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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1976/64

PRELIMINARY INVESTIGATION OF GROUNDWATER RESOURCES, COCOS (KEELING) ISLANDS, INDIAN OCEAN, 1975

by

C. JACOBSON

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SUMMARY

Groundwater resources have been investigated on Home Island, in the Cocos (Keeling) Islands, Indian Ocean, to assess the prospects of developing a reticulated water supply and sewerage system for the settlement there. Home Island is a coral atoll and contains a lens of fresh groundwater overlying sea water. Measurements of water-levels in existing wells, and levelling with respect to mean tide-level, indicate that the freshwater lens is up to 19 m thick, and averages about 15 m over an area of about 30 hectares. Allowing for tidal fluctuations and for periods of drought, the sustainable yield of the aquifer would be about 200 000 litres per day. Recommendations have been made for the development of the aquifer by pumping from infiltration galleries; pumping should never reduce the lens thickness by more than half to avoid salt-water contamination.

INTRODUCTION

At the request of the Department of the Special Minister of State (now the Department of Administrative Services), groundwater resources were investigated in the Cocos (Keeling) Islands from 2 to 17 December, 1975. The main object of the investigation was a hydrogeological assessment of Home Island in order to determine the feasibility of constructing a reticulated water supply and sewerage scheme for the village there. The sewerage system might be able to use salt water, and would discharge into the sea.

The Cocos (Keeling) Islands Territory is in the Indian Ocean, 2800 km northwest of Perth. The Territory consists of two coral atolls about 24 km apart. The smaller atoll, North Keeling Island, is uninhabited and difficult of access. The larger atoll, the South Keeling Islands (Plate 1), consists of 26 islands around a lagoon; two of the islands are inhabited. An Australian settlement on part of West Island has a population of about 100. Apart from the Australian-owned land on West Island, the remainder of the islands are owned by Mr John Clunies-Ross, and form a coconut plantation. The only other permanent settlement is on Home Island, which has a population of about 500 - mainly Malays.

Access to Home Island was by motor launch daily from West Island. Field work, in which I was assisted by Mr K. Campbell, included a data census of wells (Appendix 1), measurements of water-levels and salinities, and levelling with respect to a mean tide-level established by gauging. Water samples were chemically analysed by AMDEL in Adelaide (Table 1). Information on survey bench-marks was obtained from the Army's 5th Field Survey Squadron, Karrakatta, Western Australia. Tide-gauge data have been obtained from CSIRO Division of Fisheries & Oceanography, Cronulla, New South Wales (Appendix 2), and meteorological data (Appendix 3) from the Bureau of Meteorology, which maintains a station on West Island.

GEOLOGY

The Cocos Islands are atolls formed on a volcanic seamount rising from a depth of 5000 m. Evidence for this has been reviewed by Jongsma (1976) and includes bathymetry; a magnetic anomaly coinciding with the main atoll (Chamberlain, 1960); and samples of volcanic material dredged from the sea floor (Bezrukov, 1973). A cross-section based on bathymetric data is shown in Figure 1.

The islands were visited by Charles Darwin (1842), who described them as a type example of his subsidence theory of atoll formation. Darwin considered that the upgrowth of reefs continues as the volcanic seamounts that support them subside. His theory has been borne out by much of the drilling done on various atolls. The thickness of coral underlying the Cocos Islands is not known; it may be of the order of 1000 m (Fig. 1).

A cross-section showing some of the atoll features is given in Figure 2. The islands rise to a few metres above mean sea level, and are mostly formed of sand with some gravel at the surface, overlying a coral layer which is close to sea level.

HYDROLOGY

The monthly and yearly rainfall for the meteorological station on West Island is shown in Appendix 3. The mean annual rainfall is 2009 mm, with a minimum of 1100 mm in 1918 and a maximum of 3288 mm in 1942. The mean monthly rainfall for the period 1901-1973 is shown in Figure 3. The months of February to July are generally the wettest, and September to November the driest.

Of the 66 years for which complete records are available, 13 years had recorded rainfall below 1500 mm, that is less than 75 percent of the mean. Drought periods with less than 100 mm of rain in 3 months have been recorded in 18 years.

No surface runoff was observed during the present investigation.

Although evapotranspiration, has not been measured, it is assumed to be of the order of 1500 mm from coconut palms - the same as Mather's (1973) assumption in his study of the groundwater resources of Southern Tarawa in the Gilbert and Ellice Islands.

Groundwater forms unconfined aquifers on the larger Islands of the atoll. Freshwater lenses are developed on Home Island, Horsburgh Island, West Island, and South Island (Plate 1). The minimum width of the island to

