Table 3-6 Water Supply Facility by Villages (1/8)

CONCELHO:TARRAFAL

No.	ZONA	No. of Lugar	Population		Type of Water Source					Reservoir	Type of Public Faucets	Taps	Consumption rate (ℓ/d/c)	Supply Time (hr/day)	Water Charge (Esc/20ℓ)	Remarks
			CENSUS 1990	1,998	Borehole Well	Spring	Rainwater	Dug Well	Tank Lorry	(m^3)						
1	Achada Biscainhos	2	73	83					○	$20\ m^3$	C	2	27.0	7.0	5	Delivery : <2 times/week
2	Achada Lagoa	5	203	231		○							12.0			No Access by Tank Lorry
3	Achada Longueira	11	869	930	FTB-121					$40m^3$	A	3	11.5	9.0	4	Pump up : 3 times/week
4	Achada Meio	6	172	196					○	$40m^3$	A	2	19.0	7.0	5	Delivery : 2 times/week
							○			$600m^3$						
5	Achada Moirão	12	778	776	FBE-122					$40m^3$	2A	3	15.0	8.0	3	House Conection : 1
6	Achada Tenda	2	460	569	○					$20m^3$	A	2	13-30	8.0	4	Project is on-going
7	Biscainhos	13	417	475	FBE-122					$40m^3$	3A	3	24.0	9.0	3	House Conection : 3
8	Chão Bom	15	1,845	3,300	FBE-129					$40m^3$	A	3	17, 50	10.0	4	UNICEF Project House Conection:9
9	Curral Velho	1	324	369					○	$30m^3$	B	2	11.6	6.0	5	Delivery : <1 time/week
10	Fazenda	2	141	160				○					28.0			Project is on-going
11	Figueira Muita	3	103	116					○	$40m^3$	A	2	16.0	7.0	5	Delivery : <2 times/week
							○			$700m^3$						
12	Lagoa	7	294	335		○							12.0			No Access by Tank Lorry
13	Mato Brasil	7	216	246	○								11.0			Project is on-going
14	Mato Mendes	9	394	380	P-27					$40m^3$	A	3	7.0	7.0	4	House Conection : 2
15	Milho Branco	4	299	340	FBE-173					$40m^3$	A	3	20.0	8.0	3	
16	Ponta Lobrão	2	283	322					○	$10/30m^3$	C	2	21-23	3.0	5	Delivery : 2 times/week
17	Ribeira da Prata	4	659	750	FBE-150					$9m^3$	B		27.0	6.0	2	House Conection :54
18	Ribeirão Sal	5	75	85	○					$40m^3$	A	3	20.0			
19	Trás os Montes	5	396	349					○	$40m^3$	A	3	25.0	8.0	5	Delivery : 2 times/week
20	Vila do Tarrafal	6	3,626	4,600	○								10.0			URBAN House Conection : 757
	Total		11,627	14,612												

Table 3-6 Water Supply Facility by Villages (2/8)

CONCELHO:**SÃO MIGUEL**

No.	ZONA	No. of Lugar	Population		Type of Water Source					Reservoir	Type of Public Faucets	Taps	Consumption rate	Supply Time	Water Charge	Remarks
			CENSUS 1990	1,998	Borehole Well	Spring	Rainwater	Dug Well	Tank Lorry	(m^3)			(ℓ/d/c)	(hr/day)	(Esc/20ℓ)	
1	Achada do Monte	12	687	736	FBE-126					$40m^3$	A	3	11.0	8.0	3	House Conection
									○	$40m^3$	A	2		6.0	3	
2	Calheta de S. Miguel	12	2,599	2,800	○								35.0			URBAN House Conection
3	Casa Branca	15	711	750				○					8.0			
4	Chã de Ponta	12	554	700					○	$30m^3$	C	2	6.1	4.0	5	Delivery : <1 time/week
5	Cutelo Gomes	25	741	800					○				6.0			Project is on-going
6	Espinho Branco	7	341	389					○	$20m^3$	C	2	29.4	7.0	3	Delivery : 2 times/week
					FT-134					$10m^3$	2A	6		3.0	3	Delivery : 2 times/week
7	Gongon	12	368	414		○										No Access by Tank Lorry
8	Machado	6	251	286		○							14.0			
9	Mato Correia	13	371	423					○	$15m^3$	C	2	11.0	4.0	5	Delivery : < 2 times/week
10	Monte Bode	7	277	316				○								
11	Monte Pousada	13	402	598					○	$30m^3$ (School)			6.0			Delivery : < 1time/week
						○										
12	Palha Carga	15	628	716	FBE-128					$40m^3$	A	3	11.0	7.0	3	
					FBE-124					$20m^3$	B	2				Solar system out of service
13	Pedra Barro	8	335	382					○	$30m^3$		2	15.0	7.0	5	Delivery : 2times/week
14	Pedra Serrado	12	485	553					○	$30m^3$		2	10.3	10.0	5	Delivery : 1time/week
15	Pilão Cão	30	1,055	1,500	FBE-134					$40m^3$	3A	10	17.0	2.0	2	
16	Ponta Verde	1	489	1,000	FBE-144					$40m^3$	A	5	35.0	6.0	2	House Conection
17	Principal	30	1,277	1,457		○				$20m^3$	B	5	10.0	5.0	2	Solar system
18	Ribeirão Milho	7	197	340	FBE-129					$40m^3$						
19	Ribeireta	16	343	237				○								
20	Tagarra	20	743	789				○								
21	Varanda	11	457	500		○							7.0			
22	Xaxa	4	177	250		○										No Access by Tank Lorry
	Total		13,488	15,936												

Table 3-6 Water Facility by Villages (3/8)

CONCELHO:SANTA CATARINA (1/2)

No.	ZONA	No. of Lugar	Population CENSUS 1990	Population 1,998	Type of Water Source: Borehole Well	Spring	Rainwater	Dug Well	Tank Lorry	Reservoir (m³)	Type of Public Faucets	Taps	Consump-tion rate (ℓ/d/c)	Supply Time (hr/day)	Water Charge (Esc/20ℓ)	Remarks
1	Achada Galego	6	378	437	FB-100					40m³	A	3	2	3.0	2	
2	Achada Gomes	7	350	403	FB-83					40m³	A	3		8.0	2	
3	Achada Lazão	1	128	148		○										
4	Achada Leite	1	186	216		○										
5	Achada Lém	30	2,390	2,762	FT-127					80m³	C	3		5.0	3	
					ST-212					100m³	4A	9			2.5	House Conection
6	Achada Ponta	1	178	206	FBE-99					40m³	2A	6		5.0	3	
7	Achada Tossa	11	803	928					○	80m³						Project is under planning
8	Aguas Podres	3	144	165					○							Project is under planning
9	Arribada	2	124	143					○	60m³	C	2		8.0	5	Delivery : 3 times/week
10	Banana Semedo	3	485	562		○										To Cruz Grande
11	Boa Entrada	8	1,063	1,232		○										
12	Boa Entradinha	15	531	603					○	40m³	C	4		3.0	5	Delivery : <1 time/week
									○	40m³	C	2		3.0	5	Delivery : <1 time/week
13	Bombardeiro	16	1,023	1,180				○								
14	Chã de Lagoa	5	476	552					○	60m³	C	2		8.0	10	Delivery : <1 time/week
15	Chã de Tanque	10	1,204	1,396					○	60m³	A	3		8.0	5	Delivery : 3 times/week
	Achada Grande	1	191	222					○	11m³	C	2		7.0	10	Delivery : <1 time/week
							○									
16	Charco	1	311	361		○										
17	Cruz Grande	3	509	591	FBE-67					40m³	A	3		8.0	3	
18	Entre Picos	4	293	339					○	50m³		2				
19	Entre Picos de Reda	1	295	342					○	50m³	C	2			8	Delivery : <1 time/week
20	Figueira das Naus	24	1,091	1,257					○	40m³	C	2			8	Delivery : <1 time/week
21	Fonteana	13	1,038	1,200		○										
22	Fonte Lima	7	823	954		○					A	3		10.0	2	
23	Furna	9	453	521		○										
24	Gamchemba	3	215	249		○										
25	Gil Bispo	9	844	977					○	80m³	A			4.0	5	
26	Japluma	7	193	220		○										
27	João Bernardo	5	400	475	FTB-95					40m³	A	3		8.0	2.5	
28	João Dias	1	508	590		○										
29	Junco	3	83	95		○										
30	Librao	1	529	614	FTB-94					40m³	A	3				
31	Mancholy	7	590	681					○	50m³	A	3		2.0	3	Delivery : 1 time/week Project is under planning
32	Mato Baixo	8	528	611	○					50m³	A	3		5.5	3	Solar system
33	Mato Gege	16	1,196	1,380		○										
34	Mato Sancho	9	459	488	FBE-172					60m³		2				Project is on-going
35	Palha Carga	13	1,248	1,444					○	60m³	C	3		10.0	5	Delivery : <2 times/week
	Sub-total		21,069	24,322												

Table 3-6 Water Facility by Villages (4/8)

CONCELHO:SANTA CATARINA (2/2)

No.	ZONA	No. of Lugar	Population: CENSUS 1990	Population: 1,998	Type of Water Source: Borehole Well	Type of Water Source: Spring	Type of Water Source: Rainwater	Type of Water Source: Dug Well	Type of Water Source: Tank Lorry	Reservoir (m³)	Type of Public Faucets	Taps	Consumption rate (ℓ/d/c)	Supply Time (hr/day)	Water Charge (Esc/20ℓ)	Remarks
36	Pata Brava	5	299	345		○										
37	Pau Verde	7	289	332					○	50m³		3		4.0	5	Delivery : 2 times/week
38	Pedra Barro	5	489	567					○	30m³		2		7.0	5	Delivery : 1 time/week
39	Pedra Serrado	7	127	144					○	30m³		2		10.0	5	Delivery : 2 times/week
40	Pingo Chuva	6	369	417					○	40m³		2		4.0	5	
41	Pinha dos Engenhos	6	949	1,100	FBE-89					40m3	A	3		8.0	2.5	
42	Ribeira Acima	1	254	295		○										
43	Ribeira da Barca	3	1,557	1,809					○	22m³	A	3		8.0	5	Delivery : 3 times/week
44	Ribeirão Isabel	10	519	598				○								
45	Ribeirão Manuel	9	559	646					○	50m³	A	3		3.0	5	Project is on-going
46	Rincão	2	755	877	○					15m³	A	3		6.0	2.5	House Conection
47	Saltos Acima	17	670	769					○	50m³	A	2		5.0	6	Delivery : 1 time/week
48	Sedeguma	12	302	321		○										
49	Serra Malagueta	9	478	552					○	30m³						
50	Tomba Touro	11	355	406					○	50m³	A	2		4.0	5	Project is on-going
51	Vila de Assomada	11	3,414	3,962	○											URBAN House Conection
52	Aboboreiro	18	740	851					○	50m³		2		4.0	5	Delivery : 2 times/week
53	Achada Igreja (Picos)	18	996	1,149	FBE-97					40m³	A	3		4hr/2days	2.5	House Conection
54	Achada Leitão	8	672	777	○ Achada Igreja					50m³	2B	1 2		4.0 4.0	2.5 2	House Conection
55	Babosa	5	254	292	○					15m³		2		8.0	2.5	
56	Burbur	11	253	289		○										
57	Covão Grande	7	492	568					○	50m³	B	2		6.0	5	
58	Degredo	8	204	233		○										
59	Faveta	15	337	386				○		20m³		2			2.5	
60	Jalalo Ramos	19	534	607					○	50m³		3		4.0	5	Delivery : 1 time/week
61	Junco	1	38	44					○	10m³		2			2	
62	Leitão Grande	36	964	1,101	FBE-104					40m³	A	3		6.0	2.5	
63	Leitãozinho	22	492	561					○	50m³		1		5.5	5	Delivery : <1 time/week
64	Manhanga	9	235	268		○										Private water vendor: 800 Esc / m³
65	Mato Fortes	8	201	230				○								
66	Mato Limão	11	246	281				○								
67	Picos Acima	26	1,499	1,730		○				10m3	B	3			3	
68	Pico Freire	10	410	471	FBE-90					40m³	A	3		8.0	2.5	
69	Purgueira	9	430	495					○	60m³		2		5.5	5	Delivery : <3 times/week
70	Rebelo	1	133	154		○										
	Sub-total		20,515	23,627												
	Total		41,584	47,949												

Table 3-6 Water Supply Facility by Villages (5/8)

CONCELHO:SANTA CRUZ (1/2)

No.	ZONA	No. of Lugar	Population CENSUS 1990	Population 1,998	Type of Water Source: Borehole Well	Spring	Rainwater	Dug Well	Tank Lorry	Reservoir (m^3)	Type of Public Faucets	Taps	Consumption rate (ℓ/d/c)	Supply Time (hr/day)	Water Charge (Esc/20ℓ)	Remarks
1	Achada Laje	1	298	363					○	$40m^3$	C	2	6.2			Project is on-going
2	Achada Bel Bel	10	766	1,160					○	$40m^3$	C	2	1.3	4.0	3	Delivery : 3times/week
3	Achada Fazenda	3	1,073	2,394	○					$40m^3$	A	3	32.9	6.0	2	House Conection
4	Achada Ponta	2	331	462					○	$40m^3$	A	3	9.1			Project is on-going
5	Boaventura	14	477	522				○					4.6			Private W. vendor : 20Esc/20ℓ
6	Boca Larga	11	289	289		○							1.5			
7	Cancelo	4	919	1,694					○ ○	$10m^3$ $10m^3$	A A	3 3	3.1	2.0 1.0	3 3	Delivery : <2 times/week Project is on-going Delivery : 3 times/week
8	Chã da Silva	16	996	1,219	SP-9 FT-59 FT-93 FT-169					$50m^3$	2A		6.0			
9	Julangue	0	91	0									1.9			No Body
10	Librão	15	434	515					○	$10m^3$	A	2	4.2			
11	Matinho	13	579	1,141		○							2.0			
12	Monte Negro	19	587	804					○	$10m^3$	A	2	1.3	7.0	3	Delivery : 2 times/week
13	Porto Madeira	18	488	616					○	$50m^3$	A	2	3.0			Project is on-going
14	Rebelo	1	147	196					○	$10m^3$	C	2	17.8	8.0	3	Delivery : 1 time/week
15	Renque Purga	7	774	1,008					○	$22m^3$	A	3	11.7	5.0	3	Delivery : 3 times/week Project is on-going
16	Ribeira Seca	15	617	623	FT-63 FT-9 FT-169				○	$20m^3$ Private			5.0			Project is under planning
17	Ribeirão Almaço	9	174	260				○					2.0			
18	Ribeirão Boi	13	678	641					○	$11m^3$	A	3	1.9	4.5	3	Delivery : 3 times/week
19	Rocha Lama	3	438	534	○								32.9			House Conection
20	Saltos Abaixo	14	900	646				○					5.0			Project is on-going
	Sub-total		11,056	15,087												

Table 3-6 Water Supply Facility by Villages (6/8)

CONCELHO:SANTA CURZ (2/2)

No.	ZONA	No. of Lugar	Population		Type of Water Source					Reservoir	Type of Public Faucets	Taps	Consumption rate	Supply Time	Water Charge	Remarks
			CENSUS 1990	1,998	Borehole Well	Spring	Rainwater	Dug Well	Tank Lorry	(m^3)			(ℓ/d/c)	(hr/day)	(Esc/20ℓ)	
21	Santa Cruz	12	920	1,126	PT-31					$40m^3$	A	3	11.6	8.0	2	
									○	$30m^3$	C	2				Delivery : 2 times/week
22	São Cristóvão	21	603	700					○	$20m^3$	C	2	4.7	4.0	3	Delivery : 2 times/week
									○	$20m^3$	C	2		4.0	3	Delivery : 2 times/week
23	Serelho	13	434	466					○	$11m^3$	A	2	3.9	7.0	2	Delivery : < 2 times/week
24	Vila de Pedra Badejo	8	5,302	8,544	○								32.9			URBAN House Conection
25	Achada Costa	7	303	360					○	$50m^3$	A	2	4.7	2.0	3	Delivery : 2 times/week
26	Boca Larga	19	630	768					○	$22m^3$	C	2	6.1			Project is on-going
27	Fundura	7	219	282					○	$11m^3$	C	2	8.1	5.0	2	Delivery : < 2 times/week
28	João Goto	8	232	357					○	$11m^3$	C	2	5.0	5.0	3	Delivery : 2 times/week
29	João Teves	20	1,550	1,878	FT-84					$40m^3$	4A	6	5.8	4.0	2	House Conection Project is on-going
30	Lage	8	335	403	FT-80					$40m^3$	A	3	16.8	6.0	2	House Conection
31	Levada	10	218	310					○	$20m^3$	C	2	2.2	5.0	3	Delivery : 1 time/week
32	Longueira	9	441	326		○							10.0			
33	Montanha	21	900	972					○				1.7			Project is on-going
34	Orgaos Pequeno	14	573	708	FT-371					$40m^3$	A	3	12.0	6.0	2	Project is under planning
35	Pico Antónia/Padjom	15	659	664	FT-21					$50m^3$	A	3	12.9	4.0	2	
36	Pedra Molar	9	449	755					○	$11m^3$	A	4	13.2	5.0	2	Delivery : 2 times/week
					FT-21					$50m^3$	A	3		6.0	2	
37	Poilão Cabral	6	244	674	FT-371					$40m^3$	A	3	2.8	6.0	2	Project is under planning
38	São Jorge	9	1,132	1,451	FT-23					$16m^3$	A	4	5.0	8.0	2	Project is on-going
					FT-145					$11m^3$	C	2		2.0	3	
	Sub-total		15,144	20,745												
	Total		26,200	35,832												

Table 3-6 Water Supply Facility by Villages (7/8)

CONCELHO:SÃO DOMINGOS

No.	ZONA	No. of Lugar	Population		Type of Water Source					Reservoir (m^3)	Type of Public Faucets	Taps	Consumption rate (l/d/c)	Supply Time (hr/day)	Water Charge (Esc/20l)	Remarks
			CENSUS 1990	1,998	Borehole Well	Spring	Rainwater	Dug Well	Tank Lorry							
1	Achada Baleia	1	267	317	FT-25					$33m^3$	A	3	14.6	7.0	2	
2	Baia	6	441	524	FT-44					$22m^3$	2A	6	12.7	2.0	2	
									○	$11m^3$	A	2	13.6	2.0	4	Delivery : 1 time/week
3	Cancelo	3	226	270	FT-25					$11m^3$	A	2	12.3	6.0	2	
4	Chão de Coqueiro	6	195	213					○	$22m^3$	A	2	8.1	3.0	4	Delivery : 1 time/week
5	Dobe	2	140	167	FT-208						A	3	11.8	4.0	2	
6	Milho Branco	12	538	650					○	$22m^3$	A	2	12.3	3.0	4	Delivery : 3 times/week
7	Portal	3	368	440				○					9.7			
8	Praia Baixo	6	701	833					○	$22m^3$	A	2	4.5	6.0	5	Delivery : 2 times/week
									○	$22m^3$	A	2	14.8	4.0	5	Delivery : 2 times/week
9	Praia Formosa	11	621	740					○	$22m^3$	A	3	7.6	4.0	4	Delivery : 2 times/week
									○	$22m^3$	C	2		3.0	4	Delivery : <1 time/week
10	Vale da Custa	4	357	424					○	$33m^3$			4.4			Project is under planning
11	Achada Mitra	9	255	303					○	$22m^3$	C	2	6.2	6.0	5	Delivery : <2 times/week
12	Água de Gato	13	957	1,200		○							16.4		Free	
13	Banana	10	266	316					○	$33m^3$	A	2	5.9	2.0	4	Delivery : 2 times/week
14	Chaminé	6	119	150					○	$22m^3$	C	1	13.2	3.0	4	Delivery : 1 time/week
15	Dacabalaio	5	210	250					○	$50m^3$	C	2	14.6		7	Delivery : 1 time/2weeks
16	Fonte Almeida	13	698	830					○	$22m^3$	C	2	4.5	1.0	4	Delivery : <2 times/week
17	Godim	4	277	330					○	$33m^3$	A	3	11.3	2.0	4	Delivery : <1 time/week
18	Lagoa	1	190	230		○				$33m^3$	A		16.9		Free	Reservoir and Chafariz not in use
19	Loura	6	350	390					○	Private			7.5		5	Delivery : 3 times/week
							○			$400m^3$	A	3			2	8 Month a year
20	Mato Afonso	7	386	460					○	$22m^3$	A	3	12.2	2.0	5	Delivery : 1 time/week
21	Mendes Faleiro Cabral	7	101	120					○	$22m^3$	A	2	14.8	2.5	4	Delivery : 1 time/week
22	Mendes Faleiro Rendeiro	10	218	260					○	$33m^3$	A	3	7.2	5.0	4	Delivery : 3 times/week
23	Nora	4	380	458					○	$22m^3$	B	2	12.4	4.0	4	Delivery : 2 times/week
24	Po de Saco	2	168	210		○							9.7			
25	Ribeirão Chiqueiro	5	559	664	FT-53					$33m^2$	A	5	13.4	7.0	2	Project is under planning
26	Robão de Cal	12	216	257					○	$22m^2$			14.5			Project is on-going
27	Rui Vaz	11	812	956					○	$33m^3$	B	2	5.8	6.0	7	Delivery : <1 time/week
28	Várzea da Igreja	14	1,860	2,212	○								8.0			URBAN House Conection
	Total		11,876	14,174												

