1/25

UR1976_10

1976/10. The hydrology of Seven Mile Beach.

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Large quantities of potable water are present in unconsolidated sand deposits along the Tasmanian coastline. This virtually untapped resource lies at shallow depth, is readily accessible and can be economically extracted by simple methods. The Department of Mines has therefore initiated investigations of coastal aquifers to establish the distribution, quality and quantity of the groundwater.

Initially Seven Mile Beach was selected for examination because of its accessibility, and because its relatively large size indicated the presence of considerable groundwater supplies. Acknowledgment is made to Loongana Saw Mills Pty Ltd, which owns and controls an extensive pine plantation on the spit, and to the Department of Transport, for allowing access and investigations in the area.

INVESTIGATION METHODS

The survey combined geological, geomorphological and hydrological investigations. It attempted to establish the areal and vertical variation in groundwater quality, and to combine such data with natural recharge/discharge estimates and computed aquifer parameters in an attempt to determine a general groundwater regime for the area.

Field data were collected during the summers of 1973-74 and 1974-75, and the winter of 1975. Salinity measurements were made on water samples from 150 augered holes, and 100 sand samples from 40 of these were analysed for grain-size distribution. Forty holes were tied to three surveyed transects and one longitudinal traverse of the spit. The resulting topographic information was sufficiently detailed to produce accurate morphologies of both the extensive beach ridge system and the underlying water table. The geomorphology of Seven Mile Beach is described more fully elsewhere (Sloane and Cromer, in preparation).

Two rotary drill holes were sited at Seven Mile Beach. Each was pump tested to ascertain the hydrological parameters of the beach sand, and water samples were collected for analysis.

GENERAL GEOLOGY

The region has been mapped and described by Leaman (1971) as part of a study of the geology of the Coal River Basin. On Single Hill to the southwest of the Seven Mile Beach township a complex system of Jurassic dolerite dykes intrudes Permian sandstone and siltstone. Triassic quartz sandstone crops out at Hobart Airport and at the eastern end of Barilla Bay. West of Seven Mile Beach, Tertiary sand, clay and silt underlie the gently sloping surface near Cambridge Aerodrome.

Seven Mile Beach is composed entirely of Quaternary aeolian, marine and estuarine sands. Evidence from two rotary drill, and several augered, holes indicates that about 13 m of such unconsolidated sand overlie at least 70 m of green clay. The clay is probably Tertiary in age.

AUGERING AND DRILLING

The Quaternary stratigraphy at Seven Mile Beach has been conclusively established by augering and drilling. One hundred and fifty holes were hand

2/25

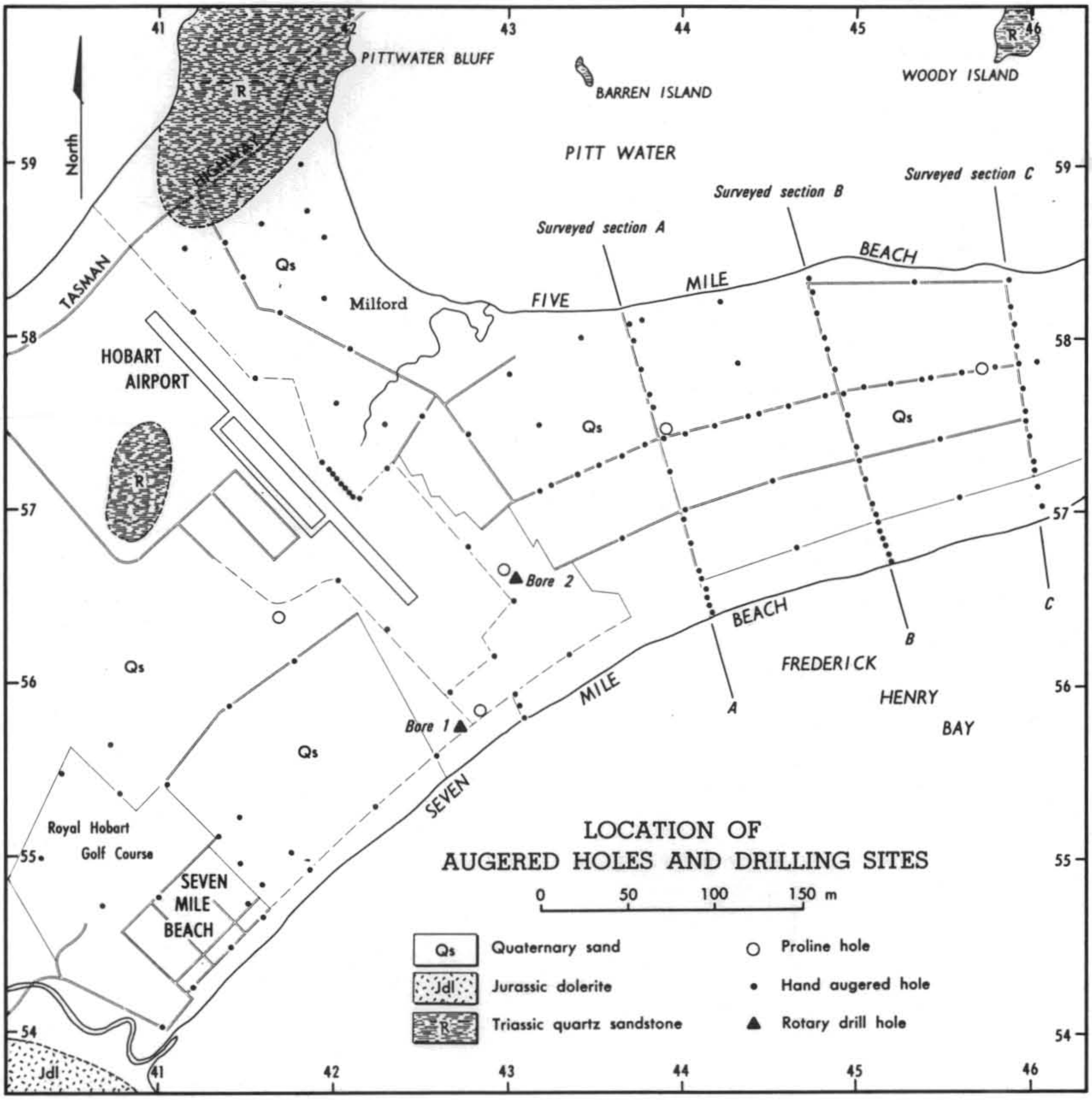

Figure 1

5 cm

augered to the water table. Early in the investigation, holes were sited on a rough grid at about 400 m intervals. Subsequently additional closely spaced sites were augered along three surveyed transects to provide vertical control on the water table. Because of the shallow nature of the water table (which prohibited deeper hand augering), five mechanically augered holes and a number of bailed-and-cased holes were sited to provide deeper stratigraphic control. Locations of all holes are shown in Figure 1.

Mottled green-white Tertiary(?) clay appears to underlie the entire spit at a depth ranging from 10-12 m. Subsequent rotary drilling at [426558]* established that the clay was at least 70 m thick. The overlying Quaternary sequence consists of a yellow-buff aeolian quartz sand cover up to 3 m thick underlain by yellow-grey shelly marine and slightly clayey estuarine quartz sand. At two localities [426558, 428566] the lower marine sequence contained a rich shelly horizon at its base. The boundary between the aeolian sand and the underlying marine and estuarine sand is difficult to determine with accuracy, but in some holes appears to approximate to the water table.

The aeolian sands are composed almost entirely of well sorted medium-fine quartz and quartzite grains. Sphericity is high (0.7) and roundness low (0.1-0.3). Many grains are pitted. The buff colour of the deposits is due to the wide variations in transparency of the material: many grains are clear, and all graduations from pale yellow-orange (citrine, and oxide stained) occur. Shelly fragments, including rare foraminifera, constitute less than 3%, and heavy minerals including zircon, rutile, topaz, garnet and magnetite, make up less than 1% of samples.

Dissolution of carbonate material in the sand by infiltrating rain water, and its subsequent reprecipitation near the water table, has caused the locally abundant formation of carbonate nodules and concretions.

The underlying marine and estuarine sands are characterised by a colour change (buff to grey), an increase in grain size, and an increase in shell and heavy mineral content.

SHAPE OF THE GROUNDWATER BODY

The water table is generally independant of the beach ridge-and-swale topography. Thus it is shallower in swales, and deeper beneath ridges. Relative to mean sea level, the groundwater body displays a gently convex surface, attaining a maximum height of about 2.5 m ASL over the area investigated (figs 3, 4). Hydraulic gradients of the order of 0.0025 $m.m^{-1}$ exist seawards and towards Pitt Water. The gradients increase sharply near high water mark and are strongly influenced by tidal effects.

The base of the groundwater body corresponds to the Quaternary/Tertiary boundary, where the Tertiary clay acts as an effective aquiclude. Near Pitt Water and along Seven Mile Beach, the groundwater maintains a virtual hydrostatic equilibrium with seawater. The freshwater/saltwater interface has not been investigated, but by analogy with coastal regimes elsewhere the salt water body probably approximates a wedge-shaped intrusion dipping sharply beneath the fresh water near high water mark. Little is known of the extent of salt water incursion in Tasmania, but its presence - or artificial inducement due to over-exploitation - may be a serious economic factor limiting water use.

The groundwater body at Seven Mile Beach thus assumes a tabular form 10-12 m thick with its upper surface slightly convex (fig. 4).

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*All grid references lie within AMG 100 kilometre square EN.