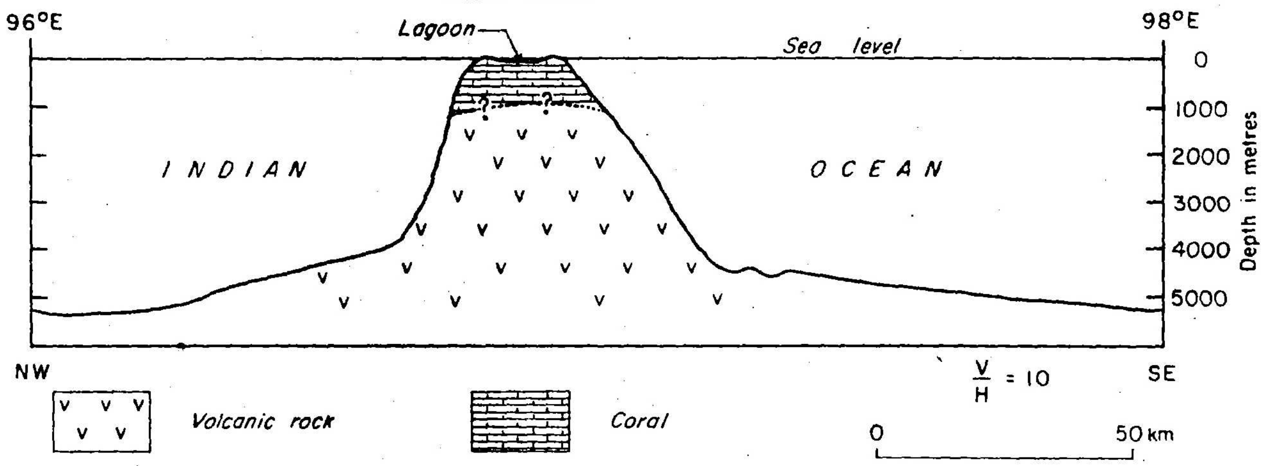

Fig. 1 Cross-section through the Cocos Islands

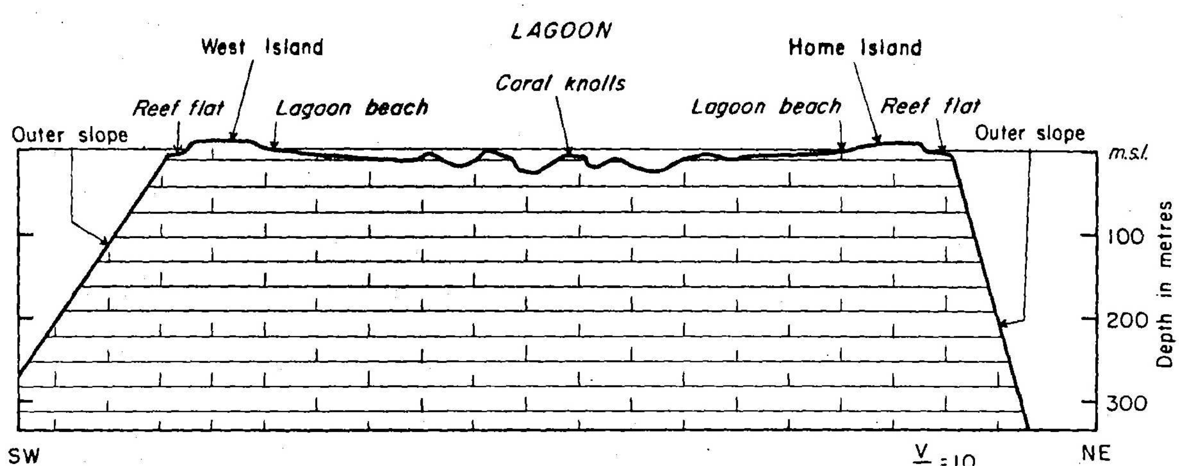

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Fig.2 Cross-section through the Cocos Islands showing atoll features

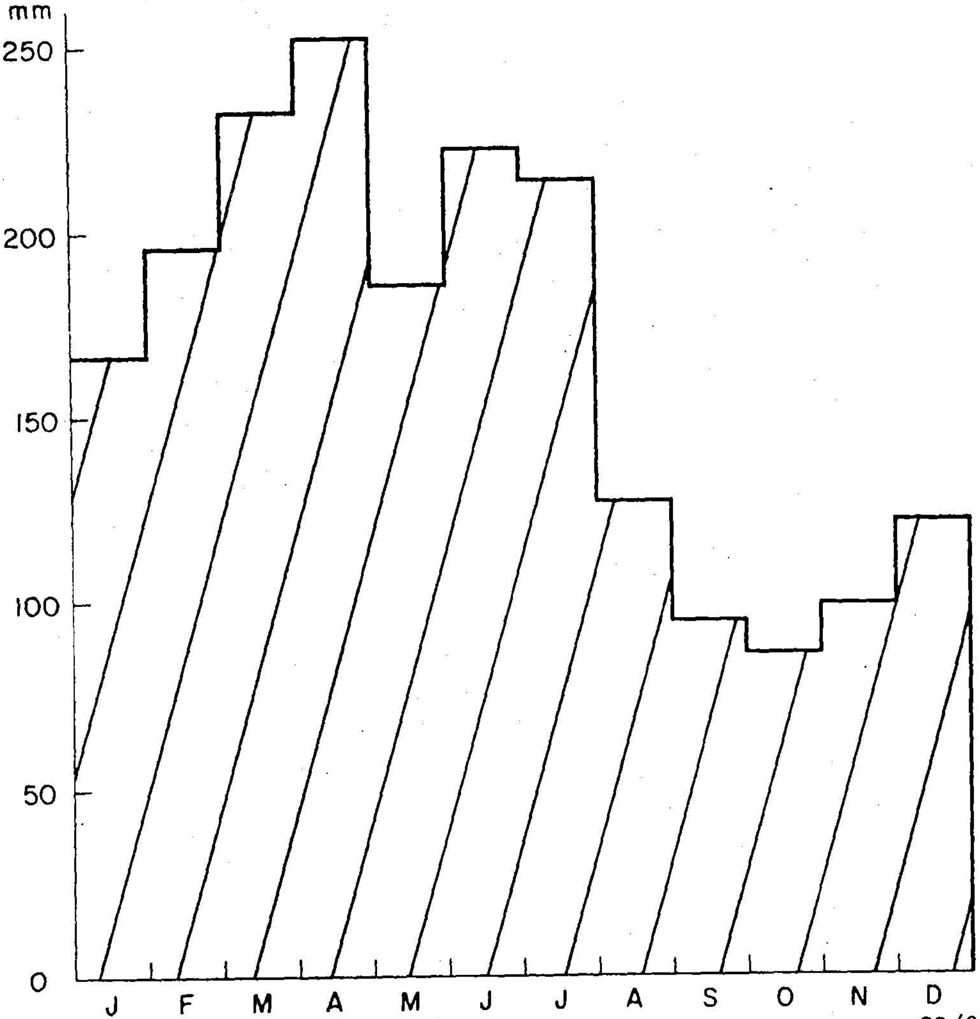


Fig.3 Mean monthly rainfall (1901-73), Cocos (Keeling) Islands

sustain a freshwater lens is about 400 m; on smaller islands such as Direction Island, there is no fresh water.

The freshwater lens floats on salt water; the depth of the freshwater/salt-water interface assuming static conditions is given by the Ghyben-Herzberg relation (Fig. 4). Theoretically the depth of the interface below mean sea level is about 40 times the height of the water-table above mean sea level. The lens is, however, a dynamic system, with continuous hydraulic flow resulting in a zone of diffusion at the interface. The lens fluctuates markedly because of tides and variations in recharge.

Monthly tidal fluctuations for the Cocos Islands lagoon over three years are shown in Appendix 2, and predictions of daily tidal fluctuations during the investigation are shown in Appendix 4.

GROUNDWATER RESOURCES OF HOME ISLAND

Groundwater forms virtually the entire water supply of Home Island; there are a few supplementary rainwater tanks. Additional rainwater tanks would improve the present water supply at minimal cost.