Table 3-6 Water Supply Facility by Villages (8/8)

CONCELHO:**PRAIA**

No.	ZONA	No. of Lugar	Population CENSUS 1990	Population 1,998	Type of Water Source: Borehole Well	Spring	Rainwater	Dug Well	Tank Lorry	Reservoir (m^3)	Type of Public Faucets	Taps	Consumption rate (ℓ/d/c)	Supply Time (hr/day)	Water Charge (Esc/20ℓ)	Remarks
1	Agostinho Alves	1	113	126					○	$10m^3$		2				
2	Calheta São Martinho	1	9	10	○											
3	Cidade da Praia	31	61,644	89,680	○											URBAN House Conection
4	Costa Achada	1	13	14	○											
5	Palmarejo Grande	1	79	88	○											
6	Pedregal	2	25	27					○							
7	São Francisco	4	446	490	○					$20m^3$	A	3		3.0	2	Project is under planning
					FBE-138						A	4		5.0	2	
8	São Martinho Grande	6	861	960	○					$30m^3$	A	3		2.5	2	
						○					A	2				Chafariz not in use
9	São Martinho Pequeno	15	1,153	1,279	FT-200					$30m^3$	A	3		5.0	2	
10	São Tomé	2	230	256					○	$22m^3$	B	2		3.0	4	Delivery : <2 times/week
11	Veneza	1	176	196		○										
12	Calabaceira	2	181	201	FT-280					$10m^3$	A	3			5	Wind power Project is under planning
13	Cidade Velha	10	961	1,068		○				$70m^3$	2A	6		7.0	2.0	House Conection Project is under planning
14	João Varela	2	309	344	○					$20m^3$	A	3		3.0	2	
15	São Martnho Grande	1	118	131	○											Project is under planning
16	Salineiro	1	856	956					○	$50m^3$						Project is under planning
17	Beatriz Pereira	3	185	205	FT-353					$20m^3$						
18	Belém	11	447	495		○				$40m^3$	A	3		9.0	2	
									○						5	Delivery : <2 times/week
19	Chã de Igreja	1	182	203	FT-153					$50m^3$	A	3		10.0	2	
20	Chã Gonçalves	1	164	183		○				$20m^3$	A	3				
21	Delgado	1	49	54		○										
22	Gouveia	5	249	219	○					$50m^3$	A	3		8.0	2	
23	Mosquito de Horta	5	117	128	FT-227					$10m^3$	A	2				
24	Mosquito Grande	2	122	135		○										
25	Pico Leão	19	653	718		○										Project is on-going
26	Porto Mosquito	1	492	549	FBE-138					$20m^3$	A	3		5.0	2	
27	Santana	6	906	1,008		○				$50m^3$	A				Free	Reservoir and Chafariz not in use
28	Tronco	5	186	206		○										
	Total		70,926	99,929												

3.3.3 Condition of Existing Water Supply Facilities

1) Pumps

Submersible motor pumps with generator and vertical borehole pumps driven by turbine engine are commonly used to pump water from boreholes. Electrical control systems, except low cut devices, are not used. The pumps are manually operated by experienced pump attendants.

Windmill pumps were once common, but almost all are out of order in Santiago Island. Five sets of solar energized pump units have been introduced under the Regional Solar Program. Two are not working at present as the panels have been stolen.

2) Reservoir tank

Most of the reservoir (distribution) tanks are made of stone blocks fixed in concrete, while some are built of concrete blocks. The tanks are generally well maintained: only 2 of the 169 tanks are broken and not used. The capacity of the tanks, commonly ranging from 20 to 40 m^3, does not seem to be in accordance with the number of population served, probably because of the availability of tank lorry water delivery services.

3) Water sterilization system

The water sterilization devices are not attached to the reservoir tanks. The tank attendant prepares chlorine solution in a bucket every day and pours it into the tank. This is only carried out, however, though if the municipal water supply office has supplied bleaching powder to the villages.

4) Trunk main and distribution pipelines

For the transmission pipelines connecting the well and tanks and the distribution pipelines connecting the tanks and public faucets, galvanized steel pipes are used for the exposed portion, while PVC pipes are commonly used for underground installation. In most cases, the pipe diameter is not properly designed in accordance with the water flow.

5) Public faucets

The following 4 types of public faucets are used in the area:

- 2 or 3 taps in a building with a shower room and/or toilet(*chafariz*, sanitary complex)
- 2 taps in a building (*chafariz*)
- Outdoor stand pipe type with 2 taps (*fontenario*)
- 2 taps directly attached to the reservoir tank

The faucets are maintained in good condition by the 'water vendor', who is responsible for the collection of water charges.

6) Tank lorry

Water is transported from the water feeding stations to the reservoir tanks, which are not linked to water source, by municipal tank lorries or private trucks on a contract basis. The transportation service is usually regularly carried out. However, vehicular breakdowns or difficult to access roads upset the service schedule especially during the rainy season.

3.3.4 Classification of Villages by Service Level

In view of the water supply service level and/or the water requirement for domestic use, 206 communities in Santiago Island (1 city, 5 towns, and 200 villages) were classified into the following 4 categories:

Category 1 92 villages

Villages without sufficient safe and stable domestic water source or very difficult to access water source. Villages where public supply services are very poorly extended, greatly inconveniencing the residents, and with an average daily water consumption rate ranging from 4 to less than 12 liters per capita (l/c/d).

Improvement projects are currently being implemented in or planned for 33 of these villages; refer to Rank A and 'On-going' in Table 3-8.

Category 2 63 villages

Conditions are similar to category 1, but slightly better; average supply/consumption rate is 8 to 16 l/c/d. Refer to Rank B in Table 3-8.

Category 3 46 communities, including 1 city and 5 towns

Good water sources (springs) are located near houses, or the public water supply services coverage has been extended, resulting in a comparatively reasonable consumption/supply amount of 15 to more than 20 l/c/d. Future population increase, however, is seen to result in a shortage in water supply. Although these areas require the implementation of the project, the need is not urgent. Refer to Rank C and 'Urban' in Table 3-8.

Category 4 5 villages (one of which has dispersed probably due to severe living conditions)

Insufficient water source (spring yield) and the absence of public water supply services. The implementation of the project in these areas is necessary, but it seems that the project implementation is very difficult hindered by steep topographic feature and poor accessibility to the village concerned. Refer to Rank D in Table 3-8.

The number of the above-categorized villages by municipality is as shown in Table 3-7, and the classified villages are listed in Table 3-8.

Table 3-7 Number of Classified Villages by Municipality

	A	B	C	D	On Going Projects	Under Planning Project	Urban	Total
TARRAFAL	1	5	7	2	4	0	1	20
SÃO MIGUEL	8	5	5	2	1	0	1	22
SANTA CATARINA	21	29	13	0	3	3	1	70
SANTA CRUZ	11	6	6	1	10	3	1	38
SÃO DOMINGOS	13	9	2	0	1	2	1	28
PRAIA	5	9	7	0	1	5	1	28
Total	59	63	40	5	20	13	6	206

Table 3-8 Priority Classification of the Villages

No.	ZONA	Pop.	W.S.	Rank	Prio.
Tarrafal					
9	Curral Velho	369	T	A	3
19	Trás os Montes	349	T	A	7
4	Achada Meio	196	T,R	B	1
11	Figueira Muita	117	T,R	B	2
16	Ponta Lobrão	322	T	B	6
3	Achada Longueira	930	B	B	15
1	Achada Biscainhos	83	T	C	8
7	Biscainhos	475	B	C	12
5	Achada Moirão	776	B	C	
14	Mato Mendes	380	B	C	
15	Milho Branco	340	B	C	
17	Ribeira da Prata	750	B	C	
18	Ribeirão Sal	85	B	C	
2	Achada Lagoa	231	S	D	
12	Lagoa	335	S	D	
10	Fazenda	160	S,D	P.G	4
6	Achada Tenda	569	B	P.G	5
13	Mato Brasil	246		P.G	9
8	Chão Bom	3,300		P.G	
20	Vila do Tarrafal	4,600		URBAN	
São Miguel					
9	Mato Correia	423	T,S	A	1
10	Monte Bode	316	S,D	A	2
14	Pedra Serrado	553	T	A	3
13	Pedra Barro	382	T	A	4
4	Chã de Ponta	700	T,D	A	5
11	Monte Pousada	598	T	A	6
3	Casa Branca	750	S,D	A	9
18	Ribeirão Milho	340	S	A	11
20	Tagarra	789	B	B	12
21	Varanda	500	S	B	13
12	Palha Carga	716	B	B	16
19	Ribeireta	237	D	B	18
17	Principal	1,457	B,S	B	28
8	Machado	285	SG	C	22
16	Ponta Verde	1,000	B	C	23
6	Espinho Branco	389	T	C	26
15	Pilão Cão	1,500	B	C	27
1	Achada Monte	784	B,T	C	30
7	Gongon	414	S	D	19
22	Xaxa	250	S	D	20
5	Cutelo Gomes	800		P.G	8
2	Calibeta de S. Miguel	2,800		URBAN	
Santa Catarina					
15	Chã de Tanque	1,396	T,S	A	1
35	Palha Carga	1,444	T,S	A	2
19	Entre Picos de Reda	342	T	A	3
20	Figueira das Naus	1,257	T	A	4
43	Ribeira da Barca	1,809	T	A	5
36	Pata Brava	345	S	A	8
13	Bombardeiro	1,180	S,D	A	10
57	Covão Grande	568	S,D	A	13
47	Saltos Acima	769	B	A	14
42	Boa Entradinha	603	T	A	
41	Chã de Lagoa	552	T	A	
40	Pingo Chuva	417	T	A	
44	Ribeirão Isabel	598	D	A	
48	Sedeguma	321	S	A	
49	Serra Malagueta	552	S	A	
56	Burbur	289	S	A	
60	Jalalo Ramos	607	T	A	
63	Leitãozinho	561	T	A	
64	Manhanga	268	S	A	
65	Mato Fortes	230	D	A	
66	Mato Limão	281	D	A	
67	Picos Acima	1,730	SG	B	7
24	Gamchemba	249	S,D	B	12
2	Achada Gomes	403	B,S	B	
3	Achada Lazão	148	S	B	
4	Achada Leite	216	S	B	
5	Achada Lém	2,762	B	B	

No.	ZONA	Pop.	W.S.	Rank	Prio.
Santa Catarina					
9	Arribada	143	T	B	
10	Banana Semedo	562	S	B	
11	Boa Entrada	1,232	S	B	
16	Charco	361	S	B	
18	Entre Picos	339	T	B	
21	Fonteana	1,200	S	B	
22	Fonte Lima	954	SG	B	
23	Furna	521	S	B	
25	Gil Bispo	977	S	B	
26	Japluma	220		B	
28	João Dias	590	S	B	
30	Librão	614	S	B	
33	Mato Gege	1,380	S	B	
37	Pau Verde	332	S	B	
38	Pedra Barro	567		B	
39	Pedra Serrado	144		B	
42	Ribeira Acima	295		B	
52	Aboboreiro	851	T	B	
58	Degredo	233	S	B	
59	Faveta	386	D	B	
62	Leitão Grande	1,101	B,S	B	
69	Purgueira	495	T	B	
70	Rebelo	154		B	
1	Achada Galego	437	B	C	
6	Achada Ponta	206	B	C	
17	Cruz Grande	591	B	C	
27	João Bernardo	475	B	C	
29	Junco	95	S	C	
32	Mato Baixo	611	B	C	
41	Pinha dos Engenhos	1,100	B	C	
46	Rincão	877	B	C	
53	Achada Igreja (Picos)	1,149	B	C	
54	Achada Leitão	777	B,D	C	
55	Babosa	292	B	C	
61	Junco	44	T	C	
68	Picos Freire	471	B	C	
34	Mato Sancho	488	S,D	P.G	
45	Ribeirão Manuel	646		P.G	
50	Tomba Touro	406		P.G	
31	Mancholy	681		P.P	6
7	Achada Tossa	928		P.P	
8	Aguas Podres	165		P.P	
51	Vila de Assomada	3,962		URBAN	
Santa Cruz					
23	Serelho	466	T	A	1
14	Rebelo	196	T	A	2
18	Ribeirão Boi	641	T	A	3
5	Boaventura	522	D	A	4
25	Achada Costa	360	T	A	5
31	Levada	310	T	A	6
27	Fundura	282	T	A	7
11	Matinho	1,141	S,D	A	10
17	Ribeirão Almaço	260	D	A	14
6	Boca Larga	289	S	A	
22	São Cristóvão	700	T,D	A	
12	Monte Negro	804	T	B	8
28	João Goto	357	T	B	9
8	Chã da Silva	1,219	B,D,S	B	
10	Librão	515	B,D,T	B	
32	Longueira	326	S	B	11
35	Pico Antónia/Padjom	664	B,S	B	
2	Achada Bel Bel	1,160	T,D	C	
3	Achada Fazenda	2,394	B	C	
19	Rocha Lama	534		C	
21	Santa Cruz	1,126	B,T,S	C	
30	Lage	403	B	C	
36	Pedra Molar	755	B,T	C	12
9	Julangue	0		D	
1	Achada Laje	363	T	P.G	
4	Achada Ponta	462		P.G	
7	Cancelo	1,694		P.G	

No.	ZONA	Pop.	W.S.	Rank	Prio.
Santa Cruz					
13	Porto Madeira	616		P.G	
15	Renque Purga	1,008	T,S	P.G	
20	Saltos Abaixo	646		P.G	
26	Boca Larga	768		P.G	
29	João Teves	1,878		P.G	15
33	Montanha	972		P.G	
38	São Jorge	1,451		P.G	
16	Ribeira Seca	623	B,D	P.P	
34	Orgãos Pequeno	708	B,D	P.P	
37	Poilão Cabral	674	B	P.P	
24	Vila de Pedra Badejo	8,544		URBAN	
São Domingo					
27	Rui Vaz	956	T,S	A	1
15	Dacabalaio	250	T	A	4
20	Mato Afonso	460	T,S	A	6
11	Achada Mitra	303	T	A	8
14	Chaminé	150	T	A	9
21	Mendes Faleiro Cabral	120	T	A	11
24	Pa de Saco	210	SG	A	12
13	Banana	316	T	A	13
16	Fonte Almeida	830	T,D	A	14
9	Praia Formosa	740	T	A	15
6	Milho Branco	650	T	A	16
8	Praia Baixo	833	T	A	17
4	Chão de Coqueiro	213	T	A	32
19	Loura	390	T,R	B	2
17	Godim	330	T	B	7
22	Mendes Faleiro Rendeiro	260	T	B	10
3	Cancelo	270	B	B	18
5	Dobe	167	B	B	19
2	Baia	524	B,T	B	20
1	Achada Baleia	317	B	B	25
23	Nora	458	T	B	27
18	Lagoa	230	T	B	29
7	Portal	440	D	C	22
12	Água de Gato	1,200	S	C	30
26	Robão de Cal	257		P.G	5
10	Vale da Custa	424		P.P	3
25	Ribeirão Chiqueiro	664		P.P	26
28	Várzea da Igreja	2,212		URBAN	23
Praia					
27	Santana	1,008	SG	A	2
28	Tronco	206	S	A	3
18	Belém	495	T,S	A	4
10	São Tomé	256	T	A	5
8	São Martinho Grande	960	B,S	A	
1	Agostinho Alves	126	T	B	
11	Veneza	196		B	
14	João Varela	344	B	B	
17	Beatriz Pereira	205		B	
19	Chã de Igreja	203	B	B	
22	Gouveia	219	B	B	
23	Mosquito de Horta	128	B	B	
24	Mosquito Grande	135	B	B	
26	Porto Mosquito	549	S	B	
2	Calheta São Martinho	10		C	
4	Costa Achada	14		C	
5	Palmarejo Grande	88		C	
6	Pedregal	27		C	
9	São Martinho Pequeno	1,279	B	C	
20	Chã Gonçalves	183	SG	C	
21	Delgado	54		C	
25	Pico Leão	718		P.G	
16	Salineiro	956		P.P	1
12	Calabaceira	201		P.P	6
7	São Francisco	490		P.P	
13	Cidade Velha	1,068		P.P	
15	São Martinho Grande	131		P.P	
3	Cidade da Praia	89,680		URBAN	

Pop. : Estimated Population 1998
W.S. : Type of water source
Rank. : Ranking by priority
Prio. : Prioritization by Municipality
P.G : Project is on-going
P.P : Project is under planning

Water Source
B : Borehole Well
D : Dug Well
R : Rainfall Collection (Large scale)
S : Spring
SG : Spring (Gallery)
T : Tank Lorry

3.3.5 Operation and Maintenance

1) Responsible agencies for operation and maintenance and their roles

According to the Water Code of the Republic of Cape Verde, the INGRH and each municipality are responsible for the management of the water sources, as well as the operation and maintenance (O/M) of their facilities. Each municipality strives to upgrade the level of their services with the supervision and technical assistance of INGRH under a concession contract.

Under the concession contract, INGRH is responsible for water quality control and manpower training for O/M. The municipalities pay water tax as a water resource management fee in proportion to water production.

Rural water supply facilities are operated and maintained by the technical divisions for water and energy of each municipality, except for the municipalities of Praia and Santa Catarina. In the municipality of Praia, water supply O/M is fully undertaken by EMAP (Municipal Enterprise of Praia). In the municipality of Santa Catarina, since a concession contract for rural water supply has not been concluded yet with INGRH, O/M is directly undertaken by INGRH through its Santa Catarina Branch Office. The municipality provides water to some areas of Assomada Town and its surroundings. The Santa Catarina Branch Office is foreseen to close down within few years, and consequently a new municipal department will be established soon to take over its responsibilities. In other municipalities, the technical divisions for water and energy are expected to be elevated to the department status to establish financial autonomy, as in EMAP of Praia Municipality.

Although some are hired as reservoir attendants or water vendor by the municipality, the majority of the villagers (beneficiaries) do not participate in O/M activities. Many of the beneficiaries complain about the short service hours or unreliable delivery services, but have no idea of how to improve the situation, entirely relying on the services of the municipality. The only contribution they make to the water supply services is paying the water fee imposed (cash on delivery basis) for the use of the facilities.