4/25

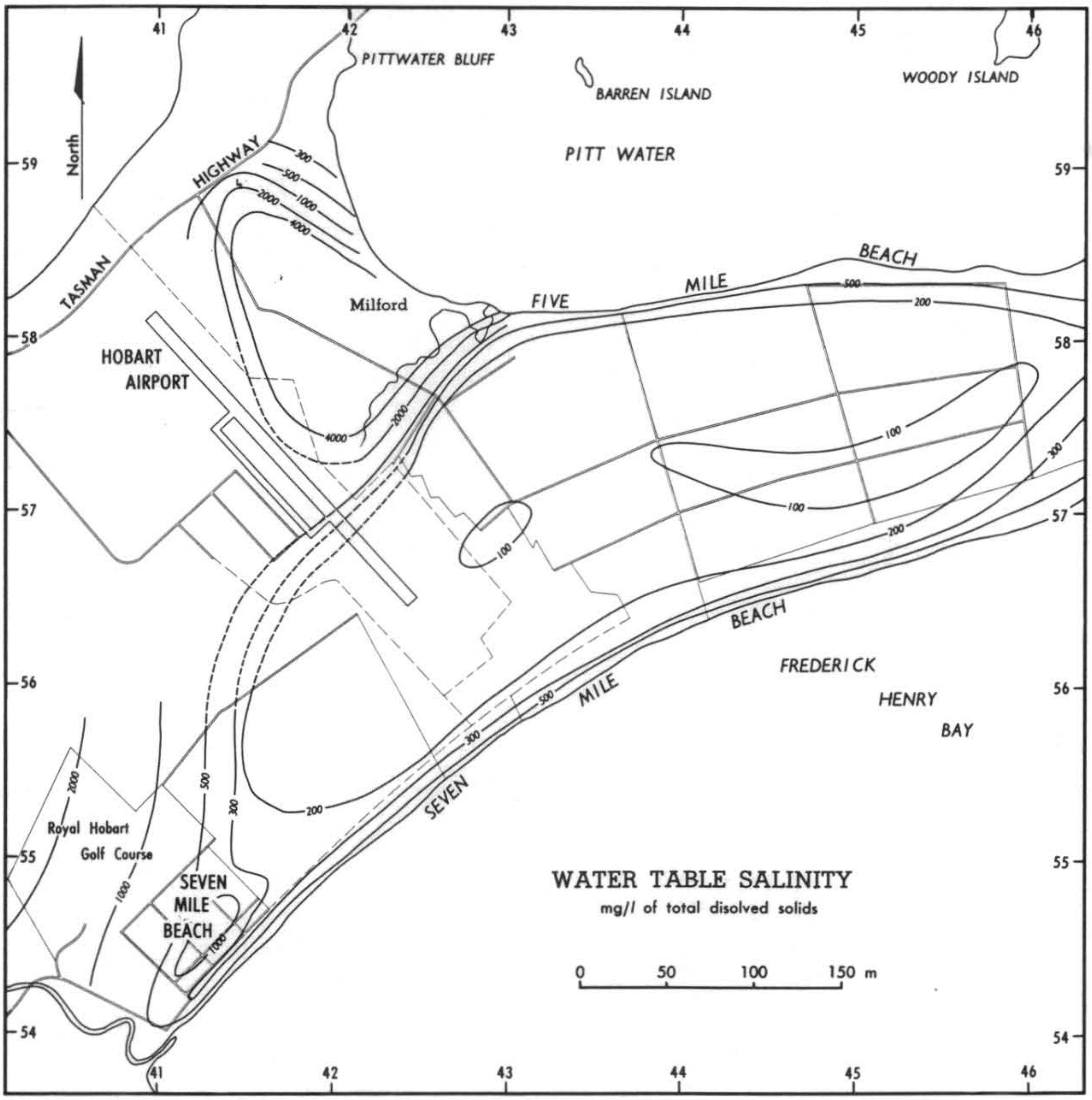

Figure 2

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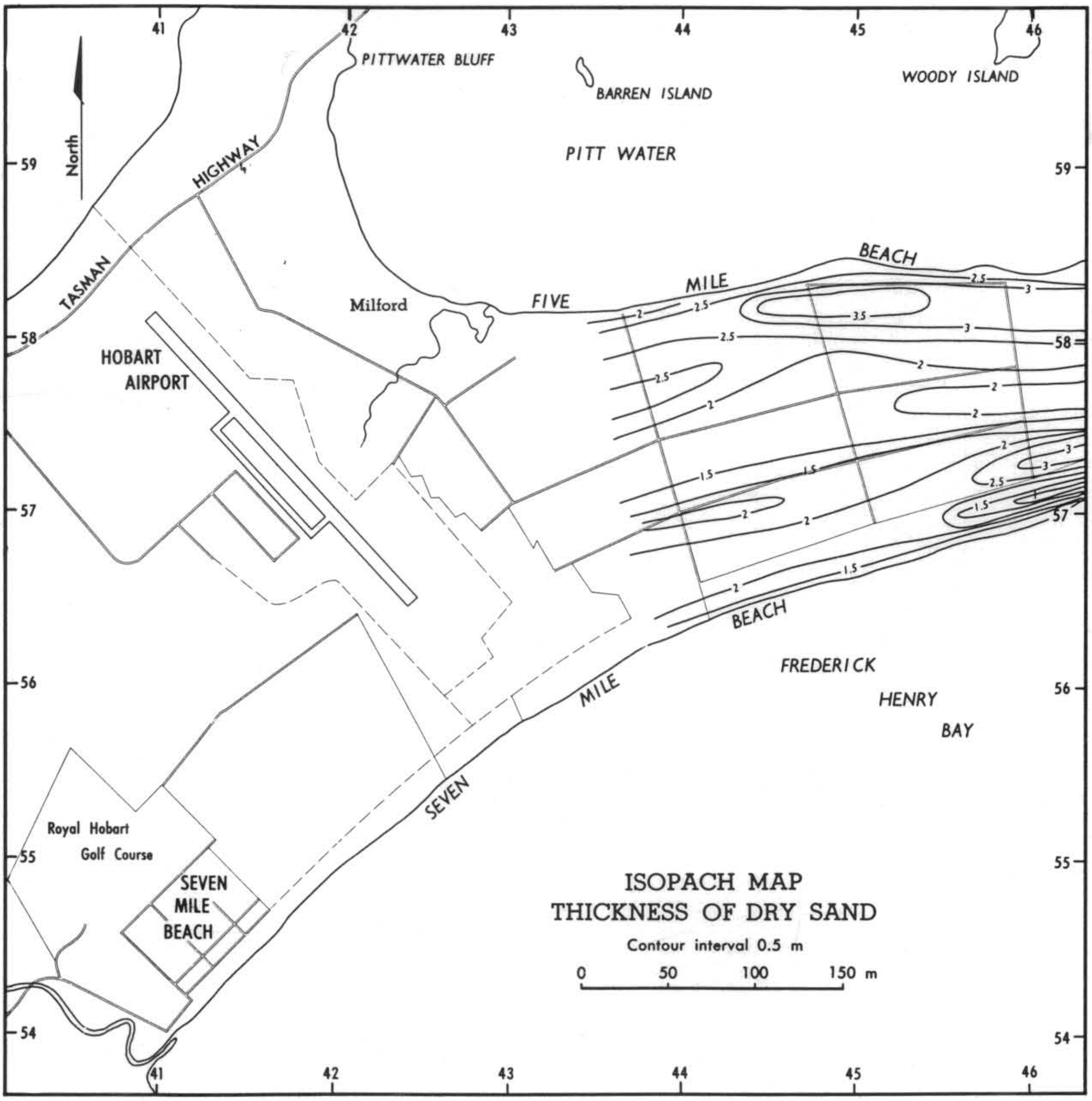

ISOPACH MAP
THICKNESS OF DRY SAND
Contour interval 0.5 m
0 50 100 150 m
North
PITTWATER BLUFF
BARREN ISLAND
WOODY ISLAND
PITT WATER
TASMAN HIGHWAY
Milford
HOBART AIRPORT
FIVE MILE BEACH
SEVEN MILE BEACH
FREDERICK HENRY BAY
Royal Hobart Golf Course
SEVEN MILE BEACH
41
42
43
44
45
46
54
55
56
57
58
59
1.5
2
2.5
3
3.5

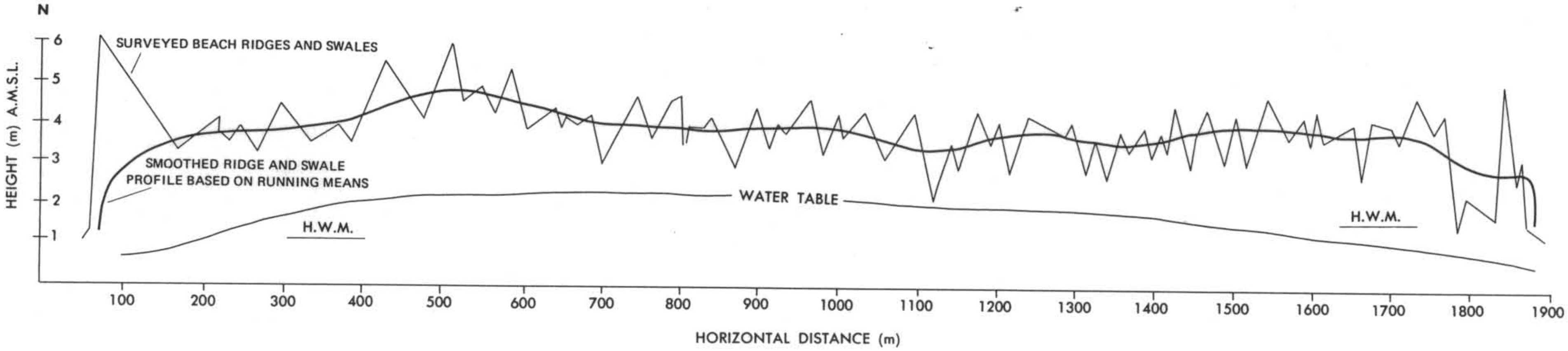
Figure 3

5 cm

SURVEYED TRANSECTS OF BEACH RIDGE SYSTEM
SEVEN MILE BEACH

$$\frac{V}{H} = 50$$

SECTION A



SECTION B

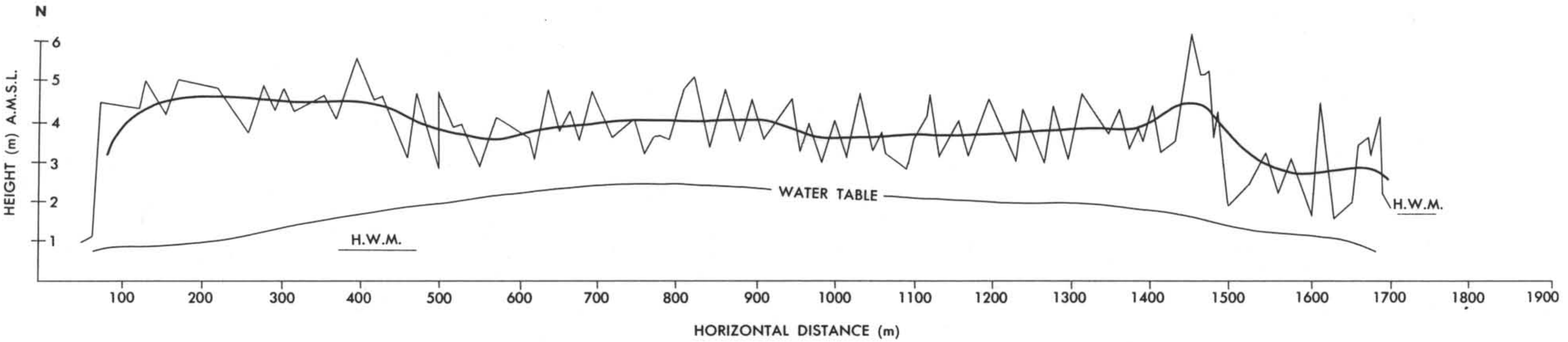


FIGURE 4.

