E-3 (1/2)
BORE HOLE RECORD (B-1 - B-4)

JAPAN INTERNATIONAL COOPERATION AGENCY









THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

Fig. E-3 (2/2)
BORE HOLE RECORD (B-5 - B-8)

JAPAN INTERNATIONAL COOPERATION AGENCY

TOWNS GULLY P-1

Depth	Soil Description (Field)
0'-0"	Dark brown silty CLAY
0'-6"	Brown SILT
2'-0"	SAND
3'-0"	Brown Clayey SILT
5'-0"	Clayey SAND
6'-0"	END OF TEST PIT

TOWNS GULLY P-2

Depth	Soil Description (Field)
	Brown CLAY
	As above
	As above
	As above
6'-0"	

TOWNS GULLY P-3

Depth	Soil Description
0'-0"	Dark brown CLAY
1'-6"	Brown CLAY
5'-0"	Brown CLAY, grey in parts.
6'-0"	END OF TEST PIT

TOWNS GULLY P-4

Depth	Soil Descripion
0'-0'	Dark brown CLAY
1'-6"	Brown CLAY
2'-6"	SAND
3'-0'	Brown silty CLAY
6'-0'	END OF TEST PIT

TOWNS GULLY P-5

Depth	Soil Description
0'-0"	Dark brown CLAY
0'-6"	Brown CLAY
2'-6"	Light brown CLAY
6'-0"	END OF TEST PIT

BLACK RIVER P-6

Depth	Soil Description
0'-0'	Topsoil (Grey CLAY with traces of sand and silt)
1'-0	Light grey CLAY with traces of silt
	Light browm silty sandy CLAY
	Brownish grey CLAY with traces of sand & silt
7'-0'	END

BLACK RIVER P-7

Depth	Soil Description
0'-0"	Topsoil (V. dark brown CLAY with a trace of silt)
1'-0"	Yellowish brown CLAY with a trace of silt
	As above
	As above, light brown
6'-6"	END OF TEST PIT

BLACK RIVER P-8

Depth	Soil Description
0'-0'	Dark brown CLAY
1'-6"	Brown CLAY
	Grey CLAY
3-0	As above but brown and grey in colour
6'-0'	END OF TEST PIT

BLACK RIVER P-9

Depth	Soil Description
0'-0"	Dark grey CLAY
1'-0"	Grey clay, brown in places
2'-0"	Light brown fine SAND and SILT
6'-0"	END OF TEST PIT