Ongoing projects (e.g., FENU project) implemented with the financial assistance of UNDP are, however, introducing new concepts in water supply O/M, i.e. O/M with public participation.

2) Workshops for facility maintenance

INGRH has workshops in Praia and Santa Catarina for the repair of pumping units, vehicles and other equipment. Repair is made in accordance with the request of the municipality concerned. The technical division of the municipality has no workshop, although repair of vehicles and general machinery are carried out at the municipal workshop; this does not require the submission of a request to INGRH.

Condition of the workshops is as follows;

- INGRH workshop in Praia

  The premises of the INGRH workshop in Praia is fenced with concrete blocks. Half of the premises is used for materials and the other half is constructed with an office building, repair shop, garage and parking space. The office building is small and old requiring renewal and expansion to provide more work space. The repair shop is open on the sides, exposing the machinery for repair to dust. There is no warehouse, therefore, the PVC pipes are laid on the ground and exposed to the sun. This workshop has a shortage of vehicles, repair tools, spare parts and standby machinery.

- INGRH workshop in Santa Catarina

  The INGRH branch office in Cruz Grande covers the water supply services for the rural area of Santa Catarina. The premises holds an office building, a large but empty warehouse, and a repair shop without any spare parts and repair tools. The office owns only one antiquated pick-up truck and one motorbike. It is, therefore, very unlikely that this office can carry out excellent maintenance services.

- Municipal workshop

  The municipal workshops are comparatively well equipped except those in the new municipalities of Sao Miguel and Sao Domingos.

  Trucks for water transportation, generators and other common machinery are usually repaired in this workshop. However, all municipal workshops are confronted with severe shortage of manpower, especially assistant mechanics, because this usually entails training of amateurs.

3) Water quality control

Drinking water quality analysis is mainly conducted by INGRH, and some of the municipalities carry out a few of the tests under the guidance of INGRH.

Water quality tests are not, however, regularly undertaken at the municipal level due to insufficient apparatus and chemicals.

3.3.6 Waterborne Diseases

Diarrhea and enteritis are among the most common water-borne diseases in the Island. Occasionally typhoid or cholera outbreaks occur as well due to contaminated water conditions.

The November 1994 cholera epidemic in Praia was so widespread, affecting the entire island and almost the entire nation itself if not for the preventive activities carried out by CCC. The epidemic lasted over a year, peaking in the rainy season (between August and November1995). Understandably, Santiago Island suffered the most nationwide, with nearly 10,000 persons affected by the disease and 205 killed (12,501 cases, 306 deaths nationwide)

From the beginning of the epidemic, the Commission for Banishing Cholera (CCC), an inter-ministerial organization headed by the Minister of Infrastructure, began promoting the following activities: sanitary campaigns and chlorination of water supply sources and facilities. These activities were continued for a while after the epidemic ended, and consequently reduced the prevalence of other water-borne diseases. From the 1994/1995 epidemic, every municipality has decided to chlorinate the water everyday. After a certain time, however, the disinfecting process is often neglected, more so recently most probably due to shortage in disinfectant or the negligence of the persons in charge.

4 HYDROLOGY AND HYDROGEOLOGY

The survey on hydrology and hydrogeology was conducted from June 1998 to December 1998 on the entire island of Santiago. The survey work began with the collection and analysis of existing data and information, then proceeded to various field surveys and their analyses. All of these surveys and analyses were intended for the evaluation of the groundwater development potential in the hydrogeological basins and the production of the hydrogeological map of the Island.

The study consists of the following surveys:

a) Collection and review of existing data

- Meteorological data
- Well and spring inventory
- Satellite images and aerial photographs
- Maps (topography, geology, hydrogeology, land use, etc.)
- Reports and materials on geological and hydrogeological surveys
- Other relevant data and information

b) Field survey and analysis

- Field reconnaissance on topography and geology
- Study on spring flow mechanism
- Survey on existing wells
- Geophysical survey (electrical resistivity sounding)
- Simultaneous groundwater level measurement
- Pumping test of existing wells
- Water quality analysis

4.1 Topography and Hydrology

4.1.1 General topographic features

Santiago Island is a volcanic island on the Atlantic Ocean about 700 km offshore of West Africa, situated within 23°26'~ 23°48' west longitude and 14°54'~15°20' north latitude. The island is about 1,005 km^2 with a maximum NNW-SSE length of 56 km and a maximum WSW-ENE width of 29 km.

Geologically made up of rocks of volcanic origin, steep mountainous and hilly areas occupy more than 80% of the island. The island features few flat areas, such as the central plateau corresponding to highly eroded mountains and narrow alluvial plains along rivers or the coast.

The island has two major mountain ranges: Serra da Malagueta running east-west along the northern part of the island, with the apex towering at 1,064m above sea level, and Serra do Pico da Antonia which runs southward through the island and then south-eastward. The latter has the highest peak in the island (Pico da Antonia, 1,394m).

Most of the rivers and tributaries have steep gradients and cut deep V-shaped valleys and gorges; they have not significantly deepened recently. The rivers seem to have been shaped during periods of higher precipitation several ten thousand years ago.

The coastline is composed mostly of rocky cliffs and shores, except at the mouth of major rivers. Sandy beaches are limited to less than 1% of the total length of the coastline.

4.1.2Division of Hydrogeological Basins

The island is divided into 5 hydrogeological basins, which all comprise several catchment areas of various sizes. The major mountain ranges, Serra da Malagueta and Serra do Pico da Antonia, which geographically divide the basins, control the directions of both surface water and groundwater flows.

The 5 hydrogeological basins are:

- Tarrafal basin: Northern side of Serra da Malagueta; divided into 2 sub-basins
- Santa Cruz basin: Northeastern side of Serra do Pico da Antonia; divided into 3 sub-basins, including the catchment area of the Ribeira Seca
- Santa Catarina basin: Southern side of Serra da Malagueta and western side of Serra do Pico da Antonia, including 3 major catchment areas of the Barca, Charco and Aguas rivers that flow westward
- Sao Joao Baptista basin: Southwestern side of Serra do Pico da Antonia
- Praia basin: The southernmost basin in the island

The division map is presented in Fig. 4-1, and the groundwater development potential of these basins and sub-basins has been evaluated.

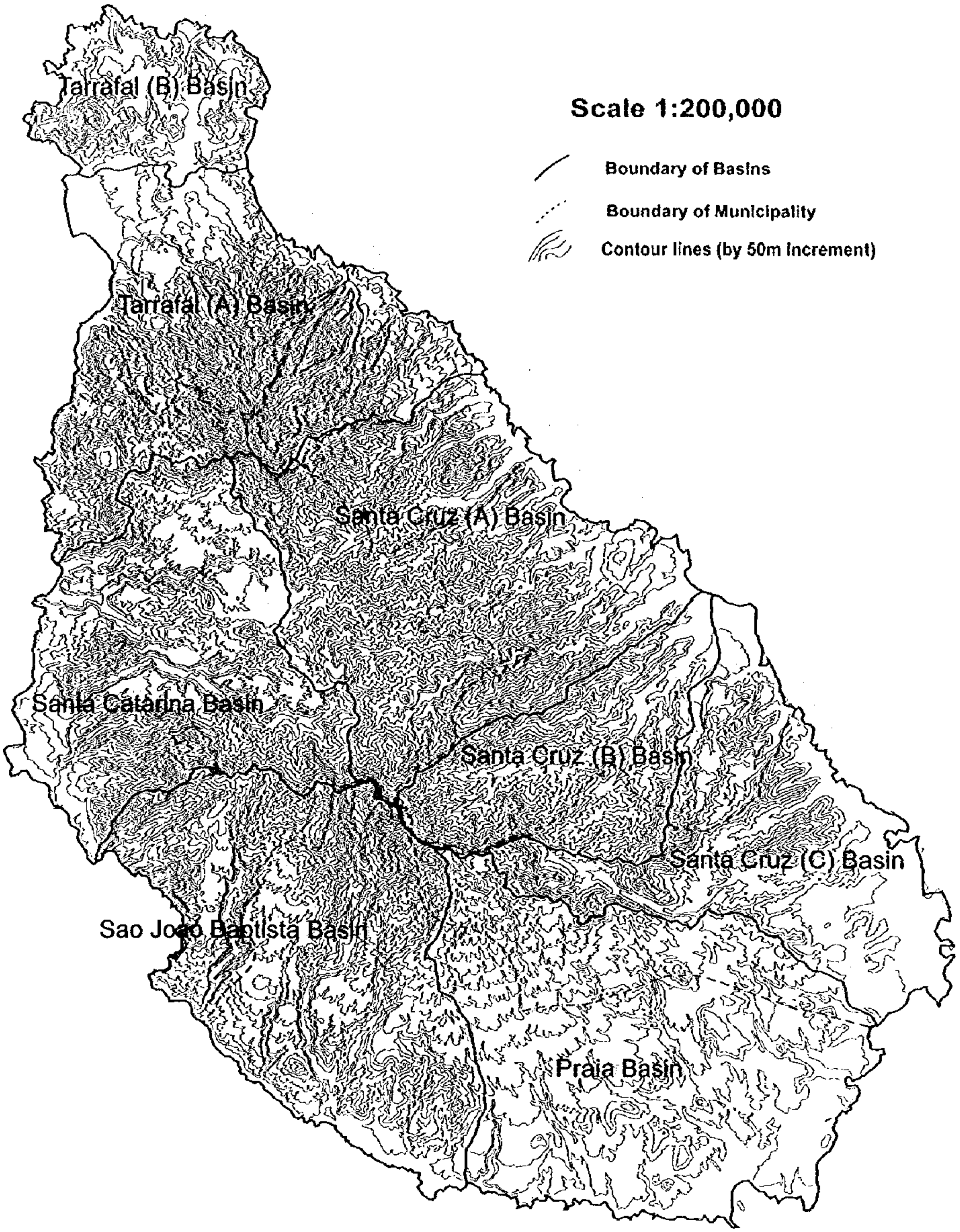

Figure 4-1 Hydrogeological Basins and Topographic Contour Map

4.1.3 Precipitation

The mean annual precipitation in Santiago Island for the past 40 years is about 270mm. The rainy season usually lasts only 3 to 3.5 months a year, from August to November, and about 80% of the total rainfall occurs within the months of August and September. Fig. 4-3 shows significant year-on-year variations in rainfall recently, especially in the last 2 decades. It also seems that the rainy season has become shorter and that the total annual rainfall has been decreasing for the last 2 decades.

Rainfall in the island increases with altitude. Whereas the central highlands have 400~700mm/annum, lower areas have limited rainfalls of 100~200mm/annum. The isohyetal pattern seems to correspond to contours. Referring to the isohyetal map presented in Fig. 4-2, the total volume of mean annual precipitation in each of the above-mentioned basins is calculated as follows:

	Total rainfall amount	Mean rainfall
- Tarrafal basin (188 km^2)	55.97 million m^3	270mm
- Santa Cruz basin (355 km^2)	114.97 million m^3	330mm
- Santa Catarina basin (128 km^2)	33.20 million m^3	260mm
- S. J. Baptista basin (155 km^2)	28.48 million m^3	180mm
- Praia basin (179 km^2)	38.20 million m^3	210mm
Santiago Island (1,005 km^2)	270.82 million m^3	(270mm)

Table 4-1 shows rainfall and its volume by area and by basin.

Table 4-1 Rainfall and Rainfall Volume by Basin

Hydrogeological Basin		Annual Rainfall (mm) 100	150	200	250	300	350	400	450	500	550	600	650	700	*Total*	*Annual Average Precepitation (mm)*
TARRAFAL(A)	Area (km2)	-	6.398	46.530	21.380	12.787	9.729	8.784	8.726	7.714	7.667	8.615	3.898	0.348	*142.576*	*325*
	Annual Rain Volume (million m3)	-	0.960	9.306	5.345	3.836	3.405	3.513	3.927	3.857	4.217	5.169	2.534	0.244	*46.313*	
TARRAFAL(B)	Area (km2)	-	4.041	25.346	15.919	-	-	-	-	-	-	-	-	-	*45.306*	*213*
	Annual Rain Volume (million m3)	-	0.606	5.069	3.980	-	-	-	-	-	-	-	-	-	*9.655*	
SANTA CRUZ(A)	Area (km2)	-	-	36.957	30.293	27.068	20.423	30.097	15.653	7.251	2.614	0.651	0.015	-	*171.023*	*320*
	Annual Rain Volume (million m3)	-	-	7.391	7.573	8.120	7.148	12.039	7.044	3.625	1.438	0.391	0.010	-	*54.780*	
SANTA CRUZ(B)	Area (km2)	-	-	-	7.360	23.060	14.879	15.454	10.338	0.023	-	-	-	-	*71.114*	*349*
	Annual Rain Volume (million m3)	-	-	-	1.840	6.918	5.208	6.182	4.652	0.011	-	-	-	-	*24.811*	
SANTA CRUZ(C)	Area (km2)	-	2.406	10.735	17.332	28.712	37.360	10.360	6.004	-	-	-	-	-	*112.909*	*313*
	Annual Rain Volume (million m3)	-	0.361	2.147	4.333	8.614	13.076	4.144	2.702	-	-	-	-	-	*35.376*	
SANTA CATATINA	Area (km2)	-	27.408	25.990	21.066	20.265	18.912	13.071	1.505	0.043	-	-	-	-	*128.259*	*259*
	Annual Rain Volume (million m3)	-	4.111	5.198	5.266	6.079	6.619	5.228	0.677	0.022	-	-	-	-	*33.202*	
S.J. BAPTISTA	Area (km2)	38.776	46.882	29.061	18.577	10.931	7.807	2.608	0.139	-	-	-	-	-	*154.782*	*184*
	Annual Rain Volume (million m3)	3.878	7.032	5.812	4.644	3.279	2.733	1.043	0.063	-	-	-	-	-	*28.484*	
PRAIA	Area (km2)	-	68.271	48.146	27.196	23.933	7.516	2.721	1.411	-	-	-	-	-	*179.194*	*213*
	Annual Rain Volume (million m3)	-	10.241	9.629	6.799	7.180	2.631	1.088	0.635	-	-	-	-	-	*38.203*	
SANTIAGO ISLAND	Area (km2)	38.776	155.406	222.764	159.122	146.756	116.627	83.095	43.776	15.031	10.281	9.266	3.914	0.348	*1005.163*	*269*
	Annual Rain Volume (million m3)	3.878	23.311	44.553	39.780	44.027	40.819	33.238	19.699	7.516	5.655	5.560	2.544	0.244	*270.823*	

(rainfall data source: ZONAGE BIOCLIMATIQUE DE L'ILE DE SANTIAGO (CAP - VERT), Centre Regional AGRHYMET, Jul 1996)

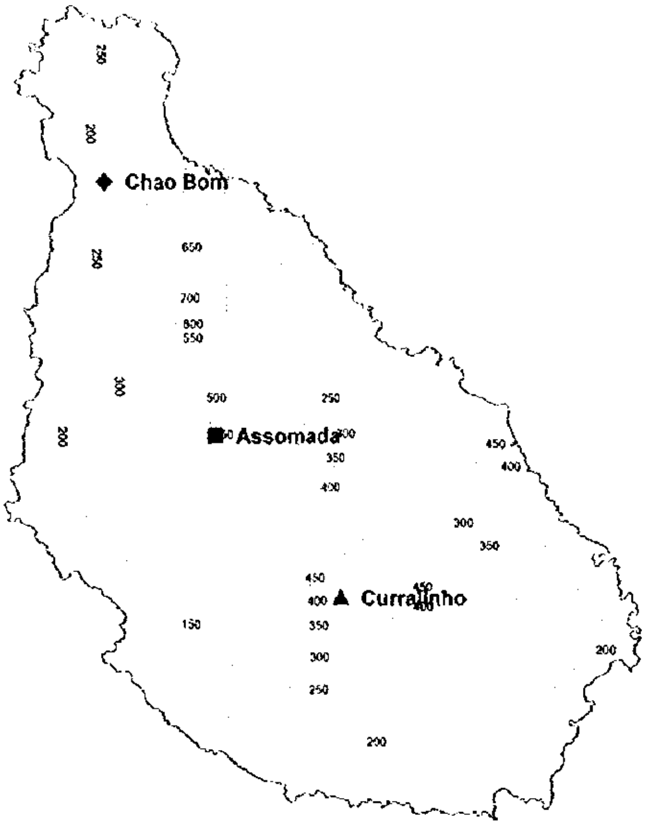

Figure 4-2 Isohyet Contour Map (compiled data from 1961 to 1990)

(Source: ZONAGE BIOCLIMATIQUE DE L'ILE DE SANTIAGO (CAP-VERT), Centre Regional AGRHYMET, Jul 1996)

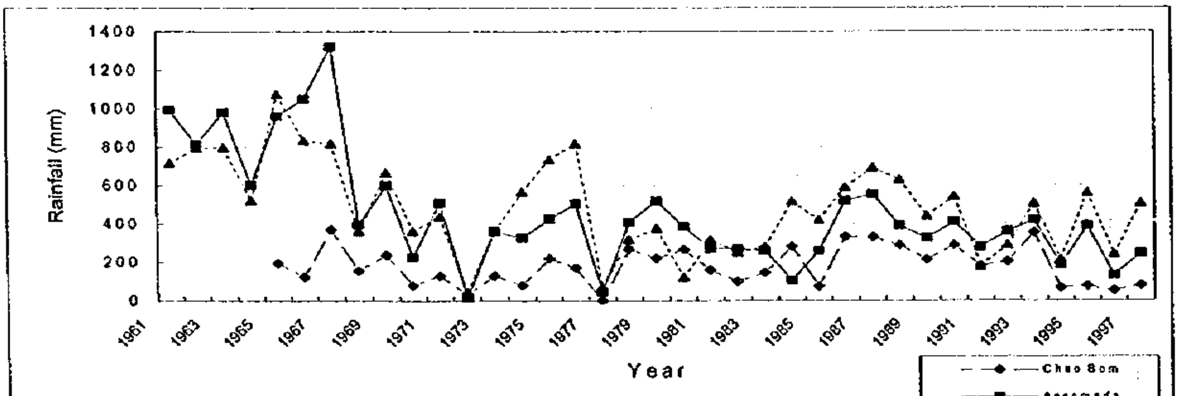

Figure 4-3 Annual Rainfall (from year 1661 to 1997)

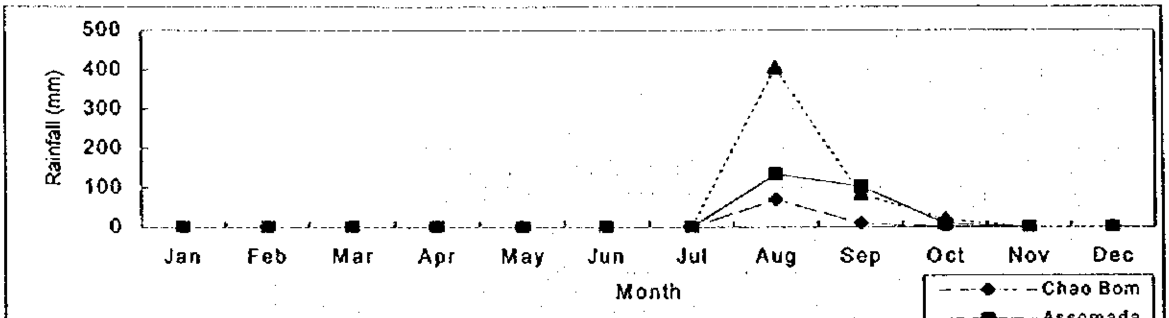

Figure 4-4 Monthly Rainfall (of year 1997)

4.1.4River flow

There are no perennial rivers in the island nowadays due to a short rainy season and limited precipitation. Until several years ago, perennial flows originating from springs were found in the upper reaches of rivers. However, these surface flows became sub-surface flows along with the decline in spring discharge.