5 cm

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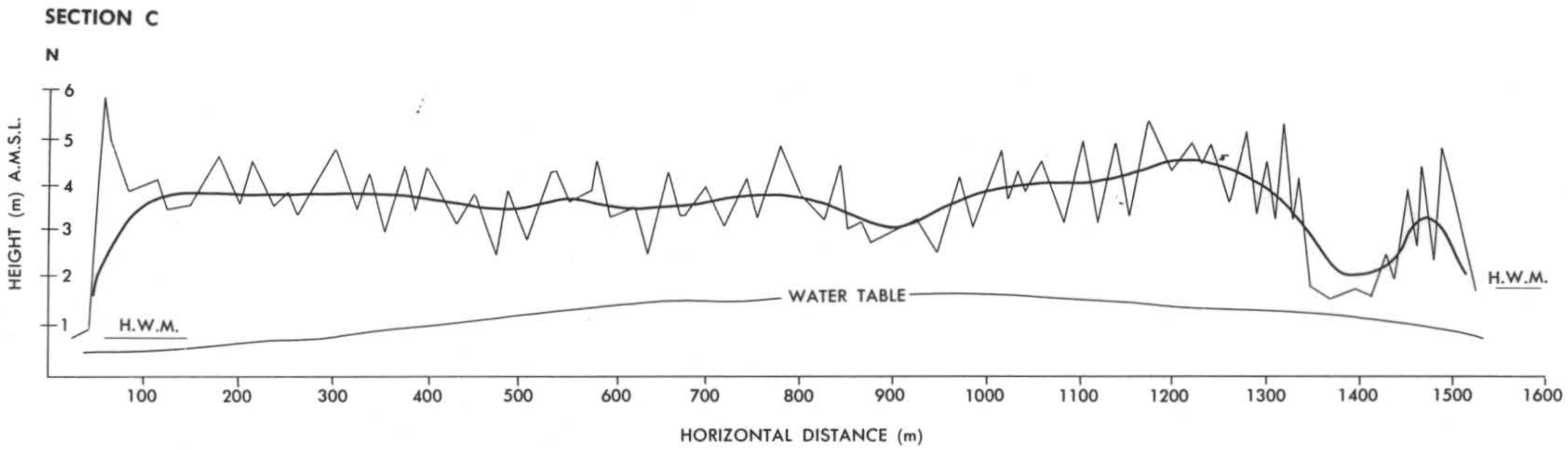

GENERALISED SECTION, SEVEN MILE BEACH

V = H

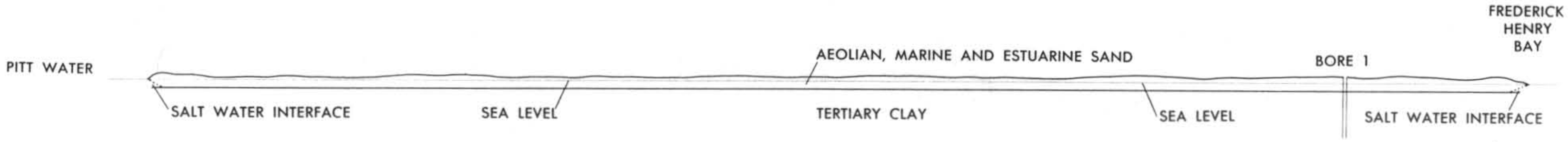

Figure 4. (cont.).

5 cm

7/65

CHEMICAL CHARACTERISTICS OF THE GROUNDWATER

Salinities of water from hand and mechanically augered holes were measured in the field by portable conductivity meter. Such measurements indicate only the water quality at the water table itself. Samples for full chemical analyses were collected during pump testing at various sites, and the analyses (table 1) reflect an *average* composition for the aquifer at each locality. Analyses (table 2) of groundwater from unconsolidated sands elsewhere in south-eastern Tasmania are included for comparison.

The survey clearly indicates that both lateral and vertical variations in quality occur within the groundwater body.

Lateral salinity variations

Water table salinities are low [<200 mg/*l* total dissolved solids (T.D.S.)] over most of the spit. This is the result of the dilution effect of infiltrating rainwater which is the predominant source of groundwater. Two areas (fig. 2), however, are underlain by poorer quality water. The groundwater beneath Seven Mile Beach township, near the tidal inlet at the south-western corner of the spit, contains up to 1000 mg/*l* T.D.S. The quality decreases inland towards the Tertiary sediments west of the town. The water is marginally suitable for domestic supplies.

A large area east of Hobart Airport near Milford contains very poor quality groundwater. Much of the area is a clayey, deflated salt marsh deposit waterlogged after heavy rain. Aeolian cover sands are generally thin or absent, and the water table is often shallower than 0.3 m. Groundwater salinities are strongly influenced by a tidal channel extending west from Pitt Water to the airport runway. Samples collected from ten closely spaced shallow holes augered across the southern boundary of the salt marsh showed a lateral water table salinity gradient of about 40 mg/*l*/m, from about 550 to >5000 mg/*l* T.D.S.

Salinities are also related to distance from the coast (fig. 2). The effects is more marked on the [illegible]ward side of the spit where water table salinities increase seawards from about 250 mg/*l* T.D.S. at the rear of the frontal dunes, to about 1000 mg/*l* T.D.S. near high water mark. This variation is probably caused mainly by salt spray contamination and is related also to the direction and intensity of prevailing winds.

Vertical changes in water quality

Evidence for such changes at Seven Mile Beach is meagre because it is difficult to obtain uncontaminated depth - representative water samples. Cooper *et al.* (1964) describe a sampling method from an array of open-ended fully cased bores penetrating cavernous limestone, but the procedure is clearly not suitable for unconsolidated sand aquifers. The evidence at Seven Mile Beach is based on analyses (table 1) of samples collected from both augered holes and Bores 1 [426558] and 2 [428566]. Water table salinities of 200-250 mg/*l* T.D.S. were measured at each site, but salinities of 3300 mg/*l* T.D.S. (bore 1) and 800 mg/*l* T.D.S. (bore 2) were recorded during pumping. Both bores penetrated the full saturated thickness of the aquifer, and the analyses reflect an *average* quality for the water removed from the cone of depression. Consecutive sampling during pumping at each site revealed only minor salinity variations which are probably mainly the result of analytical error.

The relatively high salinities measured from Bore 1 may reflect the proximity of the site to the coast, and may be due to salt water contamination.

Table 1. *CHEMICAL ANALYSES*[1] *OF GROUNDWATER FROM SEVEN MILE BEACH*
Expressed as milligrams per litre (mg/l), milligram equivalents per litre (meq/l), and percentage milligram equivalents per litre (% meq/l).

Constituent	Sea Water[2]			751661[3] 15/10/75[4]			751662 15/10/65		
	mg/l	meq/l	% meq/l	mg/l	meq/l	% meq/l	mg/l	meq/l	% meq/l
Silica (SiO_2)	0.04	-	-	12	-	-	17	-	-
Iron (Fe)	0.0	0.0	0.0	<0.1	0.0	0.0	<0.1	0.0	0.0
Calcium (Ca)	400	20	1.0	51	2.55	2.0	53	2.65	2.33
Magnesium (Mg)	1 272	104.3	8.7	96	7.9	6.6	98	8.04	7.07
Sodium (Na)	10 560	464.6	39.0	980	43.12	36.0	1 030	45.32	39.84
Potassium (K)	380	9.88	1.0	49	1.27	1.0	50	1.30	1.14
Bicarbonate (HCO_3)	142	2.27	0.1	700	11.2	9.0	710	11.36	9.99
Sulphate (SO_4)	2 560	53.80	5.0	77	1.62	1.0	80	1.68	1.48
Chloride (Cl)	18 980	531.40	44.5	1 860	52.10	44.0	1 550	43.40	38.15
Total dissolved solids	34 380	1 186		3 200	120		3 310	114	
Hardness (as $CaCO_3$)				520			540		
Alkalinity (as $CaCO_3$)				510			580		
pH		8.0-8.4			7.6			7.8	
% difference in equivalents of cations and anions[5].		1.89			15.5			4.4	
Per cent sodium		79.2			80.9			81.3	
Sodium absorption ratio		58.9			18.9			19.6	

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1. Analyses by Department of Mines Laboratory, Launceston, unless otherwise indicated.
2. Average composition; from Hem (1959), p. 10.
3. Department of Mines registered number.
4. Date of collection. Samples 751661, 751662, 751663, 751664 collected during pump test of Bore Hole 1 [EN426558] at 60, 120, 180 and 300 minutes respectively after start of test. Each sample represents a mixture of water from all levels in the aquifer, and is an average composition. Al <0.2 meq/l.
5. A check on the accuracy of the analysis. Percentage difference of cation, and anion, equivalents should be zero if all major constituents have been determined.