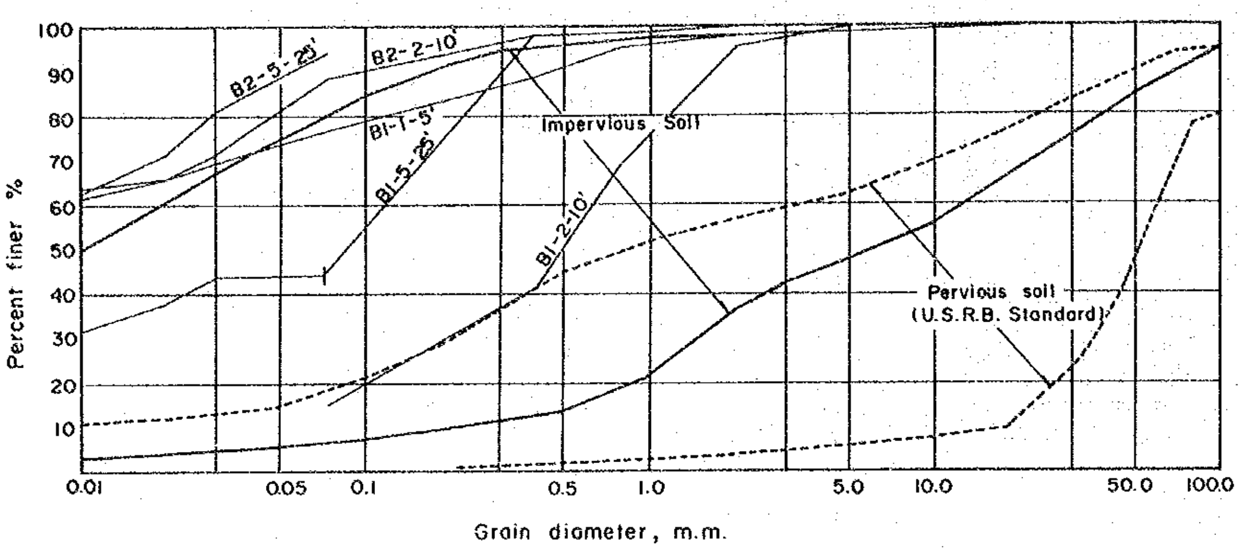
BLACK RIVER P-10

Depth	Soil Description
0'-0"	Dark brown CLAY
2'-0"	Brown CLAY
6'-0"	END OF TEST PIT

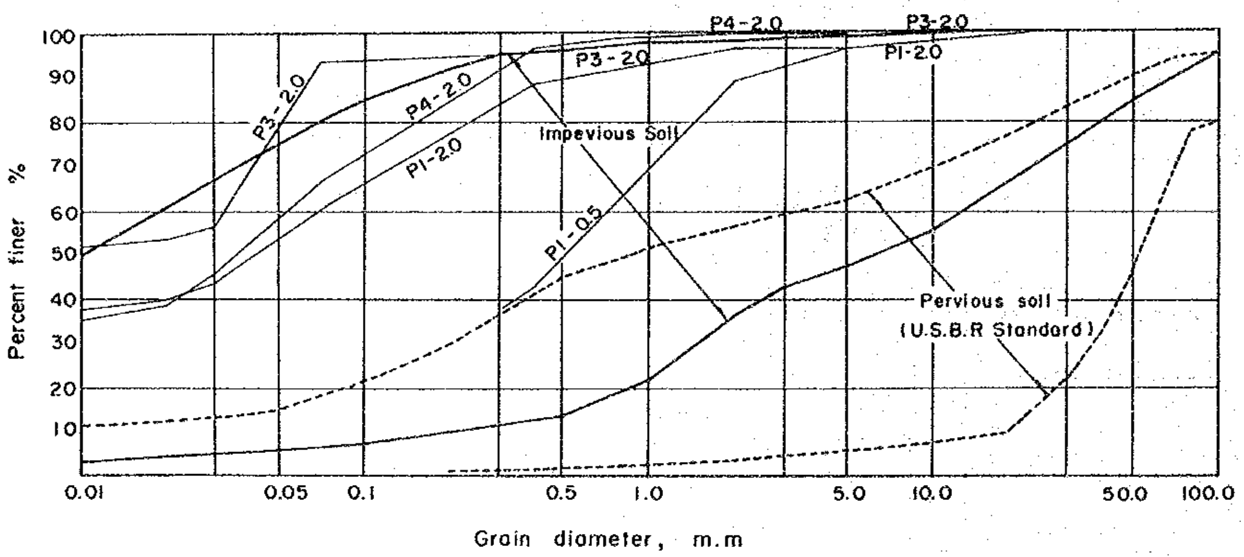
THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

Fig. E-4
SOIL PROFILE OF TEST PITS (P-1 - P-10)

JAPAN INTERNATIONAL COOPERATION AGENCY



Re: B1-2-10' means Bore hole NO.1, sample NO.2, depth 10'