Continuous river flow only occurs along main river courses during and immediately after heavy rain in the rainy season,. lasting for a short period of only a few hours to a few days. Surface flow of most tributaries stops within a few hours because of rapid run-off along steep riverbeds and rapid ground infiltration through abundant fissures in volcanic rocks. Localized storms are accompanied by flash floods that often affect adjacent areas.

4.1.5Springs

Forty-nine (49) permanent springs were surveyed at the end of the dry season, all of which were observed to flow out from the PA Formation. The discharge rate ranges from 0.2 to 28.2 m^3/h and averages about 5.4 m^3/h. Springs flow out from the boundary of basement rocks and PA Formation or at the intersection of vertical joints and horizontal joints. Fig. 4-5 shows the location of the springs.

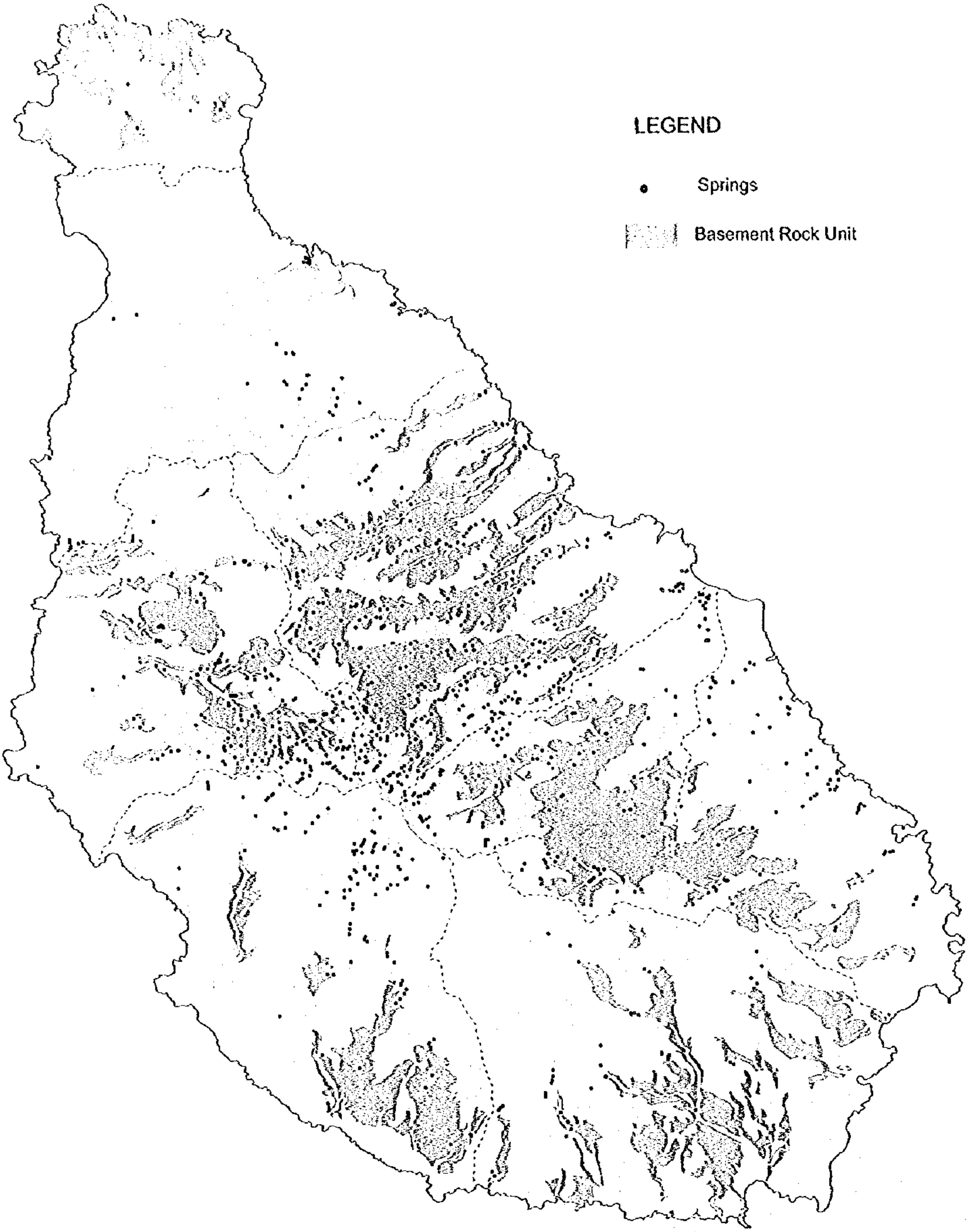

Figure 4-5 Location Map of Springs

4.2 Geology and Hydrogeology

4.2.1 Geology and Hydrogeology

Stratigraphic classification of the geology of Santiago Island is briefly presented in Table 4-2. The Island consists mostly of volcanic rocks, which occupy 94% of the total land surface. The formation of the volcanic rocks is classified into 3 types.

The basement rock is the oldest volcanic formation formed in the Pre-Miocene and Miocene age. They are broadly overlain by volcanic deposits from the next volcanic activity, although wide exposure can be seen at the Assomada highlands and areas in the south-western side, northern part and southern part of the island.

The rocks of the Pre-Miocene are composed mainly of ultra basic plutonic rocks namely, gabbro and carbonate. Appearances of these rocks are as intrusions of dykes intersecting Upper Volcanic Groups. The rocks are generally weathered and their exposures are sporadical in the central highland.

The Lower Miocene Groups are divided into three Formations: Basement Volcanic Complex, Orgas Formation, and Flamengos Formation.

Basement Volcanic Complex consists of basalt lava, agglomerates and tuff alternation accompanied by trachytic and phonolitic dykes. The rocks are generally highly weathered, fragmented, and having various colors, i.e. whitish grey, reddish brown, yellow brown.

Olgas Formation consists of agglomerates, volcanic debris and tuff breccia at the Ribeira Seca area and calcarious sandstone at the northern end of the Island. These two facies have different features. The formation around the Ribeira Seca area is composed of tuff and fragments of volcanic origin, and relatively loose, while in the northern end of the island, the formation is composed of compact calcareous sandstone with coral and shell fossils that clearly indicate the origine of marine sediments.

Flamengos formation is sub-divided into basalt lava, volcanic breccia, pyroclastics and agglomerates. These layers are generally well stratified alternating at a thickness of 2 to 30m.

The stratigraphic relation of these formations are not clear. The features of the beds, however, seem to indicate periodic gaps or structural mass movements.

These three formations are unconformably overlain by a younger mass of volcanic rocks.

The second oldest volcanic formations were formed in the Miocene and Pliocene periods. These formations are the most widespread in the island and is subdivided into the Assomada Formation and Pico da Antonia Formation.

The lower layers of Pico da Antonia Formation consist of submarine lava flow (pillow lava) and pyroclastic rocks. Laminated tuffaceous sand with round shaped pebbles and cobbles are common at the boundary of the lower formations. Beds of columnar basalt and tuff are observed to alternate at least 8 times in this formation, and the contact of each beds suggests periodic gaps. In general, these columnar basalt have chilled margin at the bottom with horizontal joints.

Outcrops of the Assomada formation are limited at the highland of Assomada. The rock facies of the formation are generally similar to those of Pico da Antonia formation. The formation intercalates loose conglomerate between the layers of volcanic rocks, clearly indicating continental sedimentation that took place during the period the formation of Assomada Formation.

The latest volcanic activities took place during the Pleistocene Epoch of the Quaternary Period. Volcanism occurred in many areas of the island during that epoch, but because it was not very active, the formations that resulted were distributed sporadically in the area. The areal extent of each of these recent volcanics is limited to less than $3km^2$.

Other geological units existing in the island are diluvial terrace deposits and recent alluvial deposits. The diluvial terrace deposits are found along large rivers, and the alluvial deposits overlay stream-dissected bedrock. However, these deposits cover a narrow area, more or less 6% of the total land area.

Fig. 4-6 shows the geological distribution, and the geological cross section is presented in Fig. 4-7.

Based on the results of satellite image interpretation, aerial photograph interpretation and field reconnaissance, it is understood that Mio-Pliocene Volcanic Complex (Pico da Antonia and Assomada formation) was formed by the drastic uplift of the island after the Pliocene Epoch. This movement formed deep valleys and elevated coasts, and resulted in exposure of the Basement Volcanic Complex.

The Pico de Antonia formation strikes mostly parallel to the coastline, dipping gently (8 to 22°) towards the coast. This suggests that the center of the volcanic activity of the Mio-Pliocene Volcanics is at the Assomada area, as well as the occurrence of uplift of the island.

The tectonic movement in the triangular zone bounded by the mountain ranges of "Serra da Marragueta" and "Serra do Pico de Antonia" (Santa Cruz and Santa Catarina Basin) seems to differ from that of other areas (Tarrafal, Sao Joao Baptista and Praia Basin), in that slight changes in elevation can be seen here and there.

The lineaments are mainly parallel to the two major mountain ranges at the NW-SE and NE-SW directions. However, it is difficult to distinguish whether these lineaments were formed through structural tectonic movements.

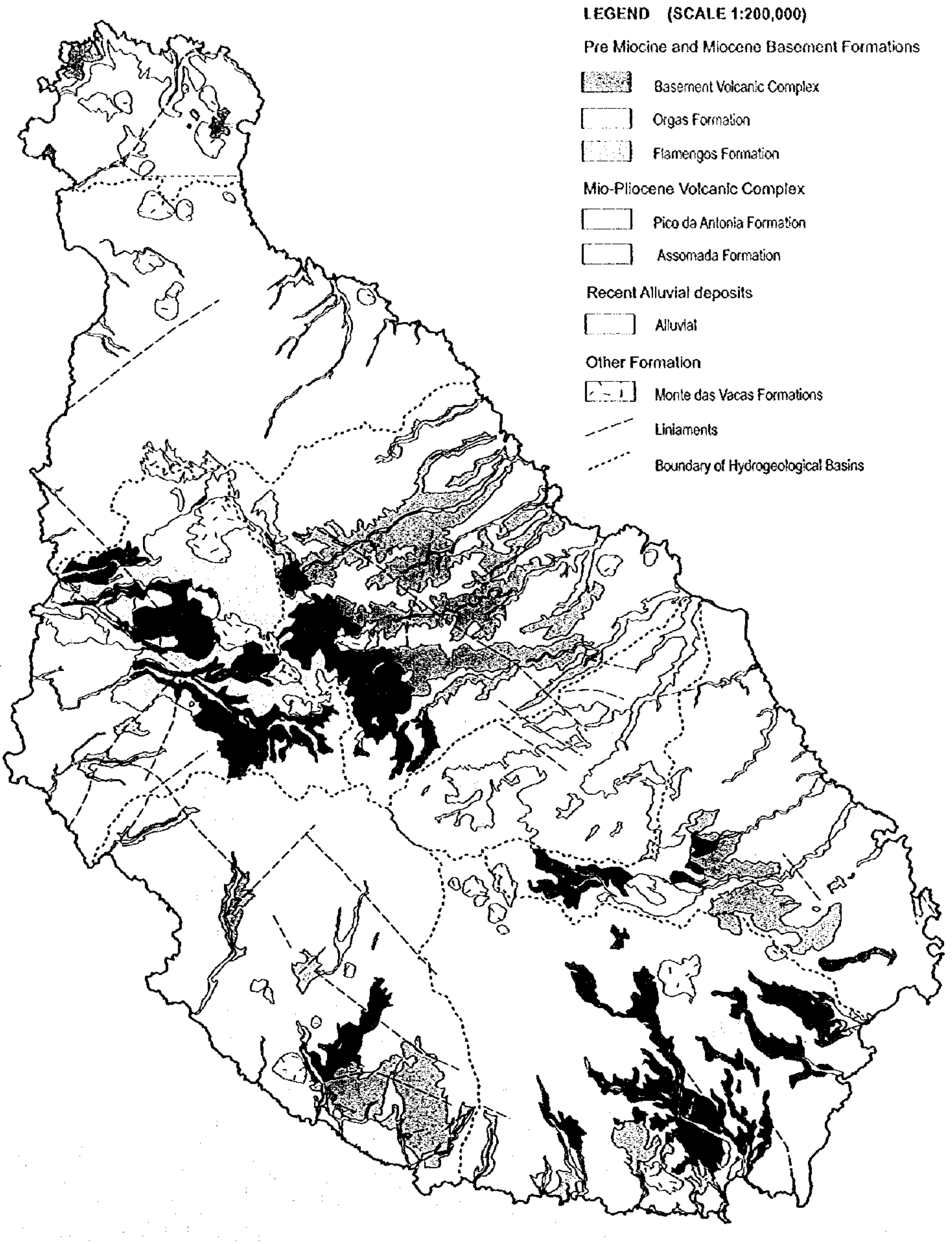

Figure 4-6 Geological Map of Santiago Island

(After Carte Geologica de Cabo Verde, IGC, 1973 with some additions)

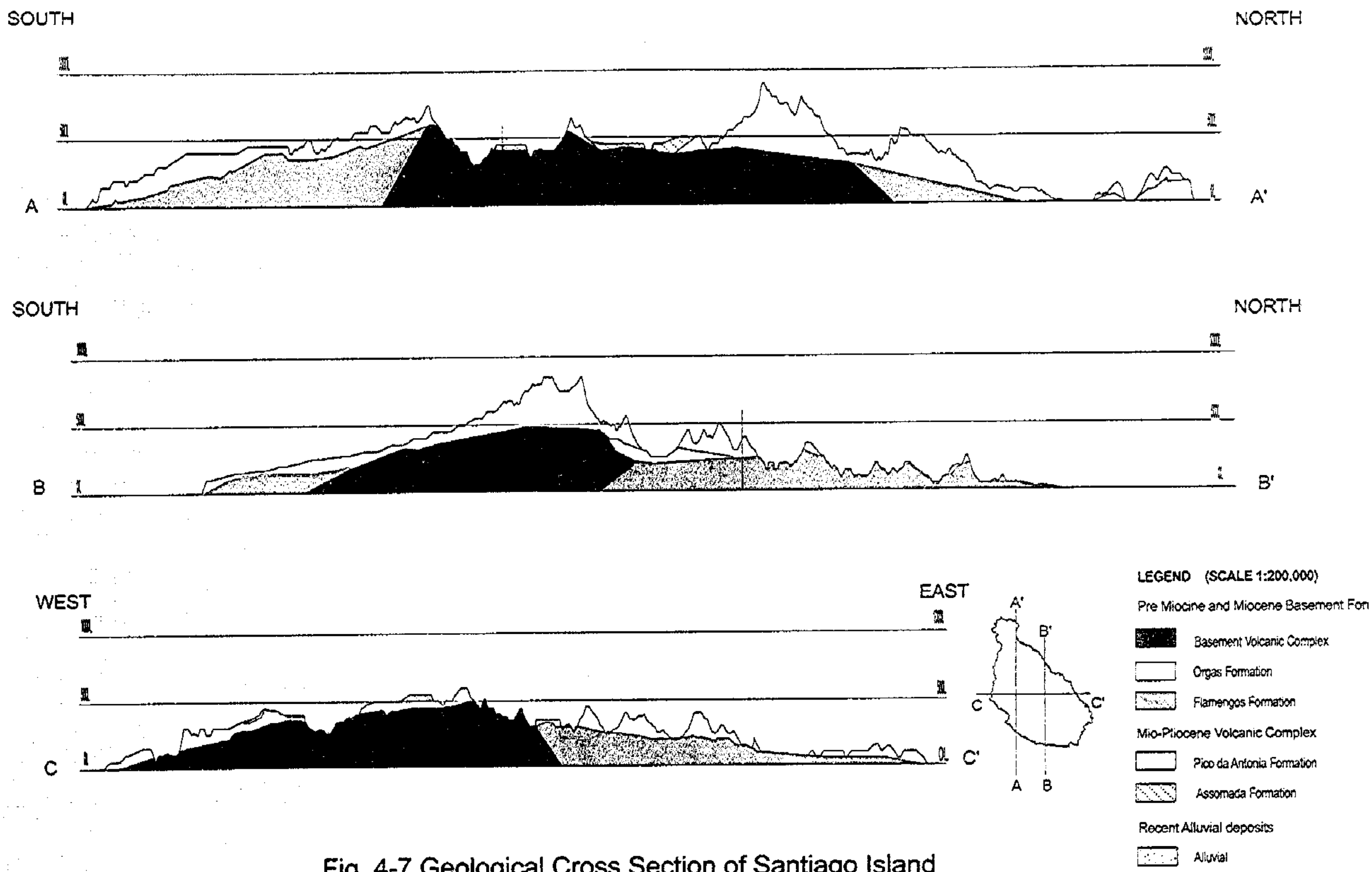

Fig. 4-7 Geological Cross Section of Santiago Island

Table 4-2 Geological Classification and Characteristics

Hydrogeological	Formations	Rock Facies	Characteristics	Distribution	Hydrogeological Remarks
Pre Miocene and Miocene Basement Formations	Basement volcanic complex (CA)	Basalt lava, volcanic breccia, agglomerate(CA) with Gabro(γ,σ) Carbonatite(cb) Trachytic, Phonolitic dykes(B). Other basic volcanic rocks(φ)	Highly weathered or altered by the intrusion of dykes. Generally yellowish brown or whitish grey	Assomada highland area, Along the rivers in Southern Praia area. North end of Tarrafal	Boundary of other formations are generally highly weathered. Less fractures and clayey in nature. Aquifuge in most cases.
	Orgaos Formations (CB)	Agglomerate, Volcanic deblis,Calcarious Sandstone	Mainly massive and consists of sandy tuff and breccia.	Ribeira Seca catchment area, North end of Tarrafal	Appearance varies by place. Wethered layers are impermeable
	Flamengos Formations ($\lambda\rho$)	Basalt lava, volcanic breccia, pyrocrastics, agglomerate	Abundant in pyrocrastics and submarine volcanic deposits. Yellowish brown tuff with layer or brecciated massive basalt	North-eastern part of Assomada, Along the catchment area of South western area	Submarine joint rich lava could be the potential aquifer. Lack of continuity of the lava layer. May contain some water locally.
Mio-Pliocene Volcanic Complex	Pico da Antonia Formation (PA)	Basalt lava, pyrocrastics, tuff breccia, submarine lava flow (pillow lava), domes	Repeatedly covered almost entire island. Dark grey columnar basalts are common. Tuff with lamination also can observed	Entire Island	Basic lava flow forms the well stratified layer of lava and tuff. Joint rich basalt and high porosity lava are excellent aquifer.
	Assomada Formation (A)	Basalt lava, pyrocrastics, tuff breccia	Hardly distinguished from PA formation. Partly conglomerate layers intercalated. Pinkish grey	Observed only in the highland of Assomada area	As well as PA formation, joint rich basalt could be the aquifer.
Diluvium Terrace	(casc)	conglomerate with sand layer	Grey to brownish laminated layer. Rounded boulders of basalt are common	Mainly along the large rivers	Regardless with its high permeability, water can not be tapped, due to small catchment and the permeable nature of base rocks
Recent Alluvial deposits	Alluvium (Al)	sand, silt, conglomerate	Lower portion of the layer is mainly silty tuff.	Along the rivers.	Yield depends on the depth of the formation and the content of sandy layer. The water near cost contact with the sea
Recent Volcanics	Monte das Vacas Formation (V)	Pyroclastics, lava, tuff	Loose tuff and pyroclasts with whitish grey.	Trending NW-SE with the area of 1-3 sq. km.	Regardless with its high permeability, water can not be tapped, due to small catchment and the permeable nature of base rocks

4.2.2 Hydrogeological Characteristics of Geological Formations

The hydrogeological characteristics of each formation, briefly given in Table 4-2, are as follows:

- Pre-Miocene to Miocene Basement formations comprise of Basement volcanic complex (CA, cb, B, γ, σ, ψ), Orgas Formation (CB, CBm) and Flamengos Formation ($\lambda\ \rho$). Since they are composed mainly of rather impermeable rocks with a highly weathered to clayey surface, these formations are regarded as the hydrogeological basement of the basins mentioned in 4.1.2. Groundwater development from these basement rocks is, therefore, somehow difficult except in the areas, i.e. joint-rich submarine lava and brecciated basalt lava of the Flamengos Formation, that are relatively porous.
- Miocene to Pliocene Volcanic Complex involves Pico da Antonia Formation (PA) and Assomada Formation (A). These formations are composed mainly of rocks of relatively high porosity, e.g. joint-rich basalt lava, pyroclastic lava, tuff breccia and submarine lava flow (pillow lava), therefore, these formations can be good aquifers. The places where these formations are thick and cover a wide area are the most promising for groundwater exploitation, depending on the depth of the water table and the shape of the basin bottom, i.e. the shape of the surface of the hydrogeological basement.
- Diluvial Terrace Deposits
  Terrace deposits consist of rounded boulders, gravel and sand. Since these materials have enough transmissivity and storage, terrace deposits usually are excellent aquifers. However, the majority of terrace deposits in this island are very limited both in extent and thickness, and the water table is below the terrace in most places. Groundwater exploitation from this bed is, therefore, impossible.
- Recent Alluvial Deposits
  The alluvial deposits of the island comprise riverbed and coastal sediments. At the lower reaches of large rivers, under-flow of the river is pumped up for agricultural use, and used for domestic purposes through dug wells. Riverbed deposits are usually excellent aquifers, being composed of materials of high transmissivity. But the potential of water exploitation depends on the under-flow volume.
- Recent Volcanics (Monte das Vacas Formation)
  The most recent volcanics that formed in the island are abundant in highly porous materials, i.e. pyroclastic and loose tuff rocks. Although a good aquifer, groundwater volume is small.