Table 1. ..(continued)

Constituent	751663 15/10/75 mg/*l*	 meq/*l*	 % meq/*l*	751664 15/10/75 mg/*l*	 meq/*l*	 % meq/*l*	751690[6] 20/10/75 mg/*l*	 meq/*l*	 % meq/*l*
Silica (SiO_2)	15	-	-	10	-	-	<5	-	-
Iron (Fe)	0.4	0.02	0.0	0.6	0.03	0.0	0.1	0.0	0.0
Calcium (Ca)	51	2.55	2.29	57	2.85	2.53	12	0.60	2.07
Magnesium (Mg)	100	8.20	7.38	100	8.20	7.29	26	2.14	7.41
Sodium (Na)	980	43.12	38.86	970	42.68	37.94	245	10.66	36.90
Potassium (K)	50	1.30	1.17	51	1.33	1.18	24	0.61	2.11
Bicarbonate (HCO_3)	710	11.36	10.24	720	11.52	10.24	460	7.54	26.10
Sulphate (SO_4)	76	1.60	1.44	79	1.66	1.47	<5	<0.1	0.0
Chloride (Cl)	1 530	42.80	38.61	1 580	44.24	39.33	260	7.33	25.37
Total dissolved solids	3 280	111		3 340	113		800	29	
Hardness (as $CaCO_3$)	540			550			140		
Alkalinity (as $CaCO_3$)	580			590			380		
pH		7.9			8.2			7.6	
% difference in equivalents of cations and anions[5]		1.1			4.1			5.8	
Per cent sodium		80.5			79.9			80.0	
Sodium absorption ratio		18.6			18.2			9.1	

5. A check on the accuracy of the analysis. Percentage difference of cation, and anion, equivalents should be zero if all major constituents have been determined.
6. Samples collected during pump test at Bore Hole 2 [EN428566], at 60 and 180 minutes after start of test. Al <0.2 meq/*l*.

Table 1. (continued)

Constituent	751691[6]			742648[7]			661[8]		
	20/10/75			13/11/74			15/10/65		
	mg/*l*	meq/*l*	% meq/*l*	mg/*l*	meq/*l*	% meq/*l*	mg/*l*	meq/*l*	% meq/*l*
Silica (SiO_2)	<5	-	-	10	-	-	n.d.	-	-
Iron (Fe)	<0.1	0.0	0.0	<0.1	0.0	0.0	n.d.	-	-
Calcium (Ca)	12	0.60	2.13	42	2.10	24.6	92	4.59	-
Magnesium (Mg)	26	2.14	7.58	10	0.82	9.6	17	1.40	-
Sodium (Na)	240	10.44	37.00	23	1.01	11.82	55	2.39	-
Potassium (K)	24	0.61	2.16	4.1	0.10	1.17	4	0.10	-
Bicarbonate (HCO_3)	450	7.38	26.15	207	3.39	39.68	n.d.	-	-
Sulphate (SO_4)	<5	<0.1	0.0	16	0.34	3.97	n.d.	-	-
Chloride (Cl)	250	7.05	24.98	28	0.78	9.13	72	2.03	-
Total dissolved solids	780	28		260	8.5		445	10.5	
Hardness (as $CaCO_3$)	140			146			300		
Alkalinity (as $CaCO_3$)	370			170			250		
pH		8.0			8.3			7.2	
% difference in equivalents of cations and anions[5]		4.4			10.6				
Per cent sodium		80.1			27.5			29.4	
Sodium absorption ratio		8.9			0.83			1.4	

5. A check on the accuracy of the analysis. Percentage difference of cation, and anion, equivalents should be zero if all major constituents have been determined.
6. Samples collected during pump test at Bore Hole 2 [EN428566], at 60 and 180 minutes after start of test. Al <0.2 meq/*l*.
7. Collected during brief pump test of shallow spear bore at site of Proline Hole 1 [EN415563].
8. Partial analysis by Government Analyst Laboratory, Hobart. Results supplied by CSIRO Forest Research Institute. Locality uncertain, collected from water table.

Table 2. CHEMICAL ANALYSES[1] OF GROUNDWATER IN COASTAL SANDS FROM SOUTH-EASTERN TASMANIA
Expressed as milligrams per litre (mg/l), milligram equivalents per litre (meq/l), and percentage milligram equivalents per litre (% meq/l).

Constituent	742680[2]			742681[3]			742683[4]		
	mg/*l*	meq/*l*	% meq/*l*	mg/*l*	meq/*l*	% meq/*l*	mg/*l*	meq/*l*	% meq/*l*
Silica (SiO_2)	3	-	-	3	-	-	13	-	-
Iron (Fe)	0.2	0.01	0.05	0.3	0.01	0.05	5.6	0.22	0.43
Calcium (Ca)	40	2.00	9.26	42	2.10	9.46	58	2.89	5.66
Magnesium (Mg)	30	2.47	11.44	31	2.55	11.49	58	4.77	9.35
Sodium (Na)	150	6.53	30.25	150	6.53	29.43	420	18.27	35.81
Potassium (K)	11	0.28	1.30	11	0.28	1.26	8.3	0.21	0.41
Bicarbonate (HCO_3)	110	1.80	8.34	120	1.97	8.88	210	3.44	6.74
Sulphate (SO_4)	43	0.89	4.12	41	0.85	3.83	220	4.58	8.98
Chloride (Cl)	270	7.61	35.25	280	7.90	35.60	590	16.64	32.61
Total dissolved solids	755	21.6		820	22.2		1 560	51.0	
Temporary hardness (as $CaCO_3$)	90			95			170		
Permanent hardness (as $CaCO_3$)	130			140			210		
Alkalinity (as $CaCO_3$)	90			95			170		
pH		7.5			7.4			7.0	
% difference in equivalents of cations and anions[5]		4.6			3.4			3.3	
Per cent sodium		60.4			50.4			70.1	
Sodium absorption ratio		4.4			4.3			9.3	

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1. Analyses by Department of Mines Laboratory, Launceston.
2, 3. Successive samples collected from pump test from shallow spear bore in windblown sand at Mortimer Bay, South Arm [EN388398]. Al = 0.2 meq/*l*. Owner: *Assman.*
4. Sample obtained during pump test of shallow well in beach sand at South Arm [EN336374]. Al <0.2 meq/l. Owner: *Fenton.*
5. A check on the accuracy of the analysis. Percentage difference of cation, and anion, equivalents should be zero if all major constituents have been determined.

Table 2. (continued)

Constituent	742684[5]			742685[5]			726822[6]			726821[7]		
	mg/*l*	meq/ *l*	% meq/*l*	mg/*l*	meq/*l*	% meq/*l*	mg/*l*	meq/*l*	% meq/*l*	mg/*l*	meq/*l*	% meq/*l*
Silica (SiO_2)	8	-	-	8	-	-	n.d.	-	-	n.d.	-	-
Iron (Fe)	0.2	0.01	0.04	0.2	0.07	0.04	n.d.	-	-	n.d.	-	-
Calcium (Ca)	36	1.80	7.96	66	3.29	13.00	65	3.24	20.37	100	4.99	24.09
Magnesium (Mg)	26	2.14	9.46	36	2.96	11.70	11	0.90	5.67	24	1.97	9.52
Sodium (Na)	190	8.27	36.58	150	6.53	25.81	68	2.96	18.62	52	2.26	10.92
Potassium (K)	1.1	0.03	0.13	0.6	0.02	0.08	n.d.	-	-	n.d.	-	-
Bicarbonate (HCO_3)	290	4.76	21.05	270	4.43	17.51	350	5.74	36.10	490	8.04	38.81
Sulphate (SO_4)	120	2.50	11.06	145	3.02	11.94	22	0.46	2.89	66	1.37	6.62
Chloride (Cl)	110	3.10	13.71	180	5.08	20.08	91	2.57	16.16	74	2.09	11.00
Total dissolved solids	690	22.6		735	25.3		550	15.9		630	20.7	
Temporary hardness (as $CaCO_3$)	200			220			n.d.			n.d.		
Permanent hardness (as $CaCO_3$)				90			n.d.			n.d.		
Alkalinity (as $CaCO_3$)	240			220			290			400		
pH		8.1			7.7			7.7			7.7	
% difference in equivalents of cations and anions[8]		8.4			1.1			10.5			11.0	
Per cent sodium		67.8			51.2			41.7			24.5	
Sodium absorption ratio		5.9			3.7			2.1			1.2	

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[5] Samples collected during pump test of shallow spear bores at South Arm [EN342357]. Al <0.2 meq/*l*. Owner: Robb.

[6] From Nine Mile Beach, depth *c.* 3 m. Al <0.2 meq/ (Cromer, 1974).

[7] From Nine Mile Beach, depth *c.* 15 m, but probably represents average composition. Al <0.2 meq/*l* (Cromer, 1974).

[8] A check on the accuracy of the analysis. Percentage difference of cation, and anion, equivalents should be zero if all major constituents have been determined.

Table 3. CHEMICAL RATIOS OF GROUNDWATER IN COASTAL SANDS FROM SOUTH-EASTERN TASMANIA

Locality and registered number	Na (meq/*l*) / Total meq/*l*	Cl (meq/*l*) / Total meq/*l*	Na (meq/*l*) / Cl (meq/*l*)	Ca (meq/*l*) / Mg (meq/*l*)	HCO_3 (meq/*l*) / Ca (meq/*l*)	HCO_3 (mg/*l*) / Total meq/*l*
Sea Water	0.39	0.45	0.87	0.19	0.11	0.002
Seven Mile Beach						
Bore 1 (average of 4 samples)	0.38	0.40	0.96	0.32	4.4	0.10
Bore 2 (average of 2 samples)	0.36	0.26	1.42	0.28	12.6	0.26
742648	0.12	0.09	1.29	2.56	1.6	0.40
Nine Mile Beach						
726822	0.19	0.16	1.16	3.60	1.8	0.36
726821	0.11	0.10	1.08	2.53	1.6	0.39
Mortimer Bay						
742680	0.30	0.35	0.86	0.81	0.90	0.08
742681	0.29	0.36	0.83	0.82	0.94	0.09
South Arm						
742683	0.36	0.33	1.10	0.60	1.19	0.07
742684	0.37	0.14	2.67	0.84	2.64	0.21
742685	0.26	0.20	1.27	1.11	1.35	0.18

The analyses from Bore 1 support this thesis. The proportions of constituents (table 3) are very similar to seawater, suggesting a dilution of seawater by groundwater (or vice versa). Additional investigations are needed to test this hypothesis, since it has bearing on large-scale water usage in coastal areas.