Details of 108 wells on Home Island have been recorded (Appendix 1); the locations are shown in Figure 5. Abstraction of groundwater is mainly by bucket, and there are no storage tanks, with the exception of three wells that are fitted with electric pumps and storage tanks. This system of abstraction (by buckets) is safe and ensures careful water usage and minimal risk of salt-water intrusion.

Some typical well cross-sections are shown in Figure 6. Sand occurs to a depth of about one metre throughout the area of settlement, and generally overlies a hardpan of cemented coral fragments, 0.4-1.0 m thick. The hardpan layer, which is absent from only a few wells, overlies sand in most of the wells.

THICKNESS OF THE FRESHWATER LENS

Water-levels in wells (Appendix 1) have been measured with respect to mean tide level on 11 12 December 1975. The datum mean tide-level was determined by gauging for 24 hours at an observation point on the Home Island wharf, and is an approximation to mean sea level at the time of the survey. Determinations of monthly mean sea level at the CSIRO tide gauge showed a variation of up to 0.52 m over three years (Appendix 2).

Tidal fluctuations in groundwater-levels were monitored in three wells (Fig. 7). The fluctuations in groundwater-levels had an amplitude of about 25 percent of the tidal amplitude in the lagoon, and a lag of 1-2 hours. Fluctuations in groundwater-level are slightly greater away from the lagoon side of Home Island, and have a reduced lag. The marked tidal fluctuations observed in the wells indicate that there is a wide zone of diffusion at the freshwater/salt-water interface.

Water-table elevations are shown in Figure 8. Because of the tidal fluctuation of water-levels meaningful water-table contours cannot be constructed. At the three wells where observations over a full tidal range were made, the average thickness of the freshwater lens is estimated as follows:

Well	Distance from lagoon (m)	Water-table elevations (cm above mean tide level)	Average thickness of lens (m)
2	40	17-34	10
1	90	23-39	12
48	190	36-61	19

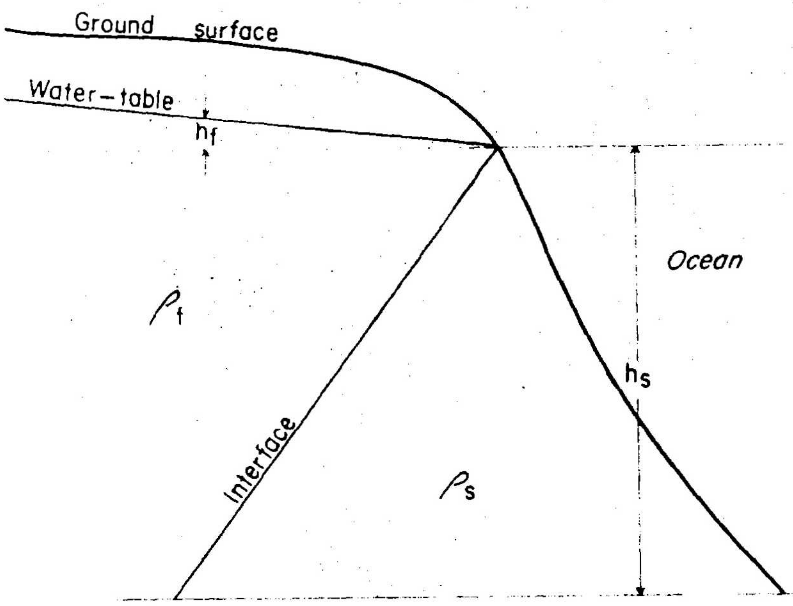
The average thickness of the freshwater lens ranges from 10 to 19 m, with an average of about 15 m in the Home Island settlement. In two of the wells the water-table was below mean tide level; the significance of this is not clear.

WATER QUALITY

Figure 9 shows electrical conductivity values of well water measured in the field with a portable meter. Contours of electrical conductivity show that most of the Home Island settlement has good quality groundwater (600-1000 microsiemens per cm). There is an area of more saline, but still potable groundwater (2000 microsiemens/cm) in the northeast of the settlement, and two other areas of 1200-1400 microsiemens/cm.

A salinity gradient was observed in some of the wells, with fresher water on top. The effect of tidal fluctuation on salinity was not investigated.

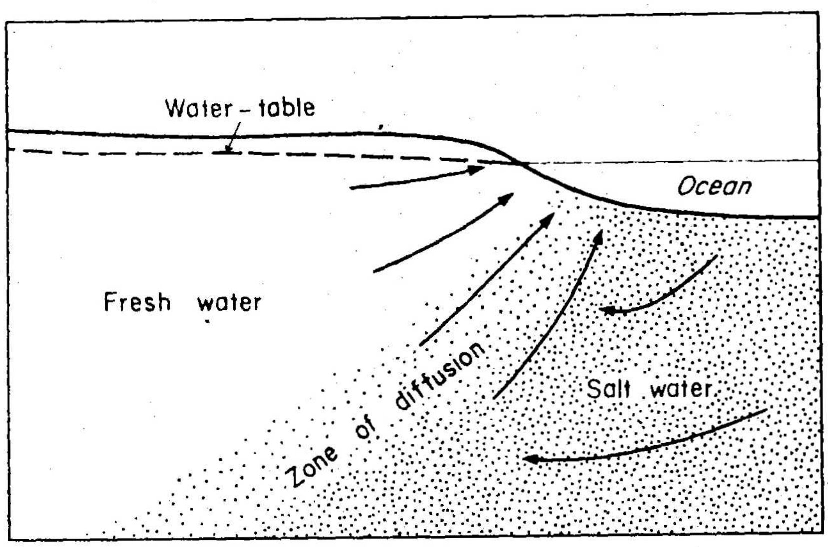
Subsequent chemical analyses of some groundwater samples (Table 1) show that electrical conductivity as measured in the laboratory in microsiemens/cm at 25°C is related to the total dissolved solids content in milligrams per litre by a factor of about 0.54. Electrical conductivity measured in the



Ghyben – Herzberg relation for freshwater/saltwater interface assuming saltwater static