4.3 Result of Hydrological and Hydrogeological Surveys

4.3.1 Electrical resistivity

For electric resistivity sounding, the Wenner Offset Method was applied (arrangement of equally spaced 4–electrodes). The survey was mainly carried out to determine the depth of the basement rock facies, which is regarded as the hydrogeological basement rock unit.

Eleven (11) survey lines were surveyed to identify the rock facies by the difference of resistivity value. Thirteen (13) points beside the existing well were also surveyed to correlate the resistivity value and the actual rock facies.

Regardless of the similarity of the physical condition of the rock types, the basement rocks are distinguishable by the distribution pattern of resistivity value. The sounding locations are shown in Figure 4-8 and the cross sections of survey lines are shown in Figure 4-9 (1) and (2). Other figures of resistivity profile with geological interpretation are attached and put together in a Data Book along with ρ-a curves and data sheets. Resistivity values and the rock type or formations are summarized in Table 4-3.

The survey revealed that the resistivity values are relatively low in the basement complex and Flamengos formation at less than 200Ωm, and higher in Miocene -- Pliocene volcanic complex (300 - 2200Ωm). An irregularity was observed at the boundary between Assomada – Pico da Antonia formations and the basement volcanic complex as presented in the cross section.

Table 4-3 Resistivity Values by Rock Types

Formation	Rock or Soil Facies	Resistivity Value (Ωm)
Alluvial deposits	Sand, clay, conglomerate	45 – 350
Vacas Formation	Scoria, basalt lava	790 – 1300
Assomada Formation	Basalt lava, pyroclastic, breccia	300 – 2200
Pico da Antonia Formation (PA)	Basalt lava, pyroclastic, tuff breccia	20 – 705
Flamengos Formation	Basalt lava flow, volcanic debris	17 – 140
Basement Complex (CA)	Basaltic dykes, gabbro, basaltic volcanic rocks	17 – 136

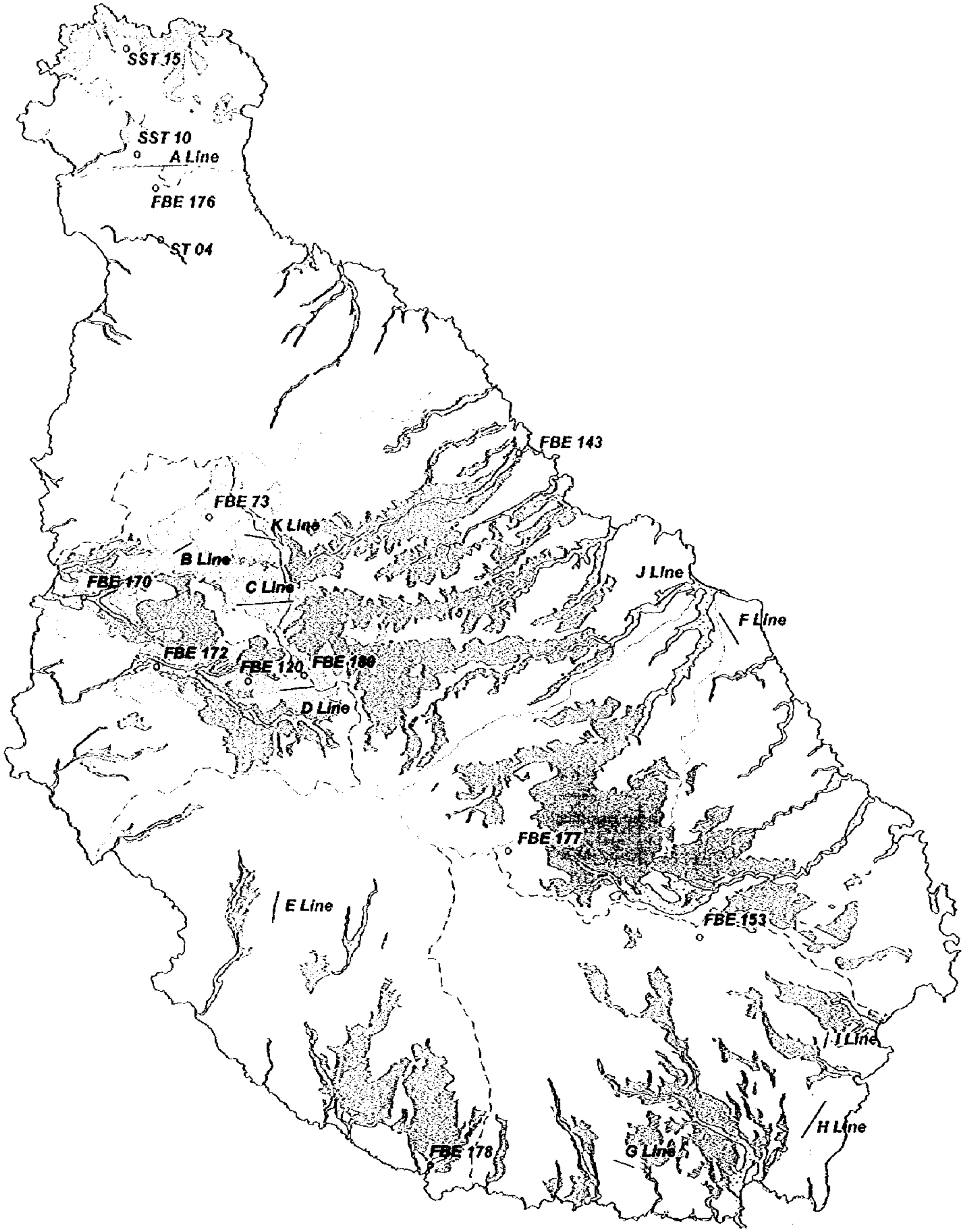

Fig. 4-8 Location Map of Electrical Resistivity Survey Lines and Points

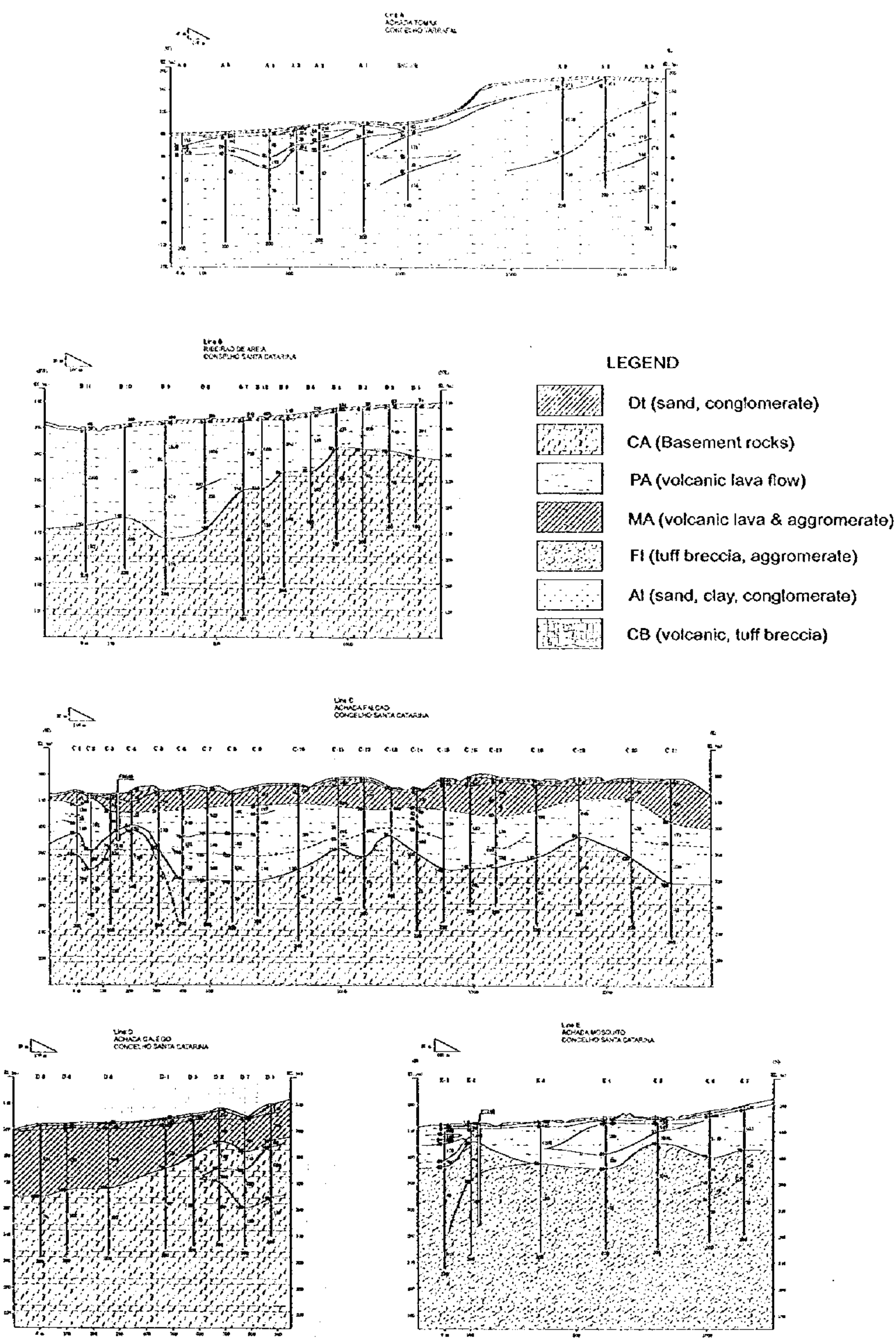

Figure 4-9 (1) Cross Section of Electrical Resistivity Survey

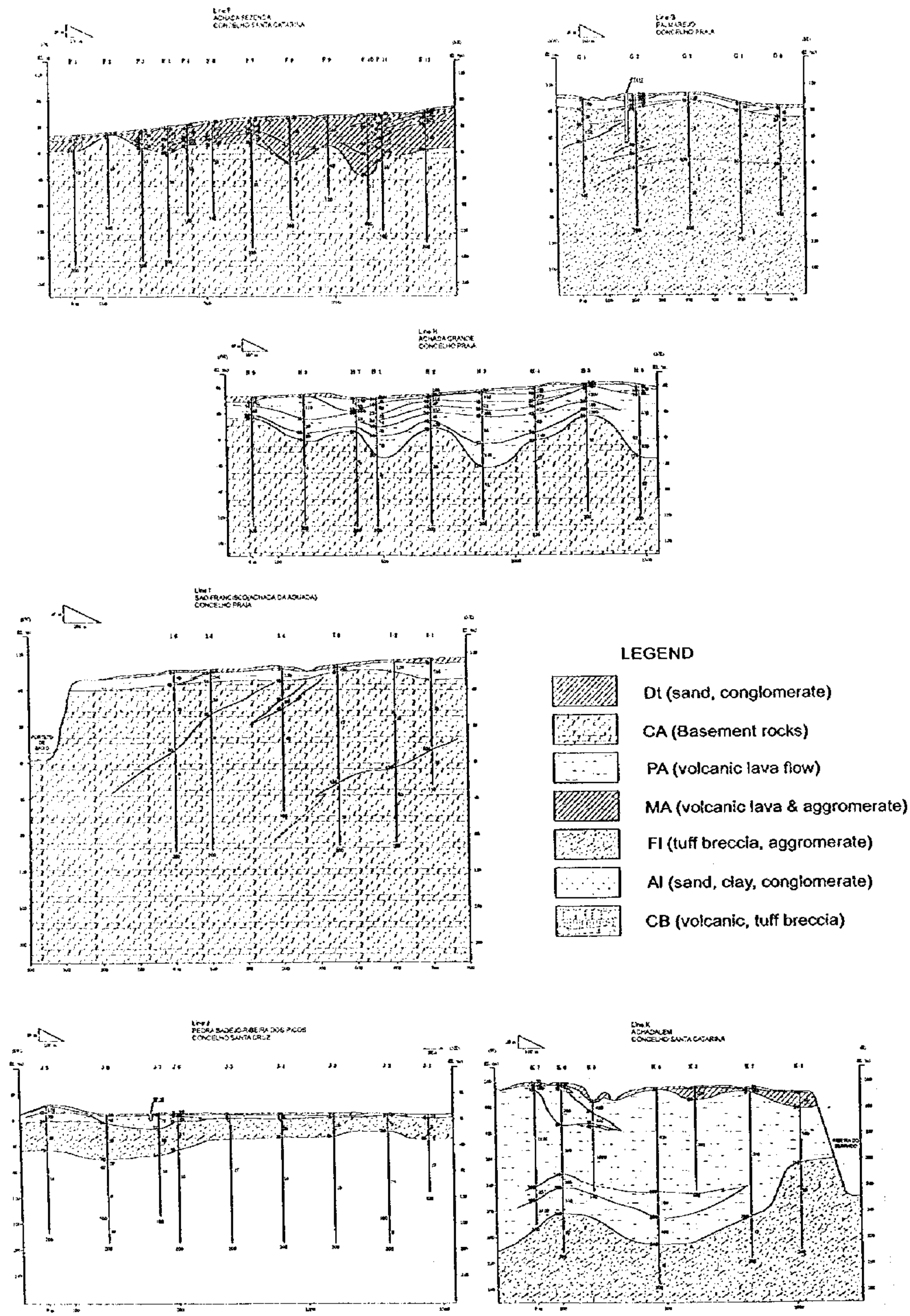

Figure 4-9 (2) Cross Section of Electrical Resistivity Survey

4.3.2 Simultaneous Water Level Measurements

Simultaneous groundwater level measurements were conducted twice in 1998, at the end of the dry (June) and wet (October) seasons, to distinguish seasonal fluctuations in groundwater level. Fifty-three (53) wells were selected to conduct groundwater level measurements within a 10-day period. Of these 53 wells, 35 were used for dry and wet season static water level comparisons.

Table 4-4 presents the measurement records. The location map of monitoring wells for the measurement is shown in Figure 4-10.

Fluctuations in water level are generally small, mostly within a range of 1 meter, except for 4 wells where the entries were probably erroneous. Of the 31 wells where water level fluctuation is reasonable, 10 had higher levels in the wet than in the dry season. The rainy season water level of the remaining 21 wells was lower or similar to the dry season water level. The absolute value for water level variation for 31 wells averaged 28 cm, with a plus variation of 27 cm in 10 wells and a minus variation of 32 cm in 20 wells.

It is understood that the water level in deep wells is not affected by seasonal fluctuations in precipitation within a year. It takes 1 to 3 years or more for rainwater to reach the deep water table, therefore, long term monitoring of the water level in deep wells is required to determine the relation between fluctuations in water level and annual rainfall.

Table 4-4 Result of the Simulataneous Grandwater Level Monitoring

Well Number	Geology	Local	Construction Date	Depth GL -m	WL Dry Season		WL Wet Season		W-D	Water Quality		Remark
					Date	SWL GL-m	Date	SWL GL-m	Difference of Dry and Wet Season	Cond	Temp C	
PT061	AL	Ceris	24/07/86	18.00	24/06/98	3.25	19/10/98	3.95	-0.70	6430	29.3	
FT117	PA	Ach. Palmarejo	30/11/73	73.30	24/06/98	33.05	21/10/98	32.99	0.06			
FBE001	PA	Bota Rama	10/11/87		01/07/98	77.03	20/10/98	78.19	-1.16	380	28.1	
FBE031	PA	J. Varela	05/11/81	126.00	17/06/98	58.92	21/10/98	59.00	-0.08	419	27.1	
FBE044	PA	Ach. S. Antonio	27/09/82	80.00	24/06/98	30.45	20/10/98	30.47	-0.02	1590	28.9	
FBE117	PA	Caiada	07/08/88	116.00	02/07/98	33.04	/10/98	-	-	-	-	Equipped
FBE164	PA	Monte Vaca	06/03/96	70.00	02/07/98	44.18	/10/98	-	-	938	28.2	Equipped
FT244	PA	Bota Rama	07/10/83		01/07/98	68.31	20/10/98	-	-	-	-	Equipped
FT301	PA	Bota Rama	17/08/85		01/07/98	68.31	20/10/98	68.18	0.13			
FT303	PA	Bota Rama	19/08/85		01/07/98	64.00	20/10/98	64.05	-0.05			
FT304	PA	Bota Rama	17/09/87		01/07/98	76.95	20/10/98	77.00	-0.05	873	28.6	
FBE016	PA	S. Martinho	28/11/80	64.00	17/06/98	17.63	21/10/98	12.51	5.12	1250	28.8	
FBE022	PA,CA	Figueira Portugal	07/04/81	81.00	26/06/98	51.18	21/10/98	51.70	-0.52	492	27.8	
FBE033	PA,CA	J. Varela	20/11/81	129.00	17/06/98	65.19	21/10/98	66.00	-0.81	440	28.3	
FBE039	PA,CA	Caiada	30/06/82	109.00	17/06/98	36.82	21/10/98	36.71	0.11	1370	28.3	
FT259	PA.CA	Salineiro	02/04/84	108.00	24/06/98	99.83	20/10/98	100.04	-0.21	-	-	
FT262	PA,FL	Salineiro	28/05/84	111.00	24/05/98	61.60	20/10/98	61.65	-0.05	-	-	
FT263	PA,FL	Salineiro	03/07/84	106.30	24/06/98	75.80	20/10/98	75.90	-0.10	-	-	
FBE116	AL,CA	Ach. Galego			18/06/98	120.56	22/10/98	120.82	-0.26	465	26.5	
FBE170	AL/CA	Charco		56.00	19/06/98	25.01	22/10/98	24.86	0.15	-	-	
FBE172	AL/CA	Mato Sancho			19/06/98	5.18	22/10/98	5.28	-0.10	1194	29.5	
FBE073	PA	Ach. Fora		252.50	19/06/98	198.56	22/10/98	198.49	0.07	660	28.8	
FBE120	PA	Ach. Carapati	16/11/88	151.00	18/06/98	113.41	22/10/98	113.53	-0.12	470	26.6	
FBE180	PA	Assomada	01/07/98	182.00	19/06/98	106.70	22/10/98	106.90	-0.20	961	27.6	
FT185	PA	Torre Assomada	12/05/77	80.00	25/06/98	70.33	22/10/98	70.51	-0.18	539	26.6	
FBE097	AL/CA	Picos	30/06/87	78.00	23/06/98	23.47	22/10/98	-	-	1240	26.5	not yet receivved data
SP010	AL/PA-Lri	Rib. Dos Picos	08/11/72		18/06/98	11.30	/10/98	-	-	1420	27	not yet receivved data
SP039	AL/PA-Lri	Rib. Dos Picos	31/01/74	19.10	18/06/98	9.76	/10/98	-	-	687	28.7	Equipped
PT038	PA	St. Cruz	20/08/83	17.00	18/06/98	7.40	19/10/98	-	-	4870	29.3	Equipped
FT059	PA	Parede Nhu Melo		50.00	18/06/98	17.64	/10/98	-	-	-	-	Equipped