Whereas Bore 1 was sited to monitor any effects of salt water incursion, Bore 2 was sited near the centre of the spit where coastal effects were expected to be minimal. To what extent this is true is not known, although most of the groundwater beneath the spit probably exhibits salinities closer to 800, rather than >3000, mg/*l* T.D.S.

Chemistry of the groundwater

Most of the samples analysed (tables 1 and 2) are of the 'sodium chloride' type, with Na and Cl constituting up to 80% of the total milligram equivalents per litre. Ca and HCO_3 are the next most common ions, and three samples (one from Seven Mile Beach and two from Nine Mile Beach) are 'calcium bicarbonate' waters.

The analyses are plotted for comparative purposes as a series of Stiff variation diagrams in Figure 5. Analyses from coastal sands elsewhere in south-eastern Tasmania are represented in Figure 6.

Na and Cl are probably derived from seawater through direct leaching of spray-derived NaCl by precipitation, and by the mixing of salt water and fresh groundwater near the coast. The limited data available (fig. 7*a*, table 3) suggest a strong relationship between Na and Cl concentrations. Both the Ca and HCO_3 contents of the groundwater are higher than seawater, but a plot of Ca against HCO_3 (fig. 7*b*) shows no discernible relationship between the two. Both ions are derived from dissolution of shell horizons, shell fragments and carbonate concretions in the zone of aeration, but the HCO_3 content is enhanced by atmospheric CO_2 dissolved in rainwater.

Acceptability of the water for domestic and agricultural purposes

Except in obvious extreme cases, it is difficult to give acceptability limits for the groundwater at Seven Mile Beach because a number of factors influence the effect of deleterious constituents. Quality varies laterally and vertically throughout the spit; the water may be used for drinking, gardening or agricultural purposes; the permeable sandy soil may permit the use of water which is generally considered unsuitable elsewhere; amd acceptability limits vary between individuals and for different agricultural purposes. Some general conclusions can be made, but the reader is referred to the detailed work of Hart (1974).

For small scale domestic and gardening use, the water is considered acceptable throughout the area provided it is drawn from *shallow* wells and spear bores tapping the upper levels of the aquifer. For large scale domestic, or agricultural purposes, where water is drawn from the full aquifer thickness, sites less than 300 m from the coastal should be avoided. Water derived from such localities (*e.g.* from Bore 1) is unsuitable for any use.

Water from Bore 2, which is probably representative of the average quality over the remainder of the spit, cannot be safely recommended for large scale agricultural purposes unless the effects of such water upon various crops are closely monitored. The agricultural suitability of the water is assessed in Figures 8 and 9. However, the classification is not strictly applicable to permeable sandy soil from which deleterious salts are likely to be leached.

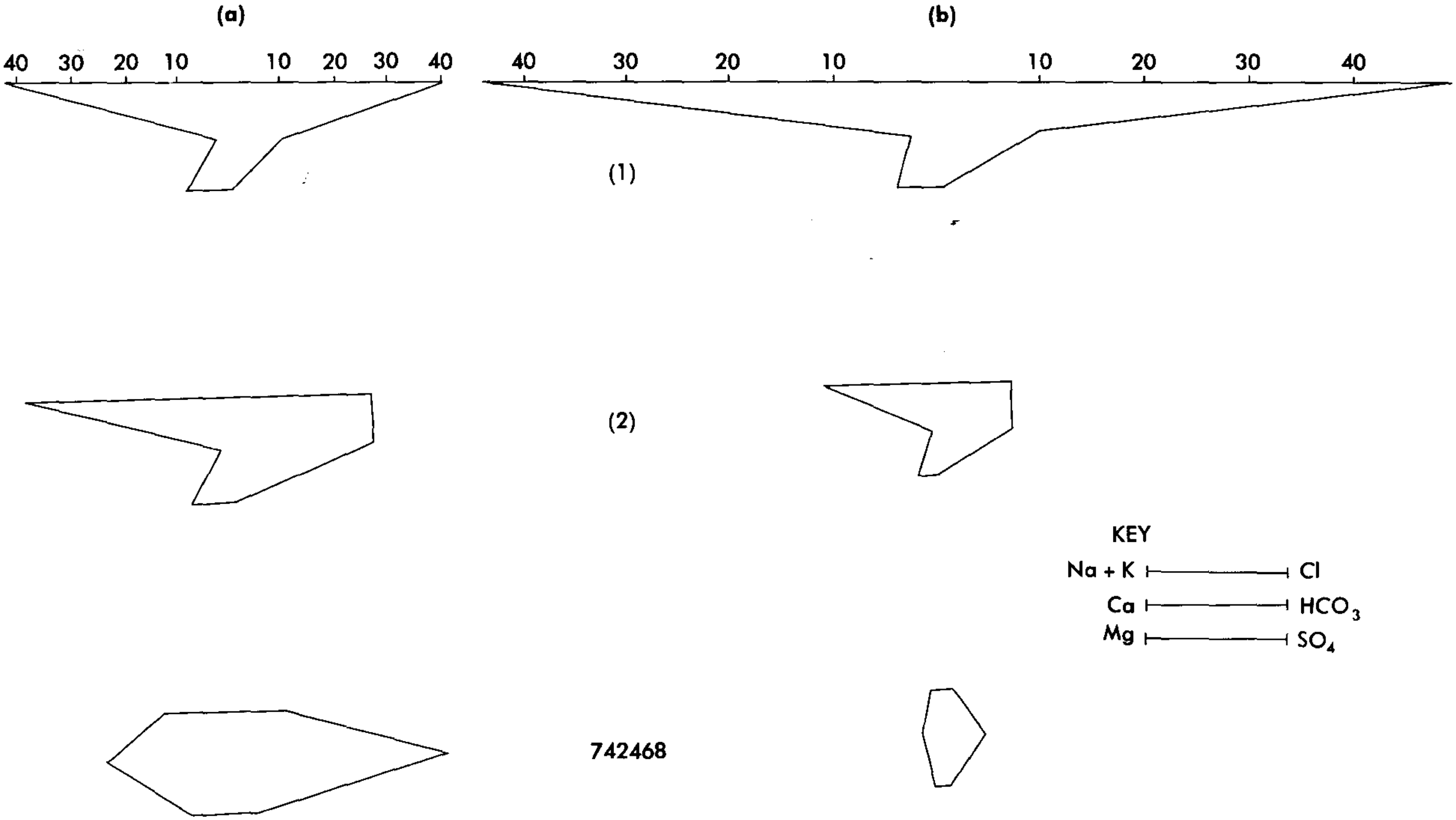


Figure 5. *Chemical analysis of groundwater from Seven Mile Beach represented as Stiff diagrams – (a) as per cent milligram equivalents per litre, (b) as milligrams per litre. Registration numbers from Table 1.*
(1) Average of analyses 751661, 751662, 751663, 751664; (2) Average of analyses 751690, 751691.

5 cm

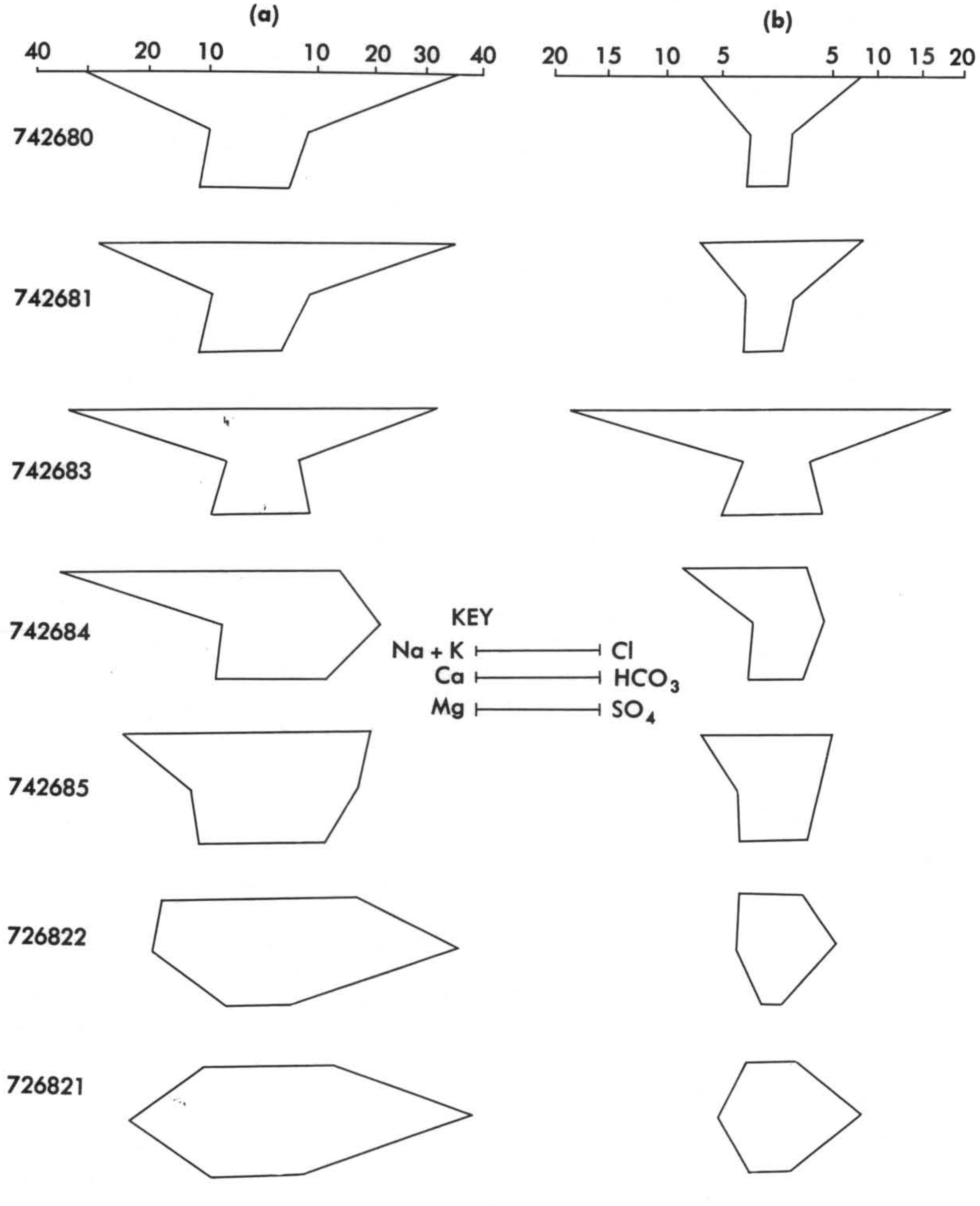
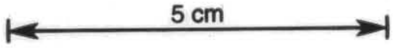


Figure 6. *Chemical analyses of groundwater in coastal sands from south-eastern Tasmania represented as Stiff diagrams*
(a) as per cent milligram equivalents per litre;
(b) as milligram equivalents per litre.