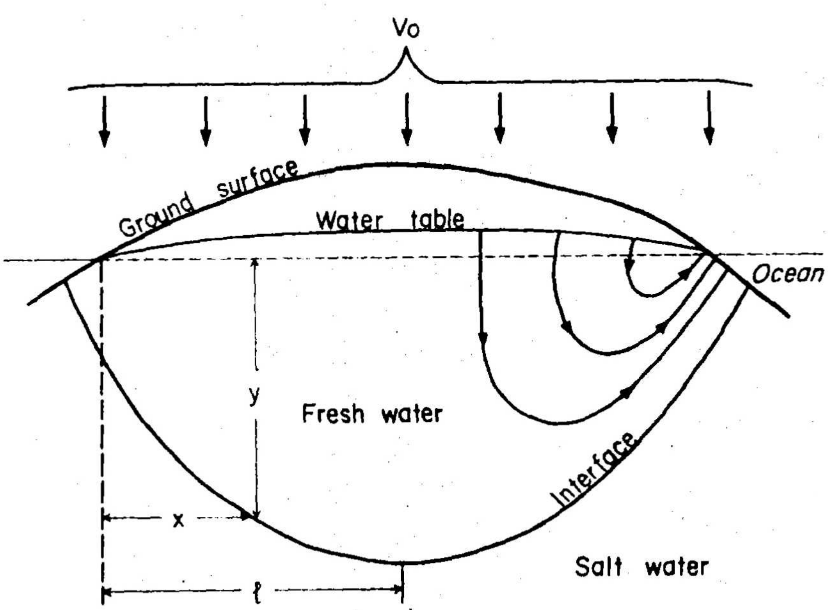
$$h_s = \frac{\rho_f}{\rho_s - \rho_f} h_f$$

$$h_s = 40\, h_f$$



Circulation of salt water from sea to zone of diffusion and back to sea

(from Cooper, 1959)



Flow pattern beneath an oceanic island (Mather, 1975)

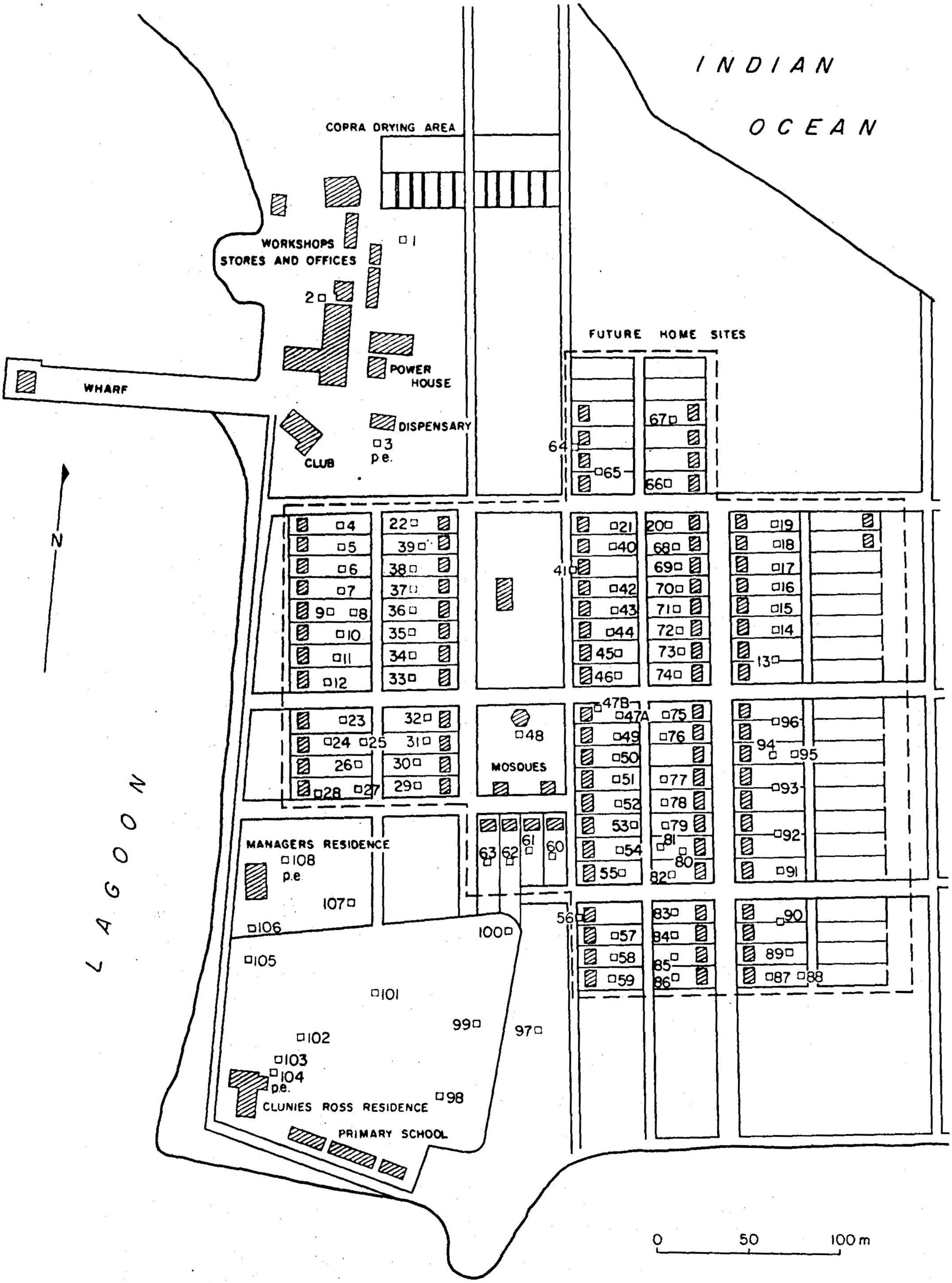
Co-ordinates of base of lens assuming static conditions

(Henry, 1964)

$$\frac{y}{\ell} = \sqrt{Vo/K_1\,(2x/\ell - (x/\ell)^2\,)}$$

$$y \propto \sqrt{Vo}$$

Fig.4 The freshwater lens



3 p.e. *Dug well equipped with pump*

36 *Dug well with reference number*

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Fig. 5 Well locations, Home Island