Well Number	Geology	Local	Construction Date	Depth GL -m	WL Dry Season Date	WL Dry Season SWL GL-m	WL Wet Season Date	WL Wet Season SWL GL-m	W-D Difference of Dry and Wet Season	Water Quality Cond	Water Quality Temp C	Remark
SP021	AL/PA-Lri	Rib. Seca	24/04/73	17.10	18/06/98	11.39	/10/98	-	-	6720	27.3	
FT063	PA	Covao Santana	22/05/73	63.00	18/06/98	26.45	/10/98	-	-	-	-	Equipped
PT008	AL	Ach. Baleia	29/12/79	16.00	18/06/98	3.40	19/10/98	3.60	-0.20	3920	30.1	
FBE177	PA,CA	Rui Vaz	30/06/97	180.00	02/07/98	120.81	/10/98	-	-	-	-	Equipped
FT235	PA,CA	Rui Vaz	14/02/83	188.00	02/07/98	121.62	/10/98	-	-	-	-	Equipped
FBE047	PA,FL	Ach. Baleia	13/06/83	34.00	18/06/98	16.00	19/10/98	16.40	-0.40	1550	28.6	
FBE061B	PA,FL	Covao Dentro	22/06/85	110.00	18/06/98	18.53	19/10/98	17.77	0.76			
FT038	PA,FL	Ach. Baleia	30/03/73	60.00	02/07/98	8.62	19/10/98	8.62	0.00	11050	30.6	
FT079	PA,FL	Portal	23/07/73	52.00	18/06/98	7.00	19/10/98	9.50	-2.50	1187	26.6	
FT260	AL,FL	Salineiro	09/05/84	48.80	24/06/98	20.39	20/10/98	19.85	0.54			
FT354	FL	Alfarroba	10/01/90	60.00	26/06/98	30.78	/10/98	-	-	-	-	Equipped
FBE178	PA	Canico	06/11/97	24.00	02/07/98	10.69	/10/98	-	-	-	-	Equipped
FT233	PA,FL	Alfarroba	31/01/83	49.50	17/06/98	32.91	/10/98	-	-	-	-	Access damaged
FBE176	PA	Monte Covada			25/06/98	82.02	/10/98	-	-	-	-	Equipped
FT271	PA	Principal	12/11/84	83.00	17/06/98	15.44	23/10/98	15.40	0.04	-	-	
FT027	PA	Tarrafal	22/11/82	34.00	25/06/98	13.53	23/10/98	13.51	0.02	699	28.5	
SST034	PA	Tarrafal	16/08/82	49.38	02/07/98	18.79	23/10/98	18.94	-0.15	-	-	
SST031	PA-LR	Tarrafal	27/08/82	116.00	25/06/98	68.89	23/10/98	67.84	1.05	1280	27	
SST025	PA-Lri	Ach. Tomas	16/02/82	120.00	23/06/98	92.74	23/10/98	92.81	-0.07	1686	28	
ST004	PA-Lri	Rib. Grande	19/04/80	75.00	23/06/98	51.63	/10/98	-	-	-	-	Equipped
SST010	PA	Cabeca de Alguem	29/10/78	129.00	23/06/98	92.76	23/10/98	92.72	0.04	1250	28.1	
SST015	PA	Ponta Pereira	05/03/81	140.88	23/06/98	59.15	23/10/98	51.16	7.99	655	28.6	

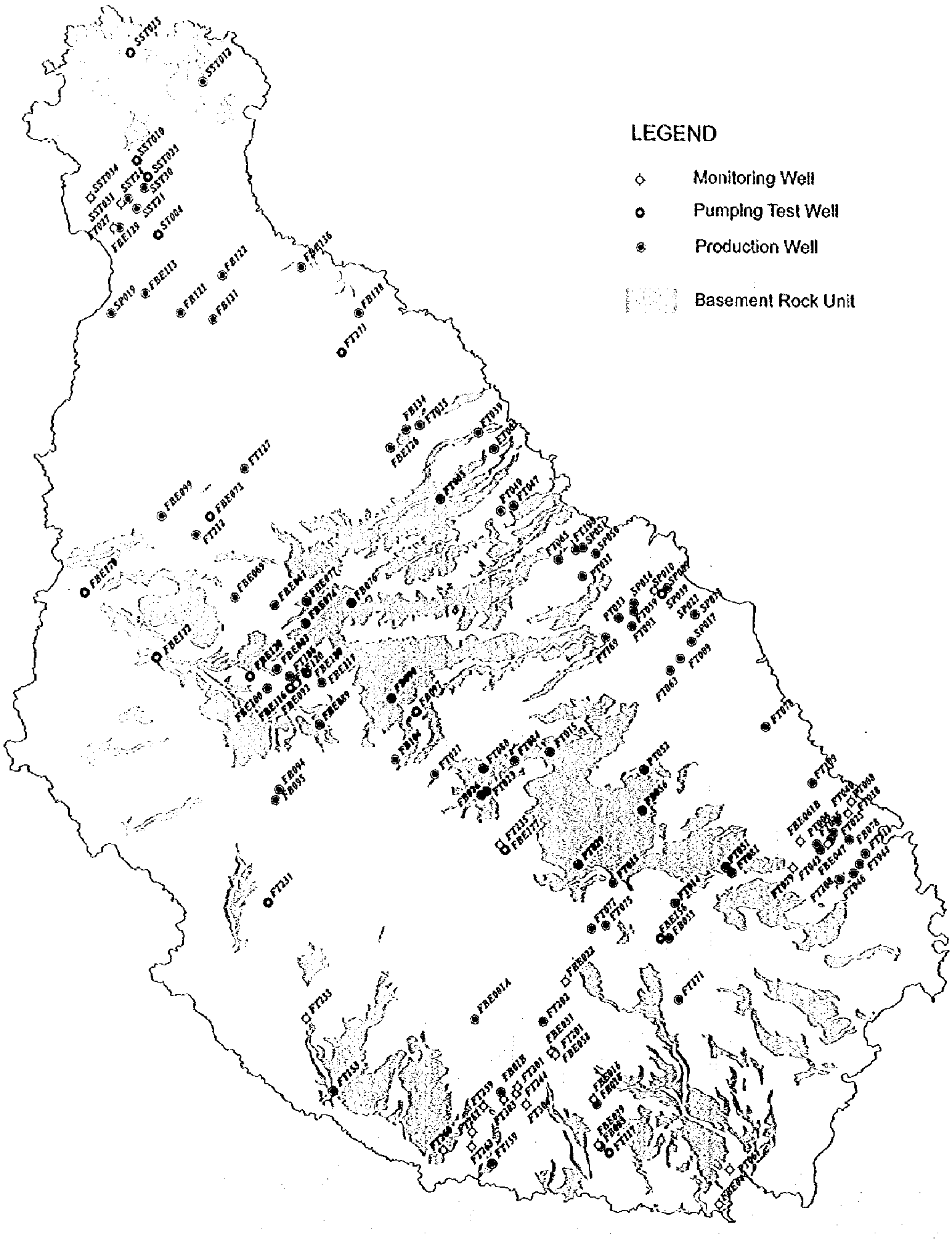

Figure 4-10 Location Map of the Wells

4.3.3 Pumping tests

Pumping tests were conducted to evaluate the hydrogeological conditions of aquifers using existing wells which are not used as production wells.

Twenty-three (23) existing wells were selected based on their structures, with the intention to choose as many types of aquifers as possible by referring to past well records. However, of these wells, only 19 were used for the tests, as illegal production was carried out in 4 of the wells prior to the tests.

The tests were accomplished satisfactorily on 14 of the 19 tested wells. Preliminary pumping proved 5 wells to be inoperative due to a long standby period.

The results of the tests on 14 wells are shown in Table 4-4, and the hydrological parameters by different formations are shown in Table 4-5.

Table 4-5 Hydrogeological Parameters by Geological Formations

*( )= average

Geological Formation	Sample Number	Discharge (m^3/d)	Specific Capacity ($m^3/d/m$)	Transmissivity (m^2/day)
Alluvium	3	432 – 909 (687)	791 – 2667 (1441)	1934 – 5026 (3775)
Assomada Formation	3	288 – 480 (462)	28 – 96 (50)	5 – 109 (66)
Pico da Antonia Formation	3	216 – 823 (538)	99.5 – 5879 (3122)	107 – 8861 (4905)
Flamengos Formation	2	240 – 567 (404)	57 – 282 (170)	1.3 – 130 (66)
CA	2	149 – 196 (173)	14 – 21 (18)	12 – 42 (27)

The average figures for each formation indicate marked differences. The hydrogeological parameters of discharge, specific capacity and transmissivity are mostly high in Alluvium and Pico da Antonia Formation, lower in Assomada and Flamengos Formations, and lowest in the Basic Volcanic Complex (CA). Except for the Alluvium, most of the values show wide variations due to the nature of the groundwater occurrence in fissures and portions of porous volcanic rocks. The parameters differ from place to place depending on the condition of the fissures and porous portions, even within the same formation. The range of parameters obtained is, however, similar to those in past studies, as shown in Table 4-7.

Table 4-6 Result of Pumping Test

Well Number	SST010	SST015	FT271	SST004	SST025	FBE097	FBE143	SP039	FBE177	FBE073	FBE116	FBE120	FBE170	FBE172	FBE180	FT231	FBE156	FT117*
Construction Date	8/10/78	5/3/81	12/11/84	19/4/80	16/2/82	30/6/87	25/3/92	31/1/73	7/8/97	3/8/86	26/8/88	16/11/88	-	-	6/8/98	2/2/82	7/4/94	30/11/73
Well Depth (GL-m)	130.00	140.88	83.00	75.00	120.00	78.00	19.50	19.10	180.00	249.00	-	151.00	56.00	-	182.00	147.50	124.00	73.30
Main Aquifer Formation	PA	PA	Fl	Al	PA	CA	Al	Al	PA	PA	A	A	Al	CA	A	PA	PA	Fl
Basement Formation	(CA)	(CBm)	(CA)	PA	(CA)	-	CBm	Fl	Fl	Fl	CA	CA	CA	-	PA	Fl	(CA)	(CA)
Date of Test Execution	26/10/98	-	14/11/98	2/9/98	20/10/98	19/8/98	14/9/98	22/2/99	-		9/10/98	2/10/98	5/8/98	25/7/98	23/9/98	-	2/11/98	10/9/88
Static Water Level (GL-m)	73.60	-	14.72	52.16	93.80	29.87	7.05	9.78	-		121.30	144.40	25.60	5.60	107.84	-	111.70	65.68
Discharge Rate (m3/d)	823	-	240	720	576	196	909	4320	-		480	617	432	149	288	-	216	567
Drawdown (m)	0.14	-	4.23	0.27	0.17	13.95	1.15	0.5	-		17.75	6.42	0.5	6.95	10.16	-	2.17	2.01
Specific Capacity (m3/d/m)	5879	-	57	2667	3388	14	791	8640	-		27	96	864	21	28	-	99.5	282
Transmissivity (m2/day)																		
a Theis	6408	-	62	2851	4162	11	876	7910	-		31	111	554	44	5	-	107	1.4
b Jacob	(5630)	-	95	-	7330	10	(2909)	(13241)	-		42	125	3859	53	5	-	-	1.2
c Recovery Test	(14544)	-	233	(7200)	-	15	(2016)	-	-		183	92	8683	29	-	-	-	-
Average	8861		130	5026	5746	12	1934	10576			85	109	4365	42	5		107	1.3

Legend
Al = Aluvium A = Assomada Formation PA = Pico de Antonia Formati Fl = Flamengos Formation CA = Other Basement Rocks
( ) = estimated or not clear * = Past record

Table 4-7 Comparison of Hydrogeological Parameters

(*() = average)

Geological Formation	Values Estimated in 1974		This Study	
	Discharge (m^3/h)	Transmissivity (m^2/s)	Discharge (m^3/h)	Transmissivity(m^2/s)
Alluvium	30-100 (35)	10^{-1}-10^{-3} ($2x10^{-2}$)	18-38 (29)	$2x10^{-2}$-$6x10^{-2}$ ($4x10^{-2}$)
Assomada Formation	3-15 (10)		12-20 (19)	$6x10^{-5}$-$1x10^{-3}$ ($7x10^{-4}$)
Pico da Antonia Formation	5-30 (15)	$2x10^{-2}$-$2x10^{-4}$ ($5x10^{-4}$)	9-34 (22)	$1x10^{-3}$-$1x10^{-1}$ ($6x10^{-2}$)
	Lri 30 (35)	10^{-1}-10^{-3} (10^{-2})		
Orgas Formation	0-10 (3)	($5x10^{-5}$)		
Flamengos Formation	0-15 (6)	($5x10^{-5}$)	10-28 (17)	$2x10^{-5}$-$2x10^{-5}$ ($8x10^{-4}$)
CA	0-10 (3)	0.2-$3x10^{-4}$ ($5x10^{-5}$)	6-8 (7)	$1x10^{-4}$-$5x10^{-4}$ ($3x10^{-4}$)

4.3.4Water Quality

1) Quality Analysis on Dissolved Ions

Water quality analysis was conducted in order to examine the level of dissolved ions in the different types of aquifer. The chemical analysis covered the following:

Na^+, K^+ , Mg^{++}, Ca^{++}, Cl^-, HCO_3^-, CO_3^-, and SO_4^-

The samples were taken from the wells where the pumping tests were carried out. Of the 14 pumping test wells, 11 were used for analysis. The results of the analyses are shown in Table 4-8.

The water sample taken from the PA Formation shows comparatively lower values of sulfates and bicarbonates, whereas water from Alluvium generally contains higher levels of anions and cations. Such results suggest that original water once stored in the PA aquifer in the highland collected mineral ions in the rocks during their movement toward lower profiles resulting in cation accumulation in the Alluvium.

In the hypothesis that the anion group of (SO_4+Cl) − (HCO_3+CO_3) and cation group of (Na+K) − (Ca+Mg) are in chemical equilibrium, the concentration values were plotted on the trilinear diagram shown in Figure 4-10. The diagram for group 1 is carbonate hardness type water, which is common in normal fresh water. Group 2 is carbonate alkali type water, which is soft fresh water. Group 4 is non-carbonate alkali type water, which is common in seawater and water in volcanic rocks.

As shown in the figure, water in CA, Assomada Formation and Alluvium are categorized as groups 1 and 2, which correspond to normal fresh water or soft fresh water. Water in the Pico da Antonia Formation is categorized as group 4, which refers to water originating from volcanic rocks or altered by dissolved ions of volcanic origin. A sample from FBE 143 falls on Group 4, which clearly indicates sea water intrusion.

Table 4-8 Result of Water Quality Analysis

No	Items / Well Number	SST010	SST004	SST025	FBE097	FBE143	FBE116	FBE120	FBE170	FBE172	FBE180	FBE156	Standard Value in Cape Verde
1	**pH**	7.5	7.3	7.1	7.4	6.8	7.0	7.0	7.3	7.3	7.3	7.5	6.5<pH<9.2
2	Conductivity (μ S/cm)	1440	310	1180	1014	8300	390	330	738	940	410	546	50 - 2000
3	Total Calcium (mg/l)	542	116	264	488	5740	130	109	364	488	100	214	100 - 500
4	Carbonates (mg/l)	0	0	0	0	0	0	0	0	0	0	0	-
5	Bicarbonates (mg/l)	289	124	259	500	173	189	139	381	405	159	149	160
6	Clorites (mg/l)	411	57	333	92	4077	43	46	142	113	64	128	200 - 600
7	Calcium (mg/l)	69	18	38	53	1128	24	18	62	92	14	34	75 -150
8	Magnesium (mg/l)	89	17	40	85	741	18	16	50	63	15	30	50 - 150
9	Sodium (mg/l)	-	80	-	228	200	-	30	180	80	60	-	20
10	Potasium (mg/l)	27	9.2	15.2	16.7	28.6	8.2	9.3	30.4	14.3	14.4	4.8	
11	Sulfates (mg/l)	65	10	28	258	111	0	5	67	93	9	19	200 - 400
	Geological Formation	PA	Al	PA	CA	Al	A	A	Al	Al/CA	PA	PA	

Legend Al = Aluvium A = Assomada Formation PA = Pico de Antonia Formation
Fl = Flamengos Formation CA = Other Basement Rocks

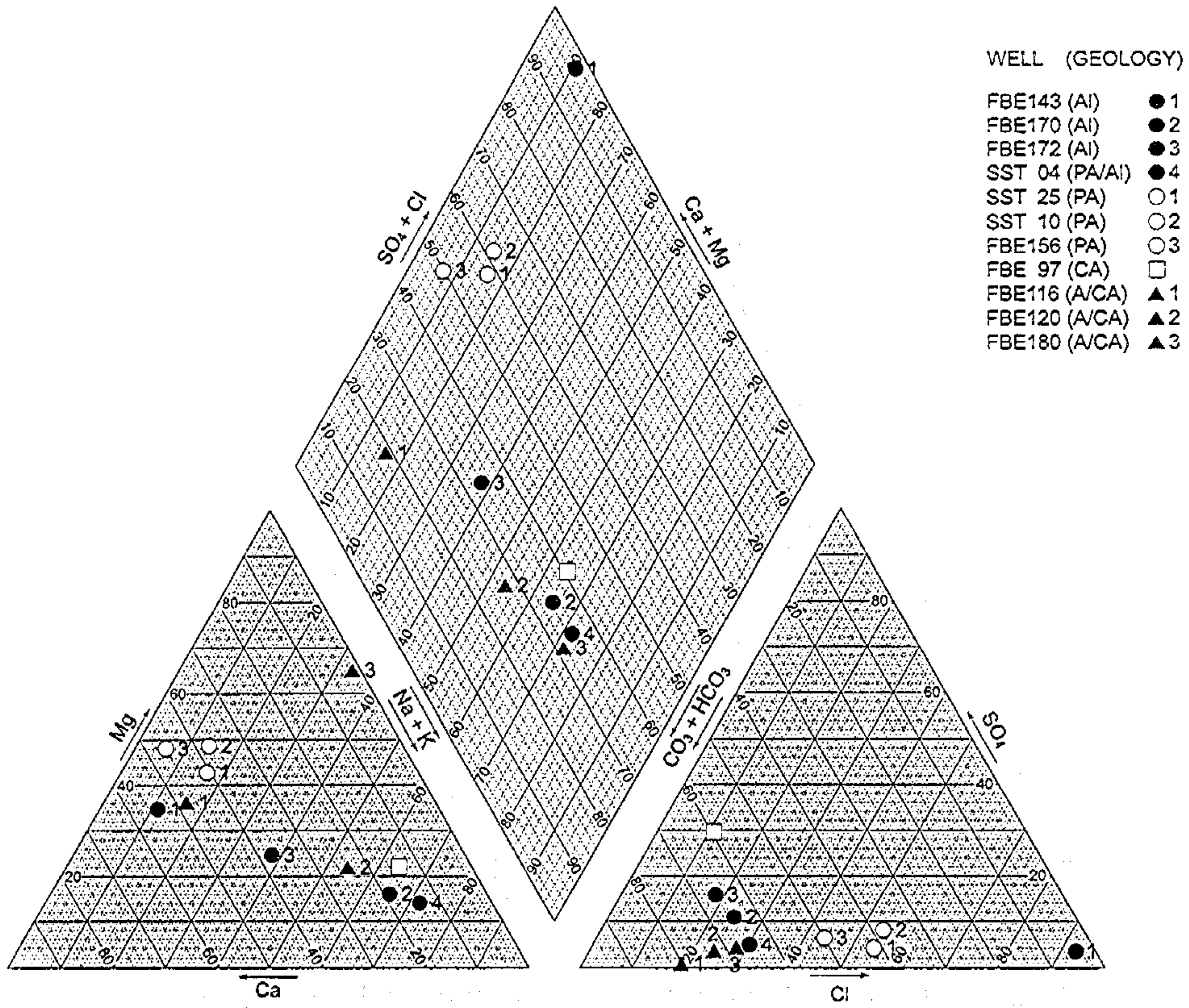

Figure 4-11 Result of the Water Quality Analysis on Trilinea Diagram

2) Analysis on Environmental Isotope

The 12 water samples collected from the pumping test wells were also used for the analysis on the isotopes of oxygen (^{18}O) and hydrogen (D), to accumulate data for the database which should be effectively used in the future, and with the expectation that particular information on the relation between groundwater and rain might be obtained.