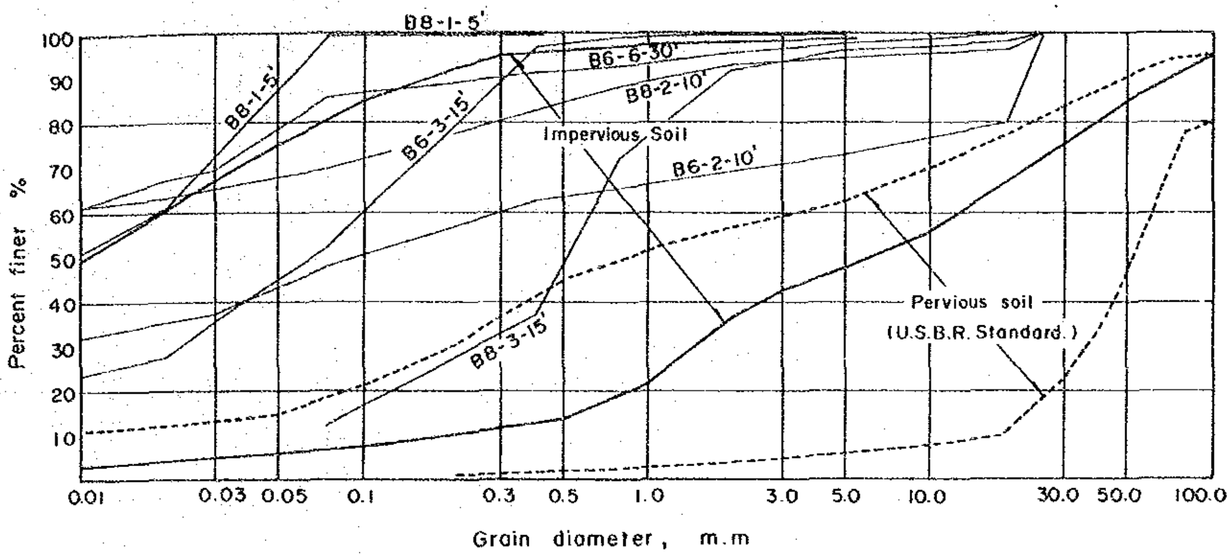


Re: P1-2.0 means Test pit NO.1, depth 2.0m

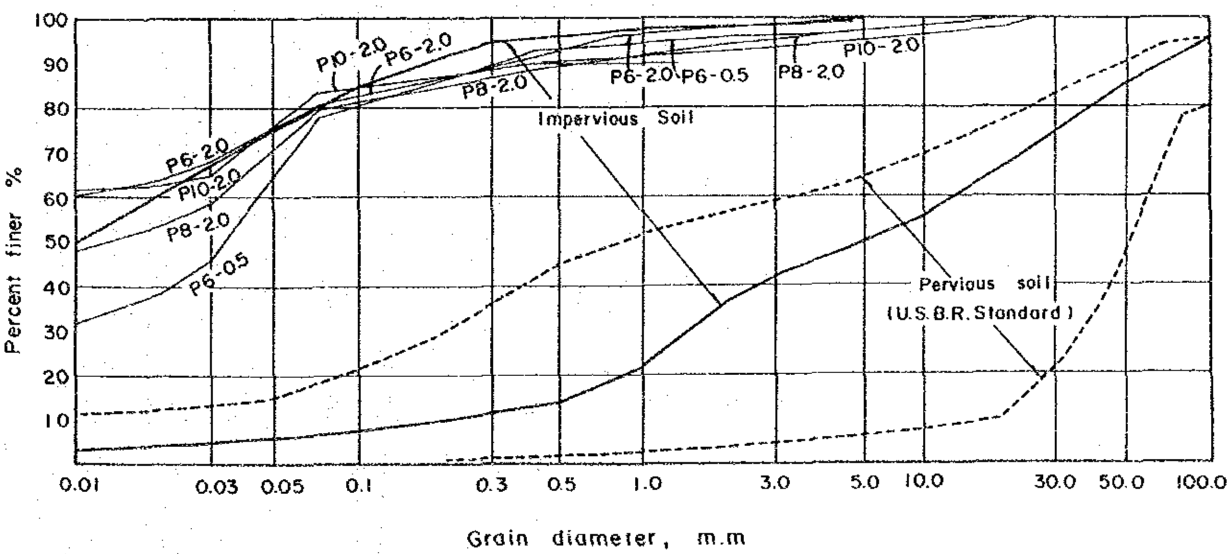
THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

Fig. E-5 (1/3)
MECHANICAL ANALYSIS OF SAMPLES
(TOWN GULLY RESERVOIR)

JAPAN INTERNATIONAL COOPERATION AGENCY



Re: B8-1-5' means bore hole NO.8, sample NO.1, depth 5'