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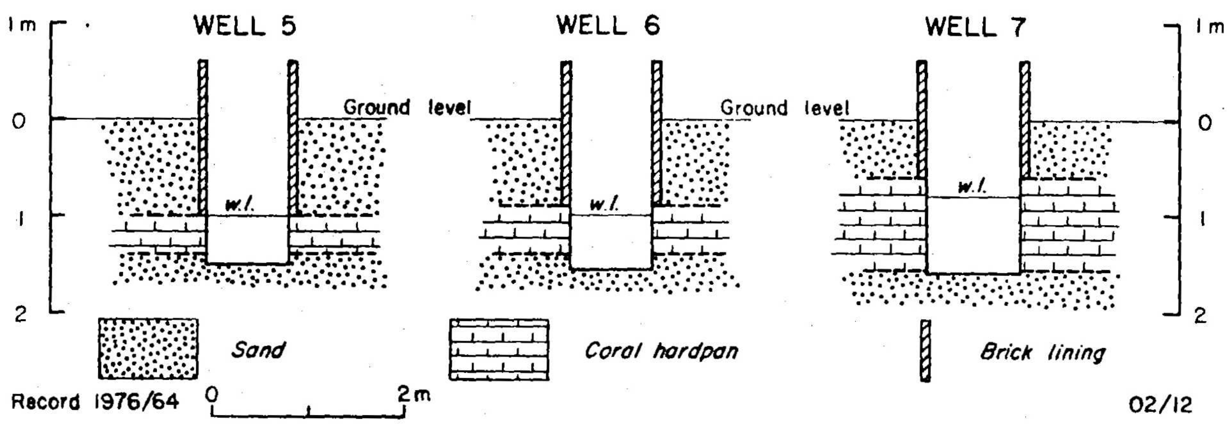

Fig.6 Home Island typical well sections (Water levels at about 10·00hrs on 4 Dec 1975)

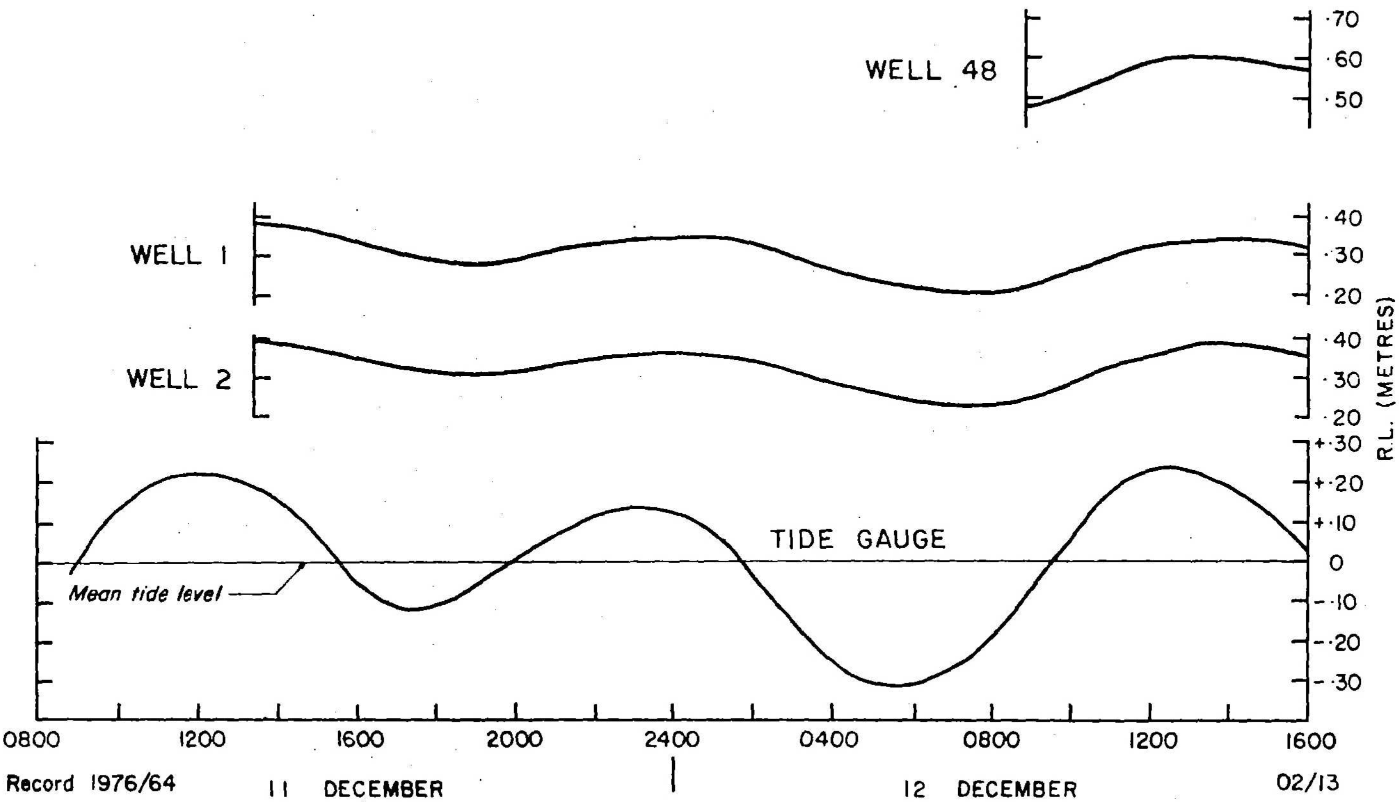

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Fig.7 Home Island tidal fluctuations in groundwater levels 11 - 12 December 1975