Registration numbers from Table 2.

5 cm



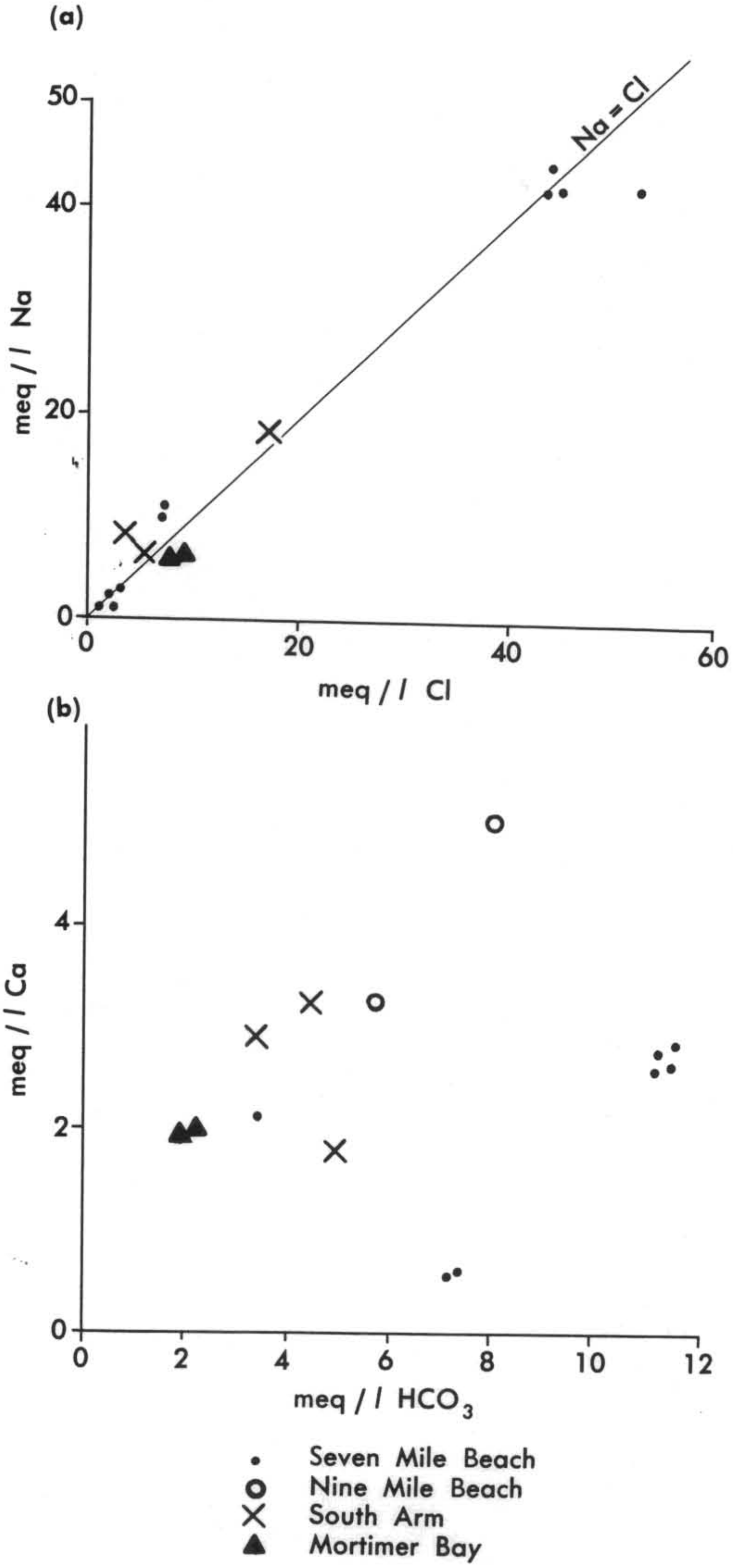


Figure 7. *Variation diagrams of Na against Cl, and Ca against HCO_3, for groundwater from coastal sands in south-eastern Tasmania.*

19/25

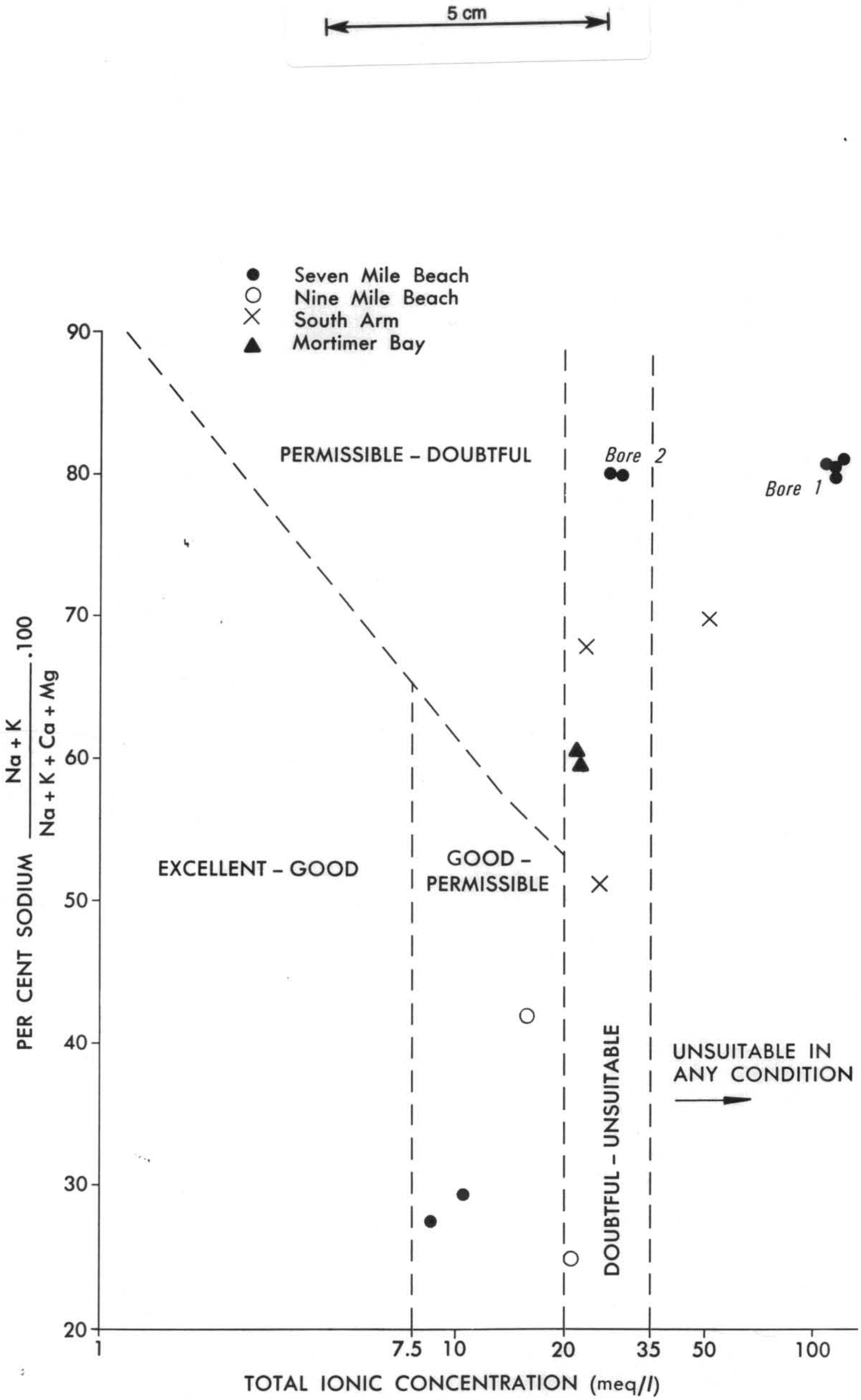


Figure 8. *Suitability of groundwater in coastal sands for agricultural purposes. Per cent sodium criterion.*