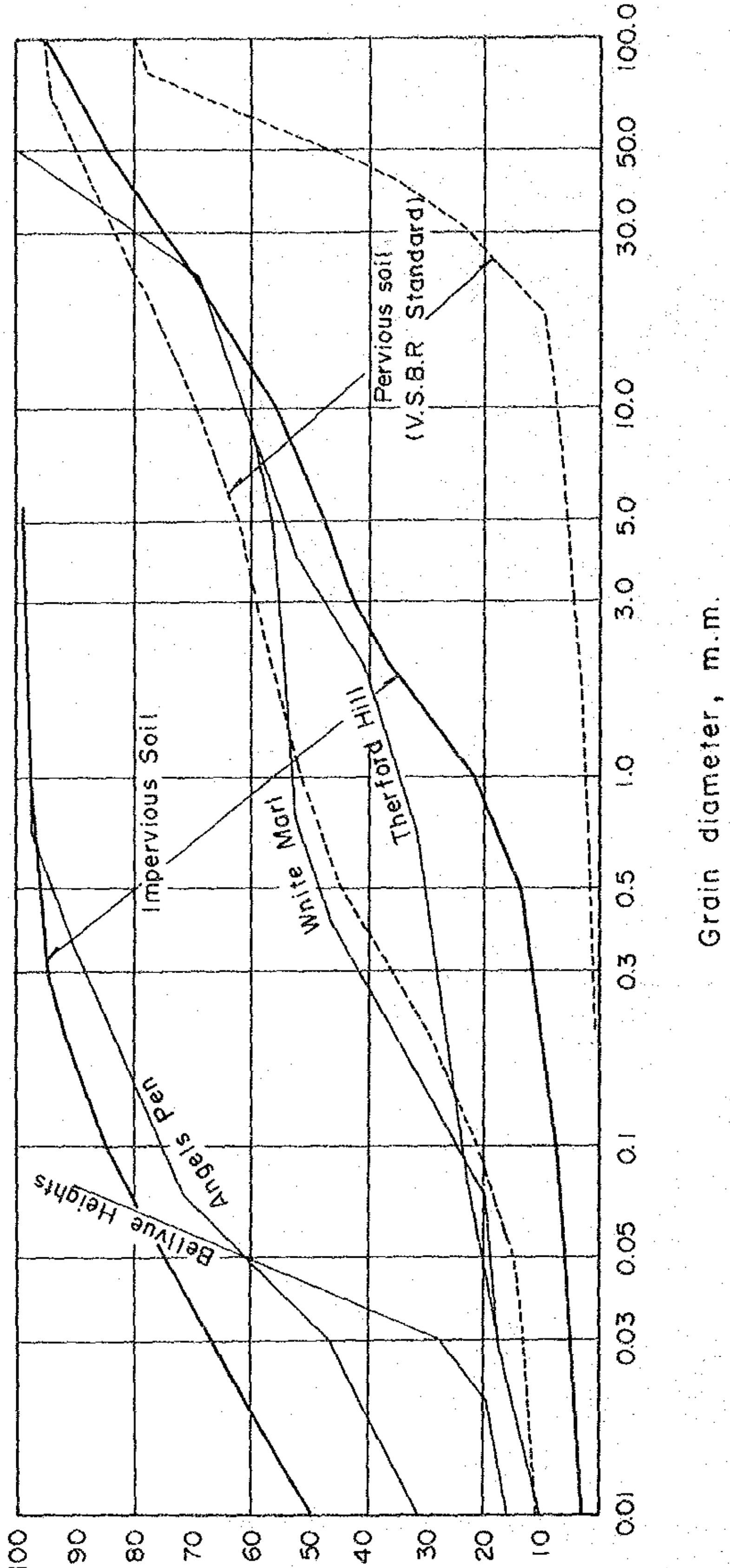


Re: P6-0.5 means Test pit NO.6, depth 0.5m.

THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

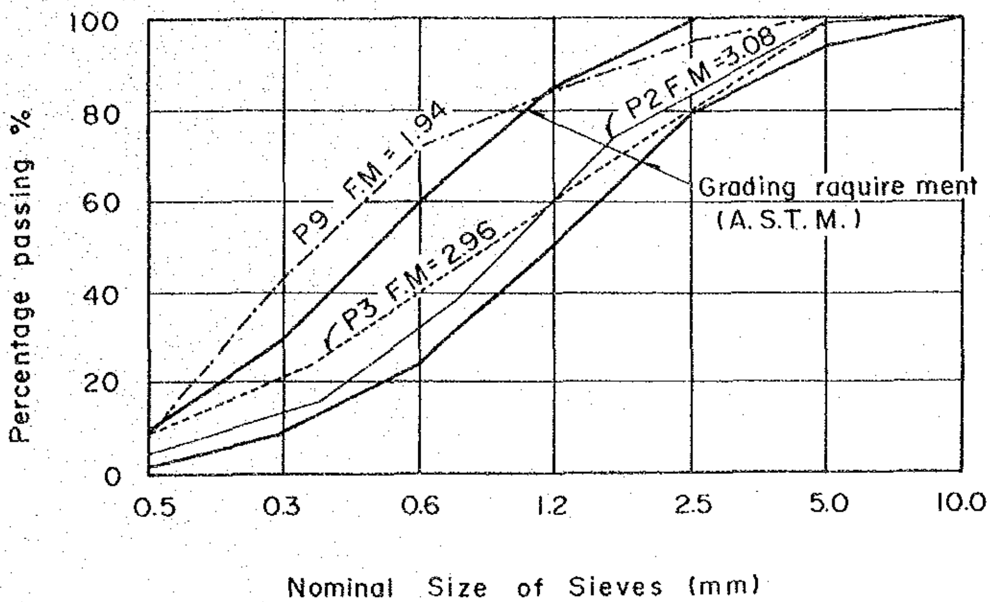
Fig. E-5 (2/3)
MECHANICAL ANALYSIS OF SAMPLES
(BLACK RIVER RESERVOIR)

JAPAN INTERNATIONAL COOPERATION AGENCY

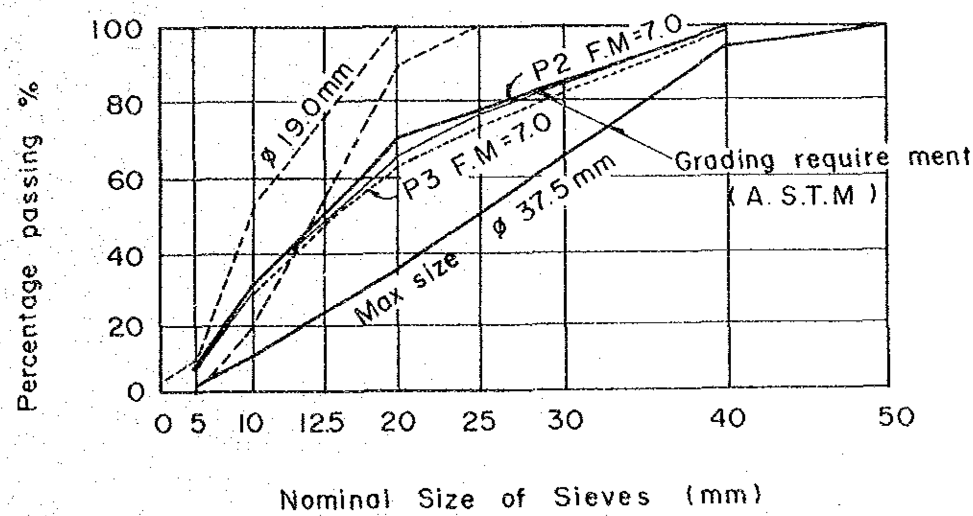


THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME
Fig. E-5 (3/3) MECHANICAL ANALYSIS OF SAMPLES (BORROW PITS)
JAPAN INTERNATIONAL COOPERATION AGENCY