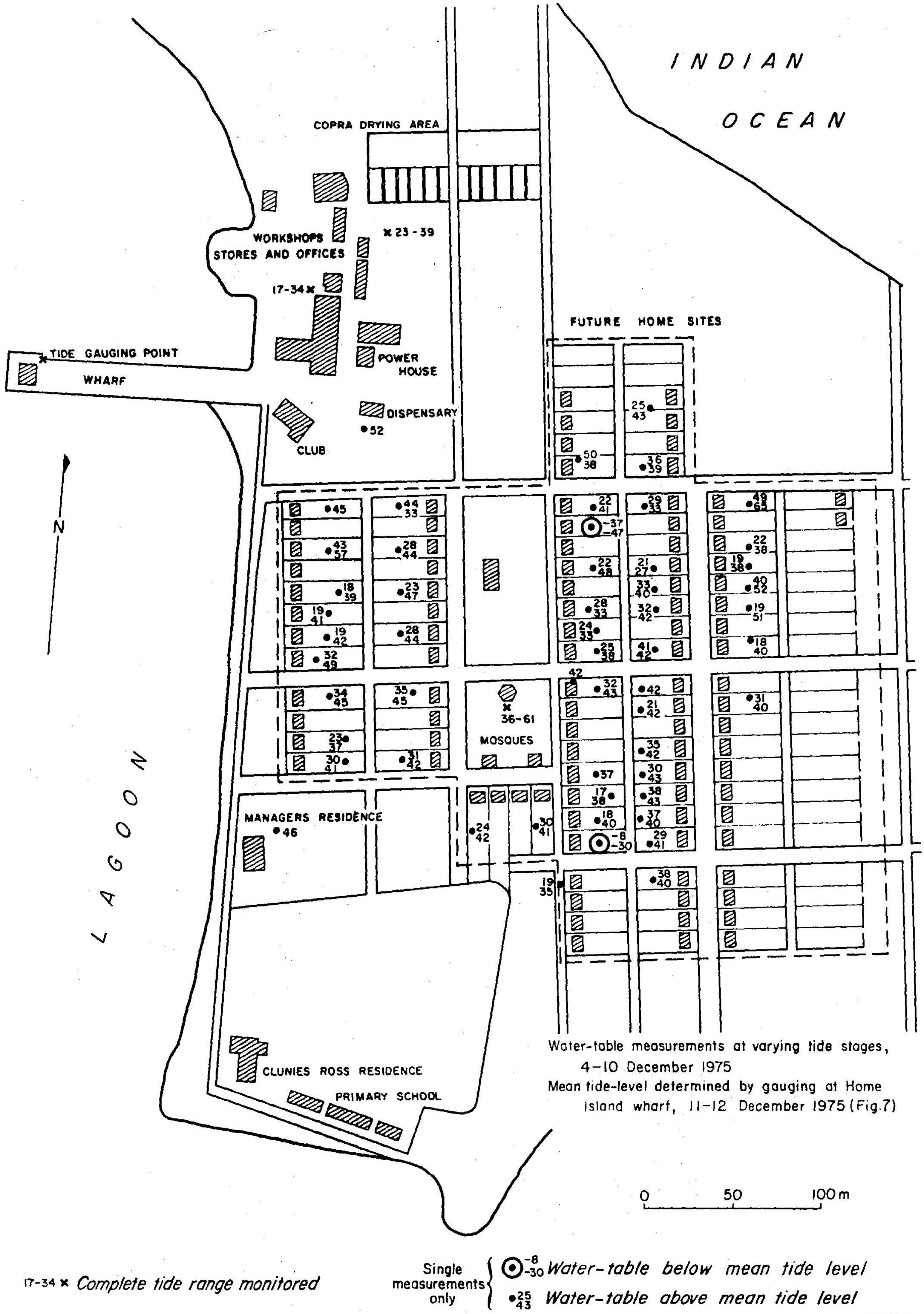
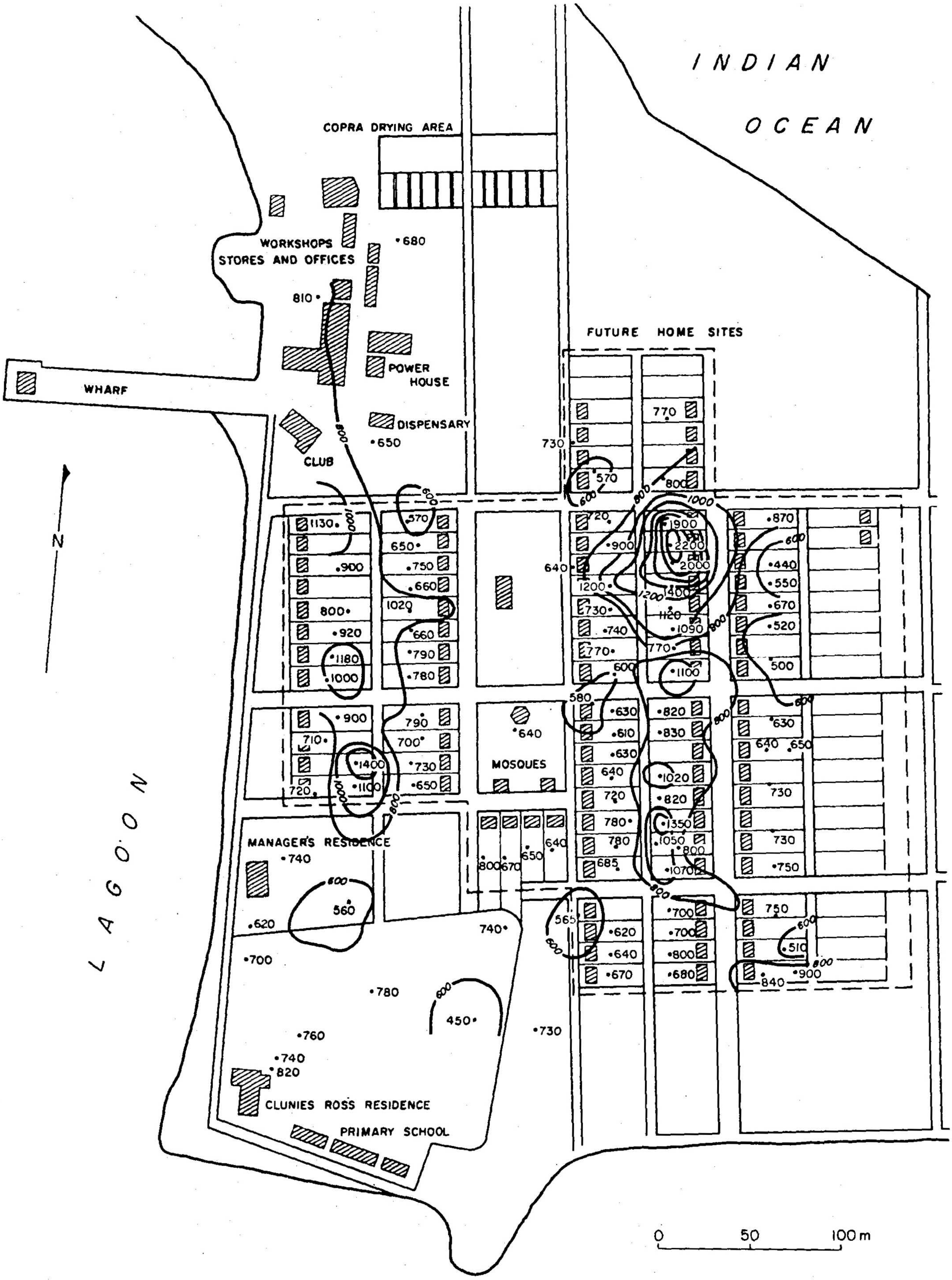


Fig.8 Home Island water-table elevations (in cm)



—600— *Contours of electrical conductivity, interval 200 microsiemens/cm*

•730 *Electrical conductivity of well water in microsiemens/cm measured with portable meter*

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Fig. 9 Groundwater quality, Home Island

laboratory was generally about 20 percent higher than the field values.