The content ratio of isotope by 1/1,000 (‰) compared with those of sea water are tabulated in Table 4-9.

Since sea water has the same level of isotope content anywhere in the world, the analyzed results are usually compared with the Standard Mean Ocean Water (SMOW). All data obtained show a level lower than sea water, indicating that groundwater sampled from the wells does not originate from sea water but rainwater.

Fig. 4-12 presents the relation between ratios of oxygen/hydrogen isotope plotted on δD-$\delta^{18}O$ diagram.

It is generally known by the study of Craig (1961) that relation between the content ratio of oxygen isotope (^{18}O) and hydrogen isotope (δD) of rainwater and rainwater originated surface/groundwater is on the Meteoric Water Line which is expressed in a simple formula of:

$$\delta D = 8 \cdot \delta^{18}O + 10$$

Therefore, if the δD-$\delta^{18}O$ of concerned water is plotted on this line, it can be understood that this water originated from rainwater.

The isotope content ratio in groundwater in Santiago Island plotted on δD-$\delta^{18}O$ diagram is not exactly on but nearly along the Meteoric Water Line, indicating that sampled groundwater originated from rainwater. The reasons for the slight difference are unclear though.

Since ^{18}O and D are heavier than ^{16}O and ^{1}H, and fall more rapidly, rainwater which falls in higher elevations should contain less of these environmental isotopes. The 3 wells in Assomada highland (FBE116, 120, 180) showed comparatively lower values in the same range, suggesting that groundwater originated from rainwater from highly elevated areas. Also, similar values suggest that groundwater from these 3 wells are of the same origin. Meanwhile, 2 wells located in the lowland of Tarrafal (SST25,ST004) showed quite different values, suggesting different origins.

Table 4-9 Isotopic Analyses of Water Samples

Reference Samples	Δ [18]O ‰ vs SMOW (± 0.1‰)	Δ D ‰ vs SMOW (± 0.8‰)
FBE 97	-3.9	-21.6
FBE 116	-4.9	-30.4
FBE 120	-4.9	-31.4
FBE 143	-3.7	-24.9
FBE 156	-5.0	-31.3
FBE 170	-4.4	-29.4
FBE 172	-4.4	-29.0
FBE 180	-4.8	-29.0
FT 271	-3.4	-19.6
SST 10	-4.9	-31.5
SST 25	-5.3	-34.1
ST 004	-4.0	-24.2

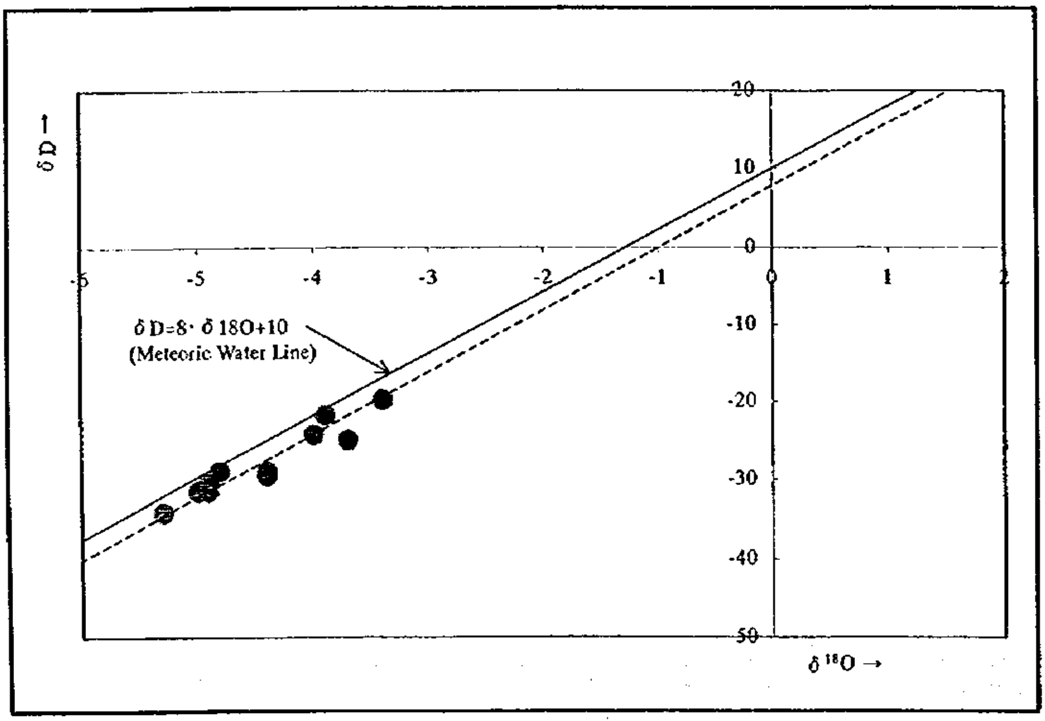

Figure 4-12 Relation Between Ratio of Oxigen / Hydrogen Isotope

4.3.5 Spring yield measurement

Spring yield measurement was conducted at 49 perennial springs at the end of the dry season.

The spot discharge measurement was made using an 18 liter bucket and a stopwatch. Conductivity and temperature were measured by electro-conductivity tester and a thermometer. At the same time, geological field reconnaissance was conducted in order to understand the stratigraphic and structural geological characteristics of the springs.

Over 900 springs were listed in the BIRCA database (1991) and 49 were surveyed. All of those surveyed were found to flow out from the PA formation at either the boundary of basement rocks or intersection of vertical and horizontal joints.

Table 4-10 shows the estimated spring discharge by basin, while Fig. 4-5 shows the location of springs with the basement rock distribution.

Table 4-10 Estimated Total Yield of Spring by Basin

BASIN		1991(Database)				Estimation 1998			
		Number		Discharge (m3/day)		Number		Discharge (m3/day)	
Tarrafal	A	143	162	1117	1402	64	66	815	1028
	B	19		285		2		213	
Santa Cruz	A	397	619	9619	18409	339	549	8077	15528
	B	128		6299		122		5344	
	C	94		2491		88		2107	
Santa Catarina			195		6621		187		5614
S. J. Baptista			116		3579		113		3031
Praia			58		6106		52		5179
Total			1150		36117		967		30380

4.4 Groundwater Balance and Development Potential

4.4.1 Groundwater in Santiago Island

The hydrogeological condition of the island was assessed to understand groundwater flow mechanism and groundwater development potential in the Study area. A hydrogeological map (1:500,000) was prepared to present existing relevant data and materials with the results of the hydrogeological surveys and interpretation.

According to the results of the surveys and interpretation, groundwater in the Island is characterized as follows:

- Major aquifers in the area are Assomada Formation, Pico da Antonia Formation and Alluvium.
- Hydrogeological parameters such as transmissivity and storativity are generally high in these aquifers.
- Water level fluctuation in the deep wells does not depend on seasonal rainfall.

To understand groundwater recharge and mechanism, a water level contour map was prepared as shown in Fig. 4-13.

Distribution of aquifers (Assomada Formation, Pico da Antonia Formation and Alluvium) with the topographic contour map is shown in Fig. 4-14. As described in section 4-1, the amount of precipitation in the island is nearly directly in proportion to the topographic features of the area.

Consequently, due to the highly permeable nature of the formations of Assomada and Pico da Antonia and their wide coverage in the highland, a considerable amount of rainwater infiltrates into the ground to form groundwater.

The water level monitoring results show a slight fluctuation in the water level of deep wells year-round, suggesting that the vertical movement of the infiltrated water in formations is very gentle due to the anisotropic feature of the formations and the alternating layers of lava, tuff and loam as previously mentioned in section 4-2.

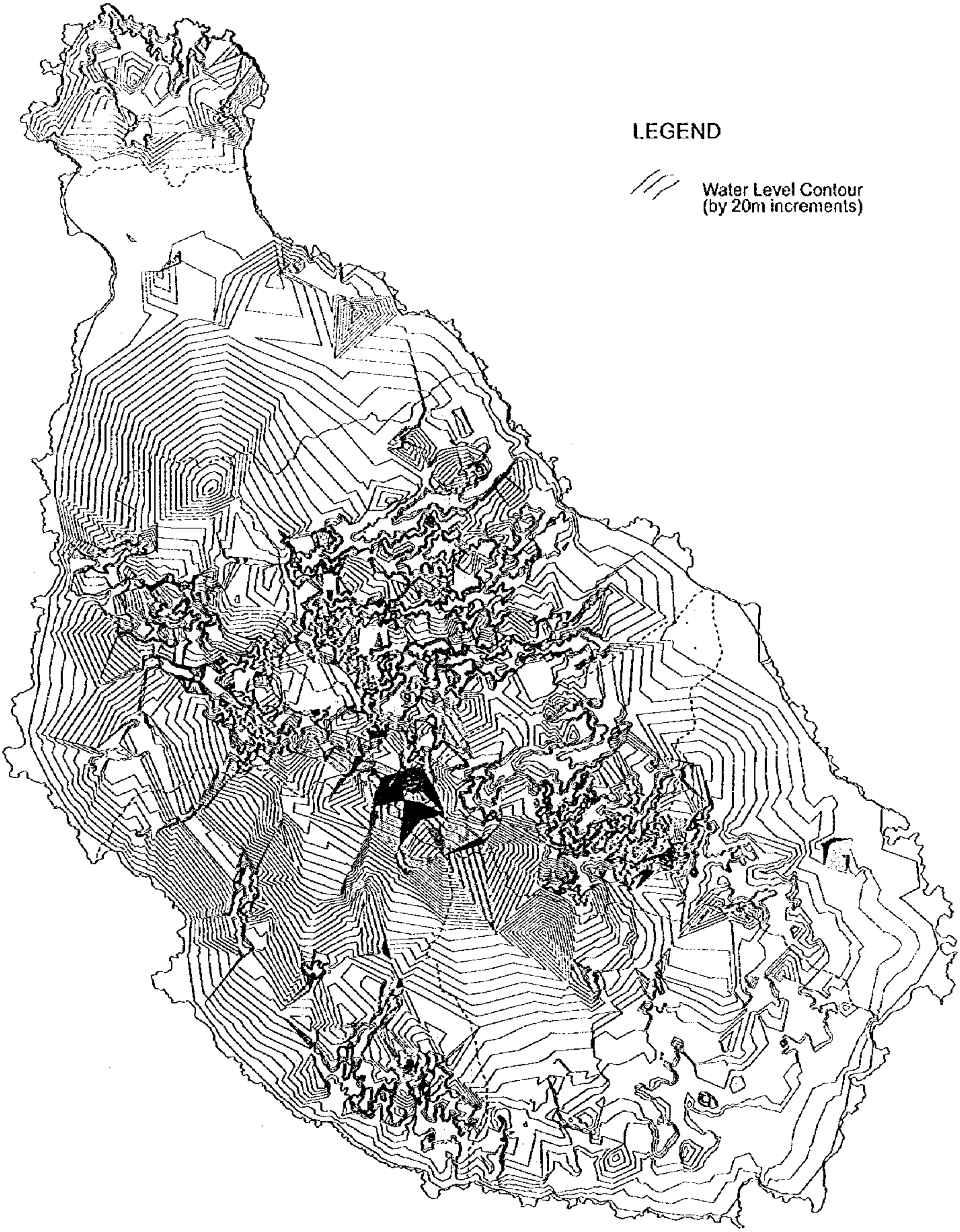

Figure 4-13 Water Level Contour Map

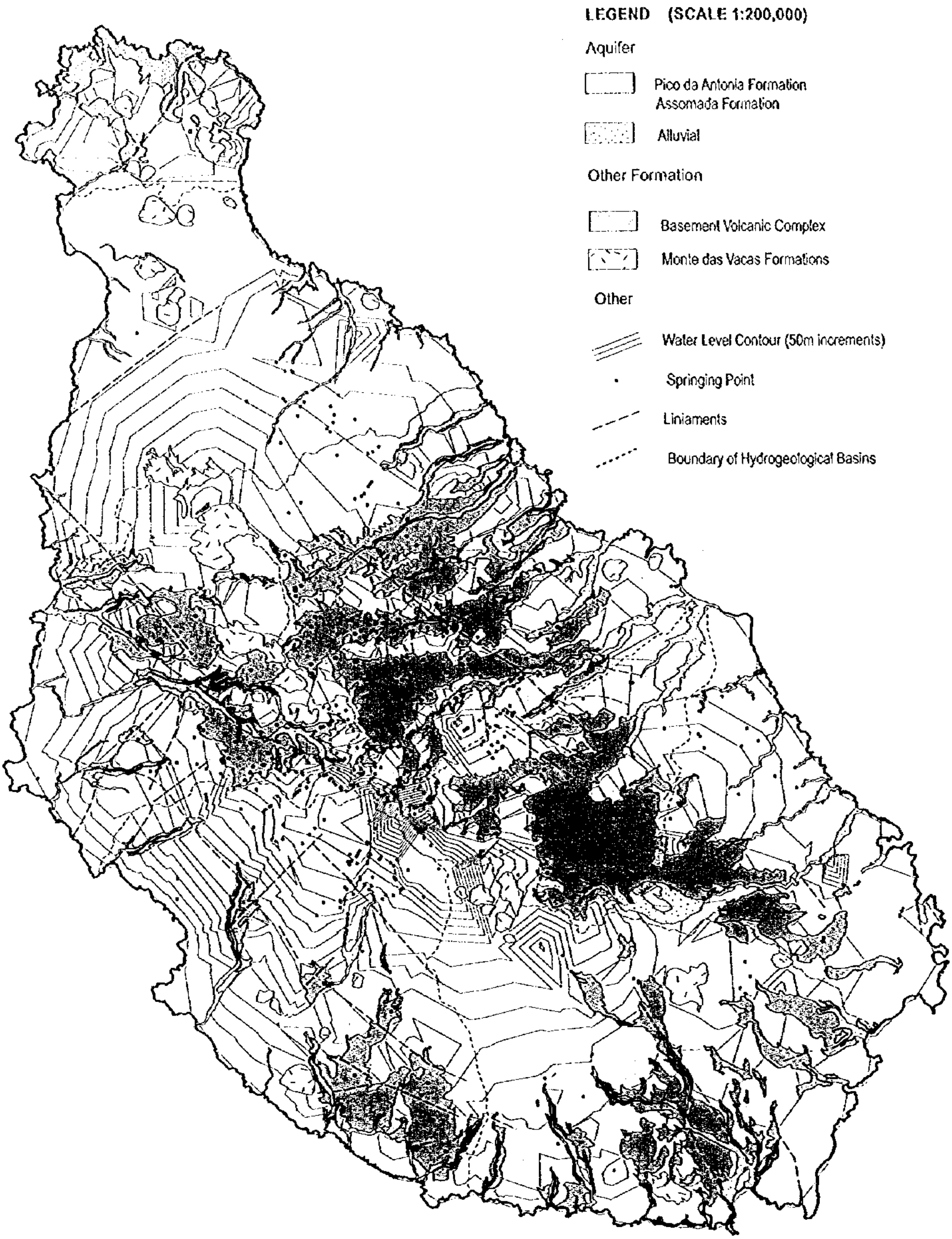

Figure 4-14 Distribution of Aquifer and Water Level Contour

The summary on aquifers and groundwater condition by hydrogeological basin is presented in Table 4-11.

Table 4-11 Summary on Aquifers and Groundwater Condition by Basin

Basin		Aquifer (PA) Thickness	Aquifer (PA) Distribution	Alluvium Distribution	Flow Direction	Water Gradient
Tarrafal	A	Thin	Poor	Poor	S – SE (radial)	Steep
	B	Thick	Abundant	Poor	NNW	Gentle
Santa Cruz	A	Thin	Poor	Abundant	NE	Gentle
	B	Thin	Poor	Abundant	NE	Gentle
	C	Thin	Medium	Abundant	E – NE	Gentle
Santa Catarina		Thick	Medium	Medium	WSW	Steep
São João Baptista		Thick	Abundant	Medium	SSW	Steep
Praia		Thick	Abundant	Medium	SSE	Gentle

Groundwater is mostly recharged in the northern side of Serra da Marragueta (Tarrafal hydrogeological basin) as it flows northward. However, this groundwater flow is blocked by a presumed E-W fault, which divides the Tarrafal basin into basins A and B. Water flow gradient is rather gentle since the layers of the Formation dip 8 – 10° northward.

Assomada highland, a volcanic plateau, is the main recharge area bounded by the two mountain ranges of Serra da Marragueta and Pico da Antonia. Groundwater in this area flows into two major directions. On the eastern side of the Assomada highland (Santa Cruz hydrogeological basin), Pico da Antonia Formation thinly and narrowly overlies the Basement Complex (CA). Groundwater flows gently in the Pico da Antonia Formation, not in the impermeable basement rocks. Surface runoff is generally rapid, but infiltrates into the alluvium and pillow lava layers of the Pico da Antonia Formation near the mouth of major rivers. Western portion of Assomada highland (Santa Catarina hydrogeological basin) comprises of steep valleys and volcanic plateaus of thick Pico da Antonia Formations. Groundwater gradient in this area is steep, being mainly recharged in Assomada highland. It should also be noted that the topographic and geological feature of the area is favorable for the development of springs.

The southern section of the Pico da Antonia mountain range is divided into two hydrogeological basins: São João Baptista basin in the west and Praia basin in the east. São João Baptista basin consists mainly of thick Pico da Antonia Formation with numerous NE – SW, NW – SE lineaments. Regardless of the thick aquifer formation, recharge is small due to deep crests and high cliffs and limited distribution of alluvial deposits. Praia basin consists mostly of gently dipped layers of the Pico da Antonia

Formation. At the south-western portion, the Basement Complex (CA, Fl) is exposed along major rivers, with a narrow distribution of alluvium. The main recharge block in the area is in the north-western section of Pico da Antonia Formation where rocks of cross sectional joints are abundant storing groundwater from Pico da Antonia mountain range.