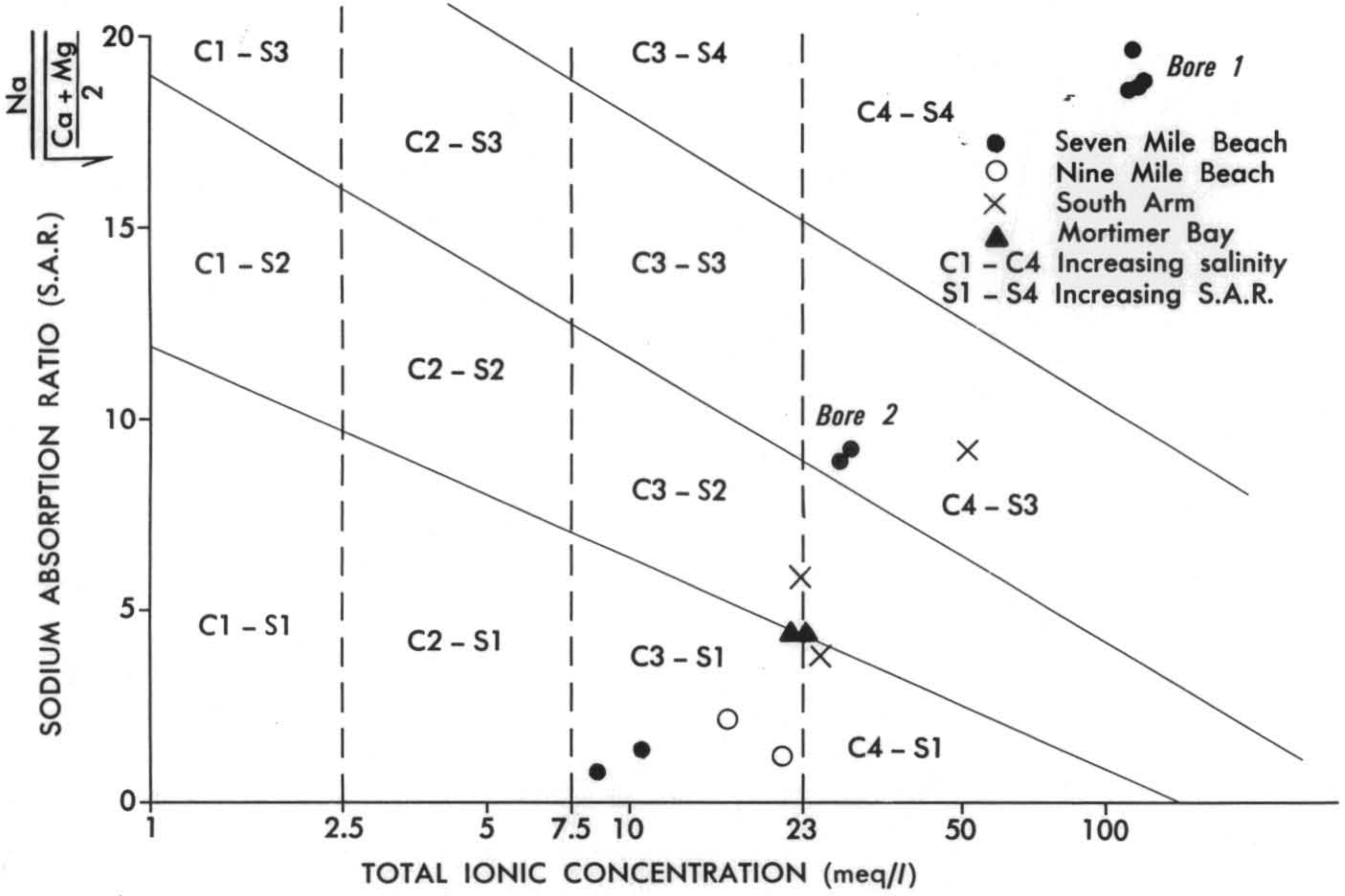


Figure 9. *Suitability of groundwater in coastal sands for agricultural purposes. Sodium adsorption criterion.*

5 cm

20/25

The Bore 2 water is marginally acceptable for domestic purposes. Although most constituents are well within recommended limits, the water is hard, and Na and Cl contents are high (Hart, 1974).

PUMP TESTS AND AQUIFER PARAMETERS

Bore 1 [426558]. Field procedures

The hole was sited at the rear of the frontal sand dunes (fig. 1). The Quaternary sequence, 13 m thick, was fully penetrated and cased with 150 mm solid steel casing (0-10 m) and 125 mm Johnson screen (opening 180 μm) from 10-13 m. The hole and surrounding formation were subsequently washed clean of drilling mud by air-lifting and bailing.

Three observation holes were jetted to depths of 3-4 m below the water table at distances of 7, 10 and 20 m, and bearings of 59, 149 and 239° respectively from the pumped hole.

During a preliminary pump test the bore was unable to sustain a yield of 70 l/min^{-1} for a time sufficient to conduct a meaningful test. Subsequently it maintained a yield of 38 l/min^{-1} for 24 hours, but produced insignificant drawdowns in each of the observation holes. The test, and the site, were abandoned.

Bore 2 [428566]. Field procedures

The hole, drilled near the centre of the spit, was cased and developed in a manner similar to Bore 1. Four observation holes were jetted at distances of 2.4, 3.6, 5.0 and 7.3 m, and bearings of 284, 284, 59 and 59° respectively from the pumped hole. The bore was pumped at 53 l/min^{-1} for 420 minutes during which time it sustained a total drawdown of 6.23 m. Maximum observed drawdown in the nearest observation hole was 0.28 m (table 4).

Analysis of pump test data

Inspection of proline and rotary bore logs shows that the Quaternary sand is an unconfined aquifer. The formation may not be homogeneous since grain size and sorting variations probably cause the vertical and horizontal permeability of the sand to differ. Such inhomogeneity affects the values for calculated transmissivity (T) and storage coefficient (S).

Data from the pumped bore are plotted as a time-drawdown curve (fig. 10). Jacob's (1963) correction was applied to the observed drawdowns, which were an appreciable fraction of the initial aquifer thickness. The curve clearly demonstrates that equilibrium conditions were not attained after 7 hours pumping, and non-equilibrium methods of analysis are therefore appropriate (Cromer, 1976). The modified Theis equations (Hazel, 1973) were applied to time-drawdown curves (fig. 11) of each of the four observation holes, but it was not necessary to apply Jacob's correction.

Since delayed yield probably affects the observed drawdowns, T and S were also calculated using Boulton's method (Hazel, 1973). T and S values obtained from both methods are listed in Table 5.

Discussion of results

Unconfined aquifer parameters (T and S) obtained from reflect the hydraulic characteristics of the formation within the radius of influence of the pumped hole. Furthermore, individual pump tests of an aquifer are semi-quantitative at best, and caution should be exercised when using them for

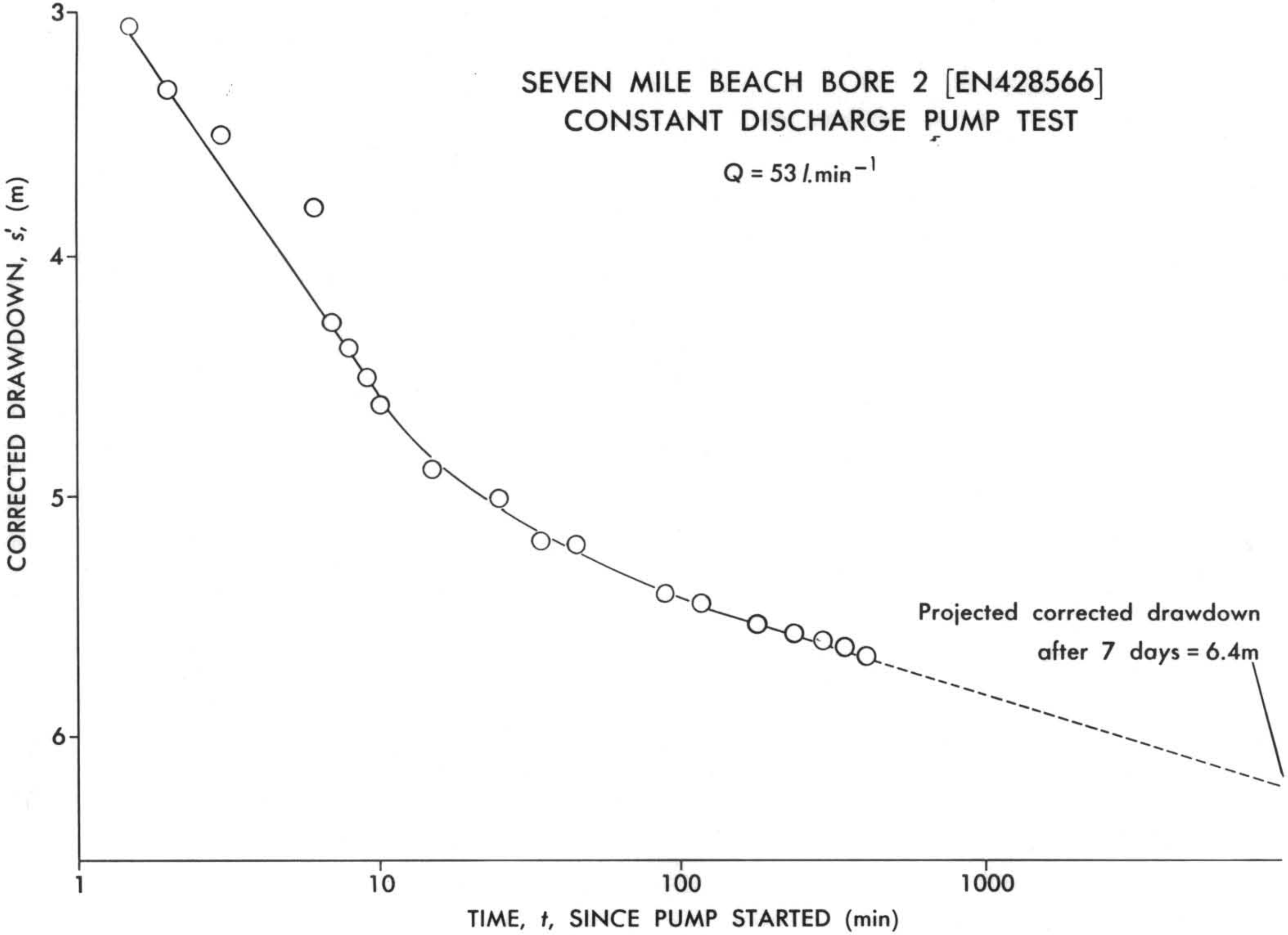
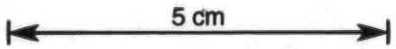

SEVEN MILE BEACH BORE 2 [EN428566]
CONSTANT DISCHARGE PUMP TEST
Q = 53 l.min⁻¹
CORRECTED DRAWDOWN, s', (m)
3
4
5
6
Projected corrected drawdown after 7 days = 6.4m
1
10
100
1000
TIME, t, SINCE PUMP STARTED (min)

Figure 10.