Figure 10 is a Piper trilinear diagram showing the ionic composition of several samples of Home Island groundwater. It is generally a bicarbonate water with appreciable chloride in the more saline samples. Sodium and calcium are the dominant cations. The water is hard for domestic use, with total hardness ranging from 264 to 488 mgle.

The relatively high nitrate content of some groundwater samples probably indicates pollution from animal refuse. Bacteriological quality of the groundwater has not been assessed.

At present the Home Island settlement is unsewered, and the sea is used for defecation. There are septic-tank systems at the two European residences and the dispensary.

TABLE 1

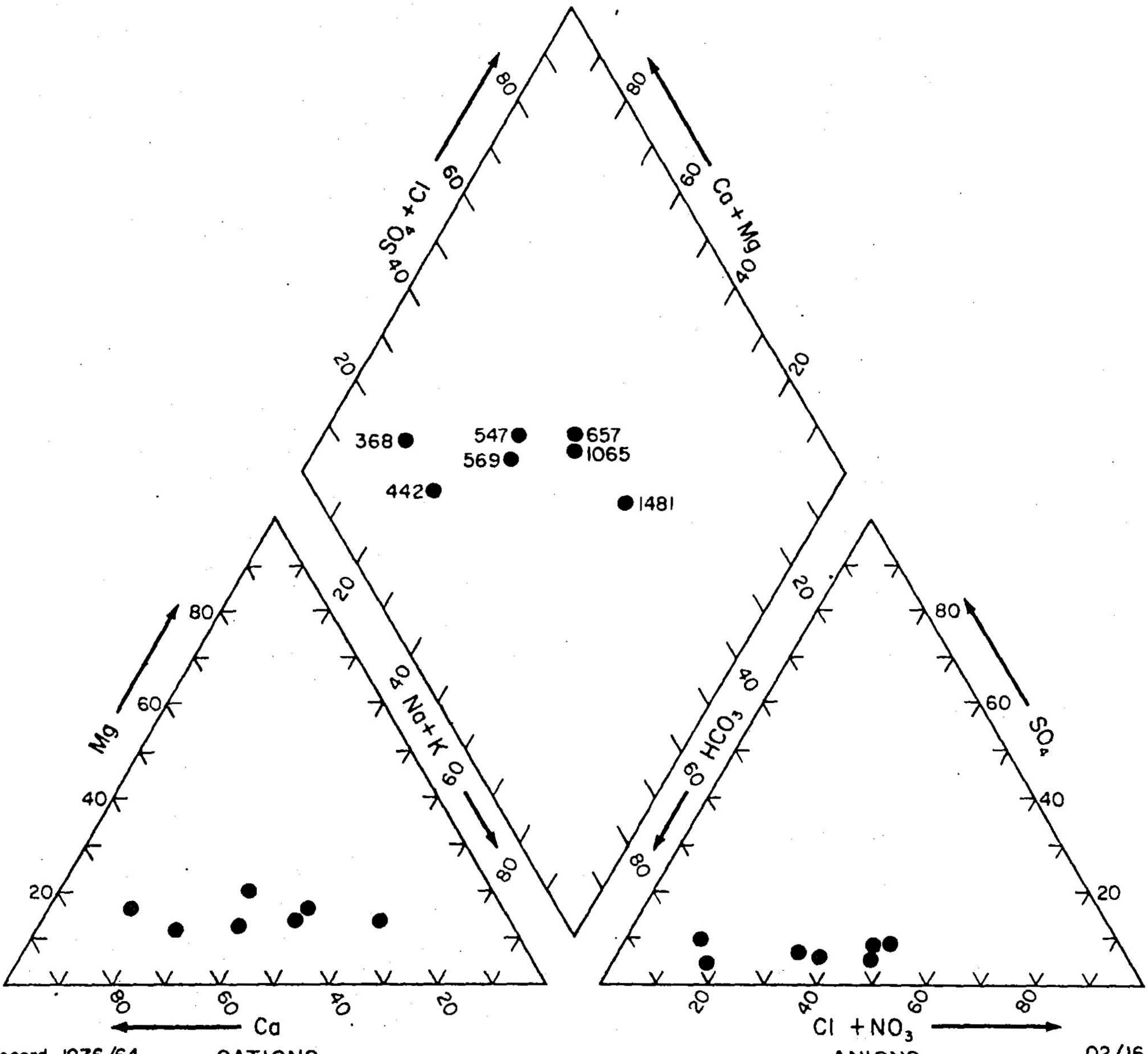
CHEMICAL ANALYSES OF GROUNDWATER SAMPLES (mg/l)

Well	Ca	Mg	Na	K	HCO_3	SO_4	Cl	NO_3	E.C. (micro siemens /cm)	T.D.S.	Total Hardness as $CaCO_3$	pH	
Horsburgh Island 1	90	15	20	1	341	11	29	0	675	334	286	7.6	*
Home Island 1	103	12	42	16	397	37	37	0	813	442	307	7.7	*
Home Island 6	90	24	65	27	346	24	109	39	981	547	323	7.7	*
Home Island 11	86	18	83	71	305	49	138	62	1190	657	289	7.9	*
Home Island 26	118	47	230	211	631	101	398	65	2549	1481	488	7.9	*
Home Island 29	99	13	21	5	338	14	30	20	691	368	301	7.7	*
Home Island 42	127	34	112	144	495	75	227	103	2007	1065	457	7.7	*
Home Island 52	99	15	55	54	372	33	106	25	1012	569	309	7.8	*
Home Island 3	86	12	–	–	–	–	–	1	–	310	264	8.5	† Fluoride 0.3 mg/l, Boron 0.1 mg/l
Home Island 66	61	13	–	–	–	–	–	56	–	350	266	7.9	† Fluoride 0.3 mg/l, Boron less than 0.1 mg/l

* Analysis by AMDEL, Adelaide

† Analysis by Government Chemical Laboratories, Perth

E.C. Electrical Conductivity measured in the Laboratory



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PERCENTAGE REACTING VALUES

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● 547 *Total dissolved solids content*

Fig. 10 Home Island groundwater ionic composition

SUSTAINABLE YIELD

With negligible run off, the water balance of Home Island is:

rainfall = recharge to groundwater aquifer + evapotranspiration losses.

With a mean annual rainfall of 2000 mm and assuming evapotranspiration of 1500 mm, the effective recharge to the groundwater aquifer would be 500 mm in a year of average rainfall.