1. Fine Aggregate



2. Carse Aggregate



R : P2 means Pit NO,

F.M means Finess modulus

THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

Fig. E-6
GRADING OF AGGREGATES

JAPAN INTERNATIONAL COOPERATION AGENCY

ANNEX - F

SOCIO-ECONOMY

ANNEX-F

SOCIO-ECONOMY

TABLE OF CONTENTS

LIST OF TABLES

1. NATIONAL SOCIO-ECONOMIC BACKGROUND

1.1 General

Jamaica is an island in the Caribbean sea, between 76°11' to 78°22' west longitudes and 17°42' to 18°31' north latitudes. It lies in the tropics, directly on the trade routes from Europe via the Panama Canal. It is the cross roads for air and sea traffic between the North and South Americas. The island is approximately 235 km (146 miles) long and varies from 35 km (22 miles) to 82 km (51 miles) in wide with a total land area of 10,947 km^2 (4,231 square miles). A central mountain range runs east to west with the highest summit in the Blue Mountains at an elevation of 2,258 m (7,402 ft.). This mountain range is close to the sea in the north, limiting the coastal plain, but allowing for some of the largest plains of the country to the south. Almost half of Jamaica's land area is over 305 m (1,000 ft.) above mean sea level. Administratively, Jamaica is divided into three (3) counties and 14 parishes.

Jamaica has a maritime tropical climate characterized by warm trade winds generally known as the north east trade winds. The annual average rainfall ranges from nearly 7,600 mm (300 inches) in the Blue Mountain to less than 760 mm (30 inches) in some parts of the south coast. The average annual rainfall for the whole island is 1,970 mm (78 inches). The annual mean temperature near sea level is 25.6°C (78°F), with mean maximum temperatures occurring in July and August averaging 30°C (86°F). The mean minimum in January and February averages 21°C (70°F).

1.2 Economic Situation

The economy of Jamaica is slowly emerging from almost a decade of decline in the 1970s. The economy began to recover in 1981 to 1983 but another downturn began to be evident in 1984 and has continued into 1985. The Gross Domestic Product (GDP) at 1974 constant prices was about J$ 1,924 million in 1984 and J$ 1,853 million in 1985 as shown in Table F-1. The annual growth rates for these years were -0.4% and -3.7%, respectively. In 1985, the decline has been most significant in the productive sectors of the economy. Mining and Quarrying recorded the greatest decline of 19.5% followed by Construction 13.5%, Agriculture, Forestry and Fisheries 3.4%, Manufacturing 0.2%. The decline in the services sectors was less significant than in the productive sectors. On average, the decline in the services sectors was estimated to be 2.9% as given in Table F–2.

GDP at current prices in 1985 was approximately J$ 11,025 million with an annual growth rate of 20.6%. This growth rate is low when compared with 32.5% in 1984. The slower rate of growth can be attributed mainly to decline in real growth in most of the sectors, although there was a fall in the price of bauxite and alumina. (see Table F-3) Per capita income at current prices increased between 1975 and 1981, from J$ 1,292 to J$ 2,436. Current per capita income has continued to grow with the increases in prices of most goods and services and the value for 1985 was estimated at J$ 4,770. With the increasing devaluation of the Jamaican dollar over most of that period, however, the current per capita income has in effect fallen from US$ 1,369 in 1981 to US$ 867 in

1985. This is about 39% less than the comparative figure of US$ 1,420 in 1975. Real per capita income of J$ 1,070 in 1975 fell to J$ 867 in 1981 and continued into 1985 when the real per capita income had fallen to J$ 802.

In 1975, the productive sectors accounted for about 43% of GDP, but since then this proportion has decreased consistently. In 1985, the contribution of the productive sectors was estimated at about 35%. Agriculture, Forestry and Fisheries is the only sector to have increased its share and this only marginally from 7.3% in 1975 to 8.8% in 1985. In the services sectors, the most significant movement has been in Public administration, where the share increased from 12.3% in 1975 to 19.2% in 1981. This high level was maintained throughout the 1980s. Recently there has been a slight decline but the comparative share has remained at 18.6%. (see Table F-4)