4.4.2Water Resource Development Potential by Area

The Mission Report (UN/DTCD/CVI/86/001) on "the Study of Water in Santiago Island" introduces various ratio of rainwater ground infiltration from previous studies, to roughly estimate groundwater development potential. The Report also mentions that many of the previous study reports have pointed out the danger and/or incoherence in the water resource evaluation methods using an assumed infiltration ratio.

However, since Santiago is an isolated island and groundwater resources in the area originate from rainwater, determining "rainwater infiltration" mechanism is the most convenient means of gaining an overview of the groundwater potential in the area.

One of the previous studies (Report on CVI/79 project) estimates groundwater potential at 55 million m^3 as detailed below:

Santiago Island

- Surface — 991 km^2 (99,100 ha)
- Precipitation — 320 mm/year (rainfall volume: 317 million m^3)
- Evapotranspiration (49%) — 157 mm/year (volume: 156 million m^3)
- Surface run-off (34%) — 108 mm/year (volume: 107 million m^3)
- Infiltration (17%) — 55 mm/year (volume: 54 million m^3)

In this study program, however, the estimated value is much smaller at 35 million m^3/year as shown in Table 4-12. As in the CVI/79 project, macroscopic water balance method was applied using $P = ET + SR + I$, where the input of water from precipitation (P) is being equated to the outflow of water by evapotranspiration (ET), surface runoff (SR) and infiltration (I).

In this Study, the estimation was made on each of the 8 hydrogeological basins using most probable ratios representing the basins topographic and geological characteristics. Mean annual rainwater volume is calculated by basin based on the rainfall record from 1960 to 1991 compiled by AGRHYMET.

For the calculation of ET, the Thornthwaite Method was applied by area, and for infiltration ratio, following experimental figures were adopted in accordance with surface geology and gradient:

Basement rocks	: 5%
Aquifer (PA, Fl, Al)	: 10% (surface gradient is more than 20 degrees)
	: 15% (between 5 and 20 degrees)
	: 20% (almost flat land = less than 5 degrees)

Table 4-12 presents the total land area, average annual precipitation, evapotranspiration, surface runoff, and infiltration by hydrogeological basin.

When taking the factors of efficiency and economy into consideration, the exploitable water may be more or less 1/2 of the apparent potential volume. In Santiago Island the exploitable groundwater resource comes to about 17 million m^3/year.

Table 4-12 Precpitation, Evapotranspiration, Surface runoff and Infiltration by Basin

Hydrogeological Basin		Total Aria(km3)	Annual Average Precepitation (mm)	Evapotranspiration* (mm)	Evapotranspiration* (%)	Surface runoff (mm)	Surface runoff (%)	Infiltration** (mm)	Infiltration** (%)
TARRAFAL(A)		142.576	325	98	30	185	57	42	13
	Volume (million m3)		46.337	13.972		26.359		6.006	
TARRAFAL(B)		45.306	213	107	50	79	37	27	13
	Volume (million m3)		9.650	4.848		3.589		1.214	
SANTA CRUZ(A)		171.023	320	99	31	178	55	43	14
	Volume (million m3)		54.727	16.931		30.362		7.434	
SANTA CRUZ(B)		71.114	349	98	28	212	61	39	11
	Volume (million m3)		24.819	6.969		15.043		2.807	
SANTA CRUZ(C)		112.909	313	104	33	176	56	33	11
	Volume (million m3)		35.341	11.743		19.882		3.716	
SANTA CATATINA		128.259	259	94	36	131	51	34	13
	Volume (million m3)		33.219	12.056		16.863		4.300	
S.J. BAPTISTA		154.782	184	92	50	67	36	25	14
	Volume (million m3)		28.480	14.240		10.367		3.873	
PRAIA		179.194	213	102	48	80	38	31	15
	Volume (million m3)		38.168	18.278		14.344		5.546	
SANTIAGO ISLAND		1005.163	272	99	36	138	51	34	13
	Volume (million m3)		273.404	99.762		138.746		34.896	

(rainfall data source: ZONAGE BIOCLIMATIQUE DE L'ILE DE SANTIAGO (CAP - VERT), Centre Regional AGRHYMET, Jul 1996)

* Potential Evapotranspiration calculated by Thornthwaite Method

** Infiltration rates are experimental figures : Basement Rocks =5%

: Aquifers (PA, FI, AI) =10%(surface gradient is more than 20 degrees)

=15%(between 5 and 20 degrees)

=20%(almost flat (less than 5 degrees)

4.4.3 Water Balance in Each Hydrogeological Basin

The present annual discharge of groundwater is about **15 million** m^3**/year**, of which 3.9 million m^3/year is artificially exploited by 102 borehole wells, and an estimated amount of about 11.1 million m^3/year is naturally discharged from about 1,000 springs.

Table 4-13 presents the daily and annual discharge of groundwater resources.

Table 4-13 Discharge of Groundwater Resources

Basin	Type of Source	Number	Discharge (million m^3/year)
Tarrafal A Basin	Production Well	13	0.539
	Spring	64	0.298
Tarrafal B Basin	Production Well	0	0
	Spring	2	0.078
Santa Cruz A Basin	Production Well	26	1.180
	Spring	339	2.948
Santa Cruz B Basin	Production Well	18	0.725
	Spring	122	1.950
Santa Cruz C Basin	Production Well	18	0.381
	Spring	88	0.770
Santa Catarina Basin	Production Well	8	0.151
	Spring	187	2.050
S. J. Baptista Basin	Production Well	7	0.250
	Spring	113	1.106
Praia Basin	Production Well	12	0.657
	Spring	52	1.890
Total			14.971

According to the BIRCA Database, 7% of the total springs are tapped as potable water source and 93 % are not in use or used for irrigation. Discharge from the springs not used as domestic purpose infiltrate into the ground and recharge aquifers in layers of alluvial deposits. During this process, about 40 % of the discharge is estimated to evaporate or used for irrigation. The rest (60%) directly permeates the ground.

For water balance analysis, 58% (60% times 93%) was assumed for the calculation of groundwater recharge.

The estimated balance of the resources by hydrogeological basin is shown in Table 4-14 (unit: million m^3/year):

Table 4-14 Groundwater Balance by Basin

		RECHARGE			Exploitable Amount of Water (1/2 of Income)	DISCHARGE			TOTAL BALANCE	Development Potential
		Recharge by Rainwater	Recharge by Spring	Sub-total		Production of Wells	Spring Discharge	Sub-total		
Tarrafal	A	6.006	0.173	6.179	3.003	0.539	0.298	0.837	5.342	2.166
	B	1.214	0.045	1.259	0.607	0.000	0.078	0.078	1.181	0.529
Santa Cruz Basin	A	7.434	1.710	9.144	3.717	1.180	2.948	4.128	5.016	-0.411
	B	2.807	1.131	3.938	1.404	0.725	1.950	2.675	1.263	-1.272
	C	3.716	0.447	4.163	1.858	0.381	0.770	1.151	3.012	0.707
Santa Catarina Basin		4.300	1.189	5.489	2.150	0.151	2.050	2.201	3.288	-0.051
S.J.Baptista Basin		3.873	0.641	4.514	1.937	0.250	1.106	1.356	3.158	0.581
Praia Basin		5.546	1.096	6.642	2.773	0.657	1.890	2.547	4.095	0.226
Total		34.896	6.432	41.328	17.448	3.883	11.090	14.973	26.355	2.475

In the **Tarrafal (A) basin,** the total amount of exploitable water is estimated at about 2.166 million m^3/year or 5,934 m^3/day. Most groundwater is stored in the northern foot of Serra da Marragueta; main Aquifer is Pico da Antonia Formation. **Tarrafal (B) basin** has a small catchment area and thin aquifer formation, therefore the development of groundwater may be limited to around 0.529 million m^3/year or 1449 m^3/day, and the area that has potential for development is limited to the eastern volcanic plateau.

Santa Cruz basin was divided into three sub-basins and the basement formations cover substantial part of the basin. Due to the narrow and thin distribution of Pico da Antonia Formation, groundwater development potential is low. In addition, groundwater is mainly extracted from layers of alluvial deposits. A recent study (Water Development Plan Ribeira Secca, MFA & TBW, 1998) has revealed that seawater intrusion was detected in wells within a distance of 2km from the coast. Santa Cruz (A) basin presents negative potential of 0.411 million m^3/year, suggesting excessive pumping and opportunities for seawater intrusion. The main aquifer in the area is in the alluvial deposit layer of the Pico da Antonia Formation. Currently, since most groundwater resources in the basin are from alluvial layers, care should be exercised when exploiting these resources to prevent excessive pumping and seawater intrusion. Although the basin shows totally negative balance, the potential is still high in the northwestern section of Pico de Antonia Formation. Santa Cruz (B) basin has currently been studied under the Ribeira Secca Water Development Project. As the basement rock covers 38 % of the total area, the potential of exploitable groundwater resources is in the negative at 1.272 million m^3/year. Some groundwater volume can be exploited from the upper Pico da Antonia Formation. In the Santa Cruz (C) basin, alluvial layers are the main aquifers. A total of 0.707 million m^3/year or 1,936 m^3/day will be exploited. Pico da Antonia Formation in the southern plateau may be the area in the basin with the highest potential for development.

In the **Santa Catarina basin**, the main aquifer is in Assomada Formation and Pico da Antonia Formation. Although the balance shows a negative figure of 0.051 million m^3/year, Assomada volcanic plateau remains to show a high potential for development, especially in the northern area. The potential is also high in alluvial layers.

Sao Joao Baptista basin is overlain mainly by the Pico da Antonia Formation. The exploitable groundwater amount is estimated at 0.581 million m^3/year or 1,592 m^3/day. Areas along the lineaments have several zones rich in fissures favorable for groundwater recharge. Because water level in Pico da Antonia Formation is generally low, these zones should be targeted when siting drilling points.

Praia Basin is also covered by the aquifers of Pico da Antonia Formation. The thickness of the aquifers in the area is favorable (50 – 180m) for groundwater exploitation, and indicate abundant groundwater recharge potential. The amount of groundwater that can be exploited from this area is estimated at 0.226 million m^3/year or 619 m^3/day.

It should be understood that the table is only a relative comparison of the basins. If the assumption ratio is other than half of the analysis given above, other figures should be used to determine potential resources and values shown in the above table should be revised.

4.4.4High Potential for Groundwater Development by Area

Hydrogeological potential for groundwater exploitation is limited in the island due to complex hydrogeological conditions. The surface of basement Complex is regarded as the bottom of the basin structure, and its shape in the basin gives important factor to determine the high potential area for groundwater development. A presumed contour map of the basement rock is presented in Fig. 4-15.

Based on the basinwise structure of the basement and natures of overlying geological formations, the areas identified as high potential for groundwater exploitation. (Fig. 4-16 shows the areas with high potential for groundwater development.)

- Assomada highland
- Lower Tarrafal volcanic plateau
- Lower Praia volcanic plateau
- Mouth of major rivers in the north-eastern section of the island

Of above 4 high potential areas, the area highly elevated is limited to Assomada highland plateau. The irregularity of the basement volcanic forms several small depressions favorable for water recharge. The topographic feature – southern foot of Serra da Marragueta and northern foot of Serra do Pico da Antonia – also contributes to facilitate groundwater accumulation and recharge in the area. Since the aquifer formations are thinly and scarcely distributed in this area (Pico da Antonia Formation and Assomada Formation), groundwater is mostly flowing out taking a form of spring. The basins of Santa Cruz and Santa Catarina, which involve plateau area similar to the Assomada highland, have some potential of groundwater development, however its volume may be limited in the highland area with same reason above.

Both of Lower Tarrafal and Praia volcanic plateau have a long and wide catchment area distributed with thick aquifers (Pico da Antonia Formation), the potential of the resources development is quite high in these area. Consideration of the lineaments in these areas suggests abundant fissures and joints of the rocks, which makes it ease for the groundwater recharge. The groundwater exploited in these areas can be transmitted to Tarrafal and Praia Municipality.

Major river mouth of north-eastern portion of the island has several good production well. According to the report of the Ribeira Secca Project, boreholes located at closer than 2km from the river mouth are suffered by seawater intrusion. The new wells should be constructed at not near to the coastline, and production rate should carefully be managed to prevent excessive pumping. Groundwater development in this area can be transmitted to villages in the low-lying plains of Santa Cruz and Sao Domingo Municipality.

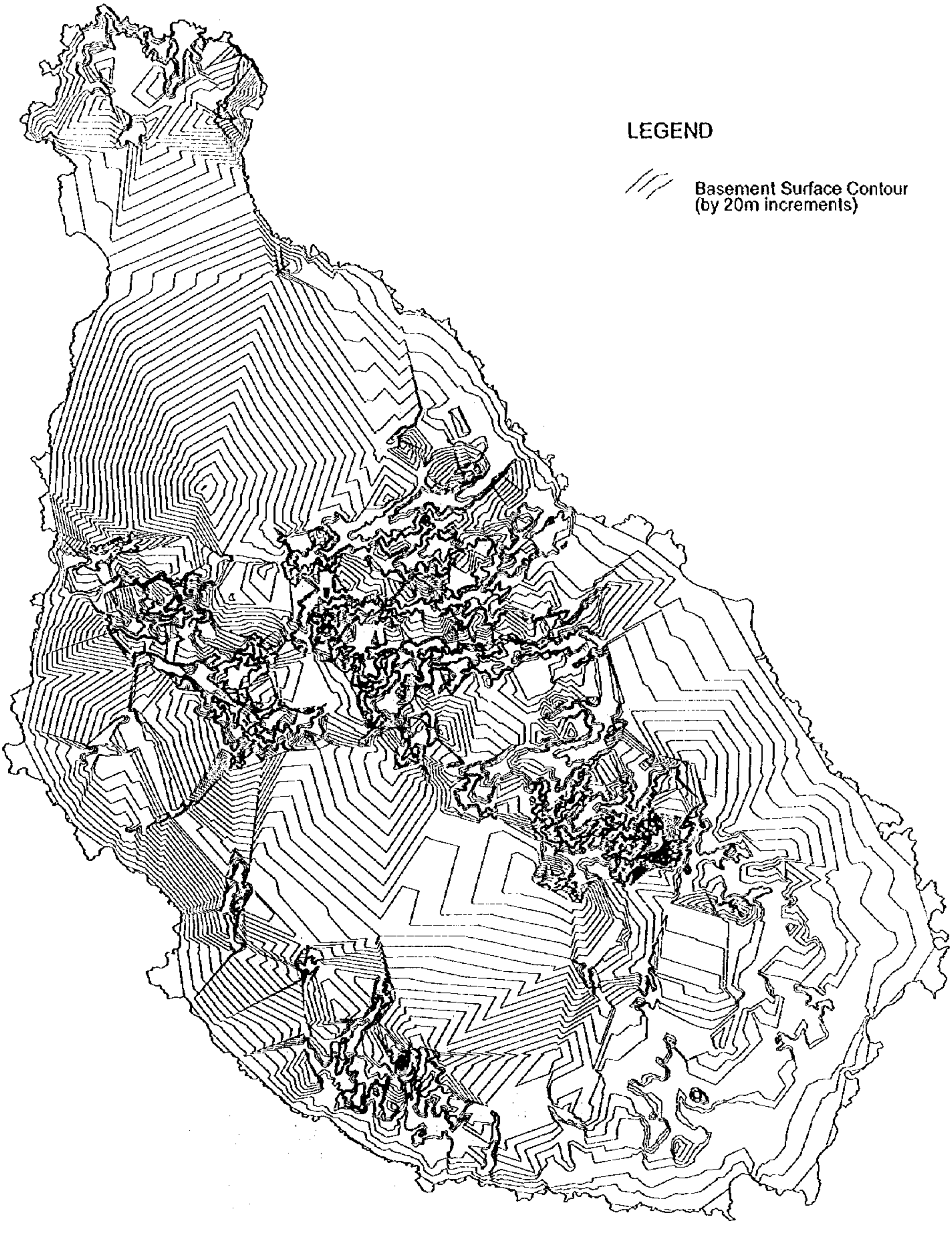

Figure 4-15 Basement Rock Surface Contour Map

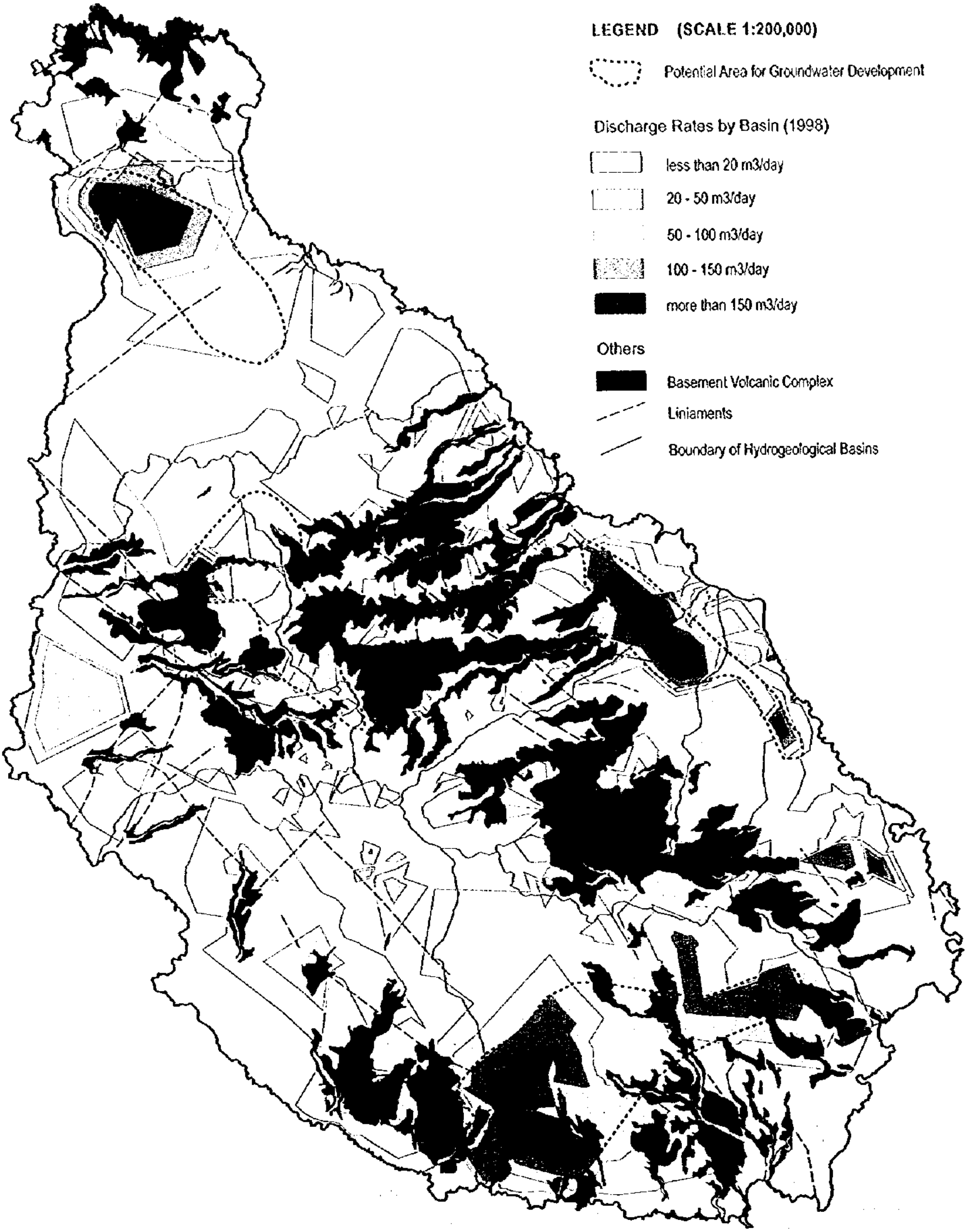

Fig. 4-16 Potential Area for Groundwater Development