5 cm

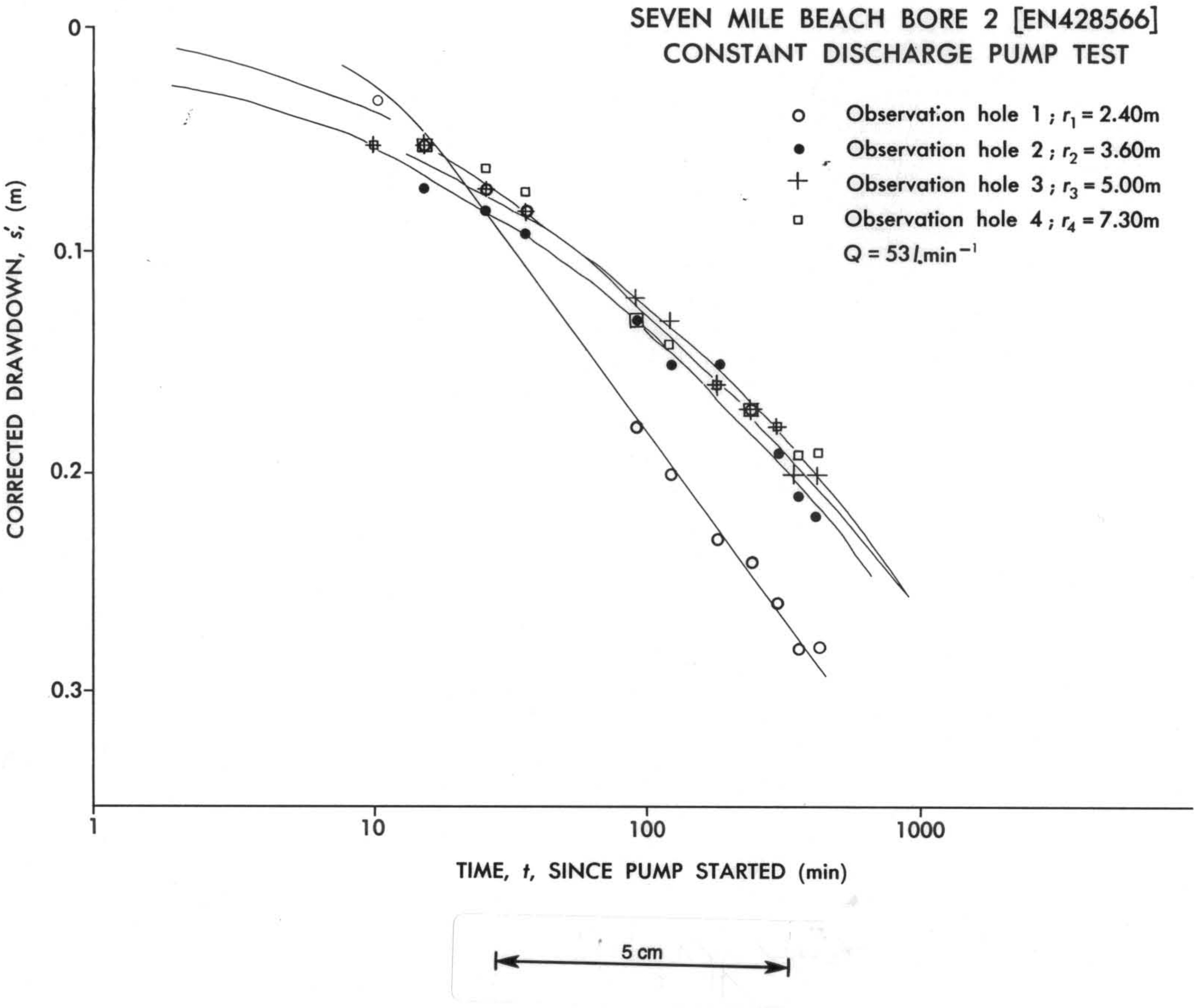

SEVEN MILE BEACH BORE 2 [EN428566]
CONSTANT DISCHARGE PUMP TEST
Observation hole 1 ; $r_1 = 2.40$m
Observation hole 2 ; $r_2 = 3.60$m
Observation hole 3 ; $r_3 = 5.00$m
Observation hole 4 ; $r_4 = 7.30$m
$Q = 53\,l.\mathrm{min}^{-1}$
0
0.1
0.2
0.3
CORRECTED DRAWDOWN, s', (m)
1
10
100
1000
TIME, t, SINCE PUMP STARTED (min)
5 cm

Figure 11.

Table 4. *OBSERVED AND ADJUSTED DRAWDOWNS, BORE 2 PUMP TEST, SEVEN MILE BEACH*

Time since pump started (min)	Pumped hole		Observation holes			
	s (m)	s' (m)	s_1 (m)	s_2 (m)	s_3 (m)	s_4 (m)
0	0.00	0.00	0.00	0.00	0.00	0.00
1.5	3.20	3.05	-	-	-	-
2	3.50	3.32	-	-	-	-
3	3.70	3.50	-	-	-	-
6	4.05	3.81	-	-	-	-
7	4.60	4.29	-	-	-	-
8	4.70	4.38	-	-	-	-
9	4.85	4.51	-	-	-	-
10	5.00	4.63	0.03	0.03	0.05	0.05
15	5.30	4.89	0.05	0.07	0.05	0.05
25	5.45	5.01	0.07	0.08	0.07	0.06
35	5.65	5.18	0.08	0.09	0.08	0.07
45	5.70	5.22	0.12	0.10	0.09	0.08
90	5.90	5.40	0.18	0.13	0.12	0.13
120	5.97	5.45	0.20	0.15	0.13	0.14
180	6.07	5.53	0.23	0.15	0.16	0.16
240	6.12	5.57	0.24	0.17	0.17	0.17
300	6.17	5.61	0.26	0.19	0.18	0.18
360	6.19	5.63	0.28	0.21	0.20	0.19
420	6.23	5.66	0.28	0.22	0.20	0.19

$Q = 53$ l/min (75 m^3/day)

$s' = s - \frac{s^2}{2b}$ (b = 10 m)

(Jacob's correction)

$r_1 = 2.40$ m
$r_2 = 3.60$ m
$r_3 = 5.00$ m
$r_4 = 7.30$ m

Table 5. *VALUES OF TRANSMISSIVITY AND STORAGE COEFFICIENT, SEVEN MILE BEACH*

Observation hole	T_M ($m^2.day^{-1}$)	S_M	T_B ($m^2.day^{-1}$)	S_B
1 (r = 2.40 m)	83	0.18	64	0.24
2 (r = 3.60 m)	117	0.14	14?	0.04
3 (r = 5.00 m)	117	0.09	122	0.04
4 (r = 7.30 m)	117	0.04	103	0.02

T_M S_M computed from modified Theis formula (Hazel, 1973)

T_B S_B computed from Boulton's method (Hazel, 1973) caution should be exercised when using them for predictive purposes. Because the cone of depression expands during pumping, T and S values also change, and approach limiting values as equilibrium conditions are approximated (Cromer, 1976). The results (table 5) suggest that gravity drainage near observation bore 1 was relatively complete towards the end of the pumping peiod, and that a value of $S_M = 0.18$ is an approximation to the *late-time* (Hazel, 1973) storage coefficient (*i.e.* specific yield) of the aquifer. When vertical flow components are partly eliminated by using Boulton's method, $S_B = 0.24$, which is probably a closer approximation. S_M values for observation bores 2, 3 and 4 suggest that gravity drainage at such distances from the discharging bore is less complete (*i.e.* delayed yield is predominant) and that the S_M values are approaching a limiting *early-time* (Hazel, 1973) storage coefficient of about 0.04.

A maximum value for T appears to be about 110-120 $m^2.day^{-1}$, indicating an average permeability, $K = \frac{T}{b}$, of 11-12 $m.day^{-1}$.

CONCLUSIONS

Excluding the area west of Hobart Airport and the eastern third of Seven Mile Beach, the unconfined aquifer has an average thickness of about 10 m extending over $10^6 m^2$. It is composed predominantly of medium-fine grained marine and estuarine sand overlying impermeable Tertiary clay. The volume of the aquifer is thus about $10^8 m^3$. The calculated average storage coefficient of 0.24 indicates recoverable groundwater resources of about $2 \times 10^7 m^3$ (4×10^9 gal), neglecting recharge. The area receives an annual average precipitation of 0.55 $m.year^{-1}$, based on figures for the last 30 years. Thus in the area investigated, $5 \times 10^6 m^3$ precipitation are added yearly. Neglecting transpiration rates, and assuming a (probably low) infiltration value of 0.3, $1.7 \times 10^6 m^3$ water percolate annually to the water table. Such yearly additions therefore represent about 10% of the storage of the aquifer. Groundwater loss occurs at sea level along Pitt Water and Seven Mile Beach. Discharge rates are expected to be of the same order as the infiltration rate since measurements over the last three years reveal only small fluctuations of the water table. Assuming a coastal length of 6000 m, a discharge rate for the area investigated is of the order of 300 $m^3.year^{-1}.m^{-1}$, corresponding to a daily water loss per metre of coastline of one cubic metre. Discharge rates calculated from transmissivity (T) and average hydraulic gradient are an order of magnitude lower than this, but are considered unreliable because of the uncertainty both of T and of the variation in hydraulic gradient near the coast.

The annual safe yield of the aquifer is therefore about $1.7 \times 10^6 m^3$ (3×10^8 gal). If the relatively low transmissivity value of 110-120 $m^2.day^{-1}$ is representative of the aquifer, such a yield corresponds to pumping 40 bores at 75 l/min^{-1} indefinitely.

Large scale exploitation of the resource should not, *on average*, exceed the safe aquifer yield. Bores should preferably be sited towards the centre of the spit to minimise the danger of salt water contamination.

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[30 March 1976]