A real constraint to economic development in Jamaica since the mid 1970s and continuing into the 1980s has been the shortage of foreign exchange to meet the increasing needs of industry for raw materials and capital goods, and for consumption not satisfied by local production. From Table F-5, it may be observed that the degree of external dependence has increased by about 50% between 1975 and 1985. Both imports and exports as a proportion of GDP have increased, with exports moving from 35.3% in 1975 to 55.1% in 1985 while imports grew from 45.6% to 66.5% in same period. The gap between imports and exports which had declined in 1984 to J$ 537 million rose to J$ 1,259 million in 1985, due mainly to the increased contribution of imports of goods and services to GDP, however, the contribution of exports of goods and services has remained the same as 1984.

1.3 Demographic Conditions

1.3.1 Population

The population in 1985 stood at an estimated 2.3 million with a density of 212 persons/km^2 (550 persons/square mile), representing an increase of 1.3% above the 1984 figure as shown in Table F-6. This growth rate is low when compared with the last four (4) years. Emigration in 1985 increased by 27.6% over the previous year. (see Table F-7) Emigration has been an important determinant of population changes in Jamaica acting as a brake on the rate of growth. In 1970 the net emigration was an estimated 46.7% of the corresponding natural increase. This high proportion continued up to 1980 and was the main cause of the low annual rate of population growth during those years. The proportion since 1981, however, has been lower than those in the preceding ten (10) years, with the average since that time being 19.7%, which is reflected in the high rate of annual population growth in recent years. (see Table F-7)

In 1970 the 0 to 9 years age group represented 32.4% of the total population but by 1982 this had declined to 25.2%. Despite this, however, the Jamaican population remains very young. 50.4% of the population is under 20 years of age, with the median age for men and women in 1982 being 18.9 and 19.9 years respectively. In the meantime, a fairly significant proportion of the female population, 17.2% is within the high fertility age range from 20 to 29 years. On the other hand, an indication of the decline in mortality levels has been the continued rise in the proportion of the population that is 65 years of age and over. In 1970 this group represented 5.6% of the population moving to 6.9% in 1982. (see Table F-8)

From a study of past trends in the components of growth a set of projections for the period 1985 to 2015 has been prepared by the Statistical Institute of Jamaica. According to this projection, the total population of Jamaica is estimated at 2.8 million in the year 2000 and 3.2 million by the year 2015 as shown in Table F-6.

1.3.2 Labour force

The total labour force in 1985 was estimated to be approximately 1.0 million representing an increase of 0.2 million over the year 1975 i.e., an average annual growth rate of 2.2%. This growth rate is high when compared with the population growth rate of 1.4% due mainly to increases in the population of 14 years of age and over with an annual growth rate of 2.4%. The increase in the labour force was more rapid in the first six (6) years of the period 1975 to 1985, than in the latter four (4) years. In 1985, the labour force grew by only 0.2%. For the same period the number of employed persons increased by a similar rate, while the number of unemployed persons increased marginally by 0.3%. (see Table F-9)

In 1975, the productive sectors accounted for 53% of the total employed labour force, moving to 54% in 1985. The level of employment in the productive sectors has shown steady growth since 1983, with a 2.3% growth in 1984, followed by a further 6.5% in 1985. The greater part of this increase was in Agriculture, Forestry and Fisheries which make up two thirds of the employed labour force in the productive sectors and approximately one third of the total employed labour force. The employed labour force in this sector has declined from 0.27 million in 1981 to 0.25 million in 1983, but has, steadily increased since 1984 and reached 0.28 million in 1985 which was considered to be attributable to introduction of new agricultural programmes. The employed labour force in the services sectors increased steadily from 1975 up to 1984 but decreased by 6.6% in 1985. This was due primarily to a decline in employment by Public administration sector which decreased by 19.3% in 1985.

In 1985, the number of unemployed persons was estimated to be 0.27 million or 25.6% of the total labour force. Such high unemployment has been relatively unchanged over the last four (4) years with unemployment rates ranging from 25.6% to 28.2%. The increase of unemployed persons between 1984 and 1985 occurred mainly in the productive sectors, while unemployment declined in the services sectors. Employment in Public administration sector is diminishing as persons previously employed in this sector have found employment in other sectors. With the increased emphasis on agricultural production more persons are looking towards Agriculture, Forestry and Fisheries for employment, this has led to an increase the level of unemployment in this sector. Unemployment in these sectors has consistently been highest for the Construction and Installation sector, and the Other services sector, because persons working in these sectors are usually unskilled and have less flexibility.

1.4 Social Services

1.4.1 Health

The Ministry of Health provides health care services through 23 government operated hospitals, the university hospital and 372 primary health care centres. (see Table F-10) These are supported at the central level by an administrative structure. The administration of the services is, theoretically, decentralized to four (4) health regions, each directing activities in three (3) or five (5) parishes in the island. The parish health department is the main field administrative unit. Each parish health department comprises several medical districts, the number of medical districts is related to the size of the parish, and each district has the following three (3) types of health centres:

(1) Type I centre: (the smallest unit)

This serves a population of about 4,000 persons and offers very basic maternal, child health and curative services.

(2) Type II centre: (one or more Type I's relate)

The population served is about 12,000 including those served by Type I.

(3) Type III centre:

This is the administrative headquarters of the medical district, serving a population of 20,000 through Types II and I centres. Dental facilities are available at some of these centres.

In addition, there is a Type IV centre, which is a combination of the parish health department and the Type III facilities and services. It is usually within easy reach of a hospital whose X-ray and laboratory facilities it utilizes. In many cases, the facilities and services are either inadequate or poorly maintained and this affects the quality of the service offered.

In recent years, there has been a decrease in the number of persons employed in the health services, largely due to the restructuring and rationalization in Public administration sector and there continues to be shortages of manpower resources within several important areas. The ratio of doctors and dentists to population in Jamaica, as well as the ratio recommended by the Pan American Health Organization (PAHO) are given in Table F-11. In 1984, the ratio of doctors and dentists in Jamaica was estimated to be 1:2,808 and 1:36,506 respectively. It is indicated that the ratios of both doctors and dentists to population are still very low when compared with the ratios 1:910 for doctors and 1:2,857 for dentists as recommended by PAHO.

1.4.2 Education

The formal education system in Jamaica consists of four (4) levels, i.e. pre-primary, primary, secondary, and tertiary education. Educational institutions by type in each parish are given in Table F-12.

(1) Pre-primary level

Formal education begins at age three (3) to four (4) years. In the public system pre-primary education is offered in infant schools and infant departments of some primary and all-age schools. Privately owned institutions offering pre-primary education are nursery and kindergarten departments of private preparatory schools and recognised and unrecognised basic schools.

(2) Primary level

The primary level comprises grades one (1) to six (6) and caters to pupils in the age grouping of six (6) to eleven (11) years. Primary education is offered in public primary, all-age (grades 1 to 6) and private preparatory schools.

Special education is primarily offered in institutions run by private voluntary organizations each of which receive a monthly subvention from the Government. A number of unit classes have also been established in public primary and all-age schools.

(3) Secondary level

The secondary level consists of first cycle secondary and second cycle secondary.

(a) First cycle secondary

Education at this level is offered in grades seven (7) to nine (9) of all-age, new secondary, comprehensive high, secondary high and grades seven (7) or eight (8) to nine (9) of technical high schools. Students gain entry to the different types of secondary institutions offering first cycle education either selectively or non-selectively. Students in grade nine (9) of all-age schools sit the Grade Nine Achievement Test (GNAT) through which entry may be gained to grade nine (9) of secondary and comprehensive high schools.

(b) Second cycle secondary

Education at this level is offered in grades ten (10) to eleven (11) or 13 of secondary high schools, grades ten (10) to eleven (11) of comprehensive high, technical high, new secondary and vocational schools. Entry to grade ten (10) of comprehensive, technical, secondary high and new secondary schools involve an automatic flow from grade nine (9) within each institution. Entry to vocational and agricultural schools is based primarily on students' performance at GNAT. There are two (2) agricultural schools which provide training in agriculture and home economics, and a vocational school which offers home economics for girls only.