Groundwater in the freshwater lens flows into the surrounding and underlying sea water, with a transition zone of diffusion at the freshwater/sea-water interface (Cooper, 1959; Kohout, 1960). The effective recharge to the lens is balanced in the long term by the outflow into the sea (Mather, 1975). Groundwater abstraction will result in a reduction in this outflow, which is equivalent to a reduction in effective recharge. Consequently a new equilibrium position of the freshwater/sea-water interface will be established.

The sustainable yield of the lens without contamination by saline water has been estimated using Mather's analysis (1973, 1975). This analysis is based on the equation of Henry (1964), who showed that the depth below sea level to the interface is proportional to the square-root of the rate of uniform recharge per unit area (Fig. 4).

Table 2 is based on this relation, and shows calculated changes in the equilibrium position of the interface with a reduction in effective recharge because of pumping. It assumes that the freshwater lens on Home Island can be considered as an equilibrium system resulting from an effective recharge of 500 mm annually.

An analysis of rainfall statistics (Appendix 3) shows that the worst series of drought years recorded on Home Island was 1961-5. Three successive years had rainfall averaging 30 percent below the mean, and, over the five years, rainfall averaged 21 percent below the mean. If the three-year drought reduced the effective annual recharge by 30 percent from 500 to 350 mm, then over the three-year period there would be a total deficit of 450 mm. Assuming a specific yield of 15 percent for the aquifer, then 450 mm of groundwater would be stored in 3 m of aquifer thickness. The effects of the three-year drought on the position of the interface are shown in Table 3.

Similarly, the five-year drought would reduce the effective annual recharge by 21 percent from 500 to 395 mm, with an accumulated deficit of 525 mm over five years. Assuming a specific yield of 15 percent then 525 mm of groundwater would be stored in 3.5 mm of aquifer thickness. The effects of the five year drought on the position of the interface are shown in Table 4.

TABLE 2

EFFECT ON FRESHWATER/SEA-WATER INTERFACE OF REDUCING ANNUAL RECHARGE BY PUMPING FROM THE LENS

Original depth to interface assuming recharge of 500 mm (m below m.s.l.)	Estimated depth to interface (m) if pumping reduces recharge to 400 mm	300 mm	200 mm
20	18	15	13
15	14	12	10
10	9	8	6
5	4.5	4	3

TABLE 3

EFFECT ON FRESHWATER/SEA-WATER INTERFACE OF REDUCED RECHARGE DURING A THREE-YEAR DROUGHT

Original depth to interface assuming recharge of 500 mm (m below m.s.l.)	Estimated depth to interface (m) after a 3-year drought if annual recharge is reduced to 400 mm	300 mm	200 mm
20	15	12	10
15	11	9	7
10	6	5	3
5	1.5	1	0

A substantial rise and fall of the freshwater lens on Home Island is attributable to the tides, and is the major control on the width of the transition zone. Pumping is expected to reduce the natural hydraulic flow in the aquifer, and consequently increase the width of the transition zone. In order to maintain conditions in the transition zone as steady as possible, pumping should be carried out at a constant rate and continuously so that a new set of equilibrium conditions are set up. The rate of pumping should be such that the thickness of the freshwater lens is maintained at more than half the original thickness, and this could be monitored by ensuring that the freshwater/salt-water interface is not raised by more than half the original thickness of the lens.

Possible abstraction rates for lenses of varying thickness, allowing for a five-year drought, are shown in Table 5. For a lens thickness of 15 m over an area of 30 hectares on Home Island, the sustainable yield would be about 200 000 litres per day.

ABSTRACTION OF GROUNDWATER

Table 5 shows that where the lens is less than 10 m thick it will not be capable of long-term development. Abstraction points are best sited where the lens is thickest.

Pumping tests are needed to determine specific capacity and drawdown characteristics of the aquifer, and to assess movement of the freshwater/sea-water interface. From these, it will be possible to work out pumping rates and the distribution of abstraction points for large-scale development of the aquifer.

Drawdown should be minimized; infiltration galleries are preferable to dugwells for this reason. The aquifer might possibly be developed by a field of four galleries each drawing from 7.5 hectares with a steady pumping rate of 2000 litres per hour. Intermittent pumping is not advisable as it would increase the width of the transition zone and decrease water quality. Inverts of the galleries should be above the calculated base of the lens when it attains its new equilibrium position.

Careful control and monitoring will be necessary to avoid salt-water intrusion, especially in view of the substantial tidal fluctuations in the lens, and the variations in mean tide level. The freshwater/sea-water interface could be monitored by a salinity probe. A tide gauge will have to be installed to obtain a datum for water levels. Maintenance of the water-supply system will be necessary and the people will have to be educated not to waste water.

TABLE 4

EFFECT ON FRESHWATER/SEA-WATER INTERFACE OF REDUCED RECHARGE DURING A FIVE-YEAR DROUGHT

Original depth to interface assuming recharge of 500 mm (m below m.s.l.)	Estimated depth to interface (m) after a 5-year drought if annual recharge is reduced to 400 mm	300 mm	200 mm
20	14.5	11.5	9.5
15	10.5	8.5	6.5
10	5.5	4.5	2.5
5	1	0.5	*

* negative value, indicating that there would be no freshwater layer.

TABLE 5

RECOMMENDED ABSTRACTION RATES FOR LENSES OF VARYING THICKNESS

(Based on Table 4)

Original depth to interface (m below m.s.l.)	Recommended depth to interface (m below m.s.l.)	Recharge to lens required to maintain recommended depth (mm of rainfall)	Excess rainfall available for extraction (mm)	Extraction rate (litres/day/hectare)
20	10	225	275	7500
15	7.5	250	250	6850
10	5	350	150	4100
5	2.5	500	nil	nil

Large-scale abstraction by pumping from galleries will lower the water-table by as much as 25 cm, and depending on the state of the tide many of the existing dugwells may go dry. Measures might need to be taken to prevent the disposal of refuse in the existing dugwells, and so avoid pollution of the aquifer.

THE OTHER ISLANDS

Several of the other islands have freshwater lenses developed (Plate 1). The minimum width of island necessary to sustain a freshwater lens is about 400 m. Some wells on West Island and Horsburgh Island were inspected briefly during the investigation.

WEST ISLAND

Four wells supply 70 000-90 000 litres per day to the settlement on West Island (Fig. 11). The water is softened and chlorinated, then pumped to an elevated storage tank and reticulated by gravity to the houses. Occasional difficulties are experienced when water-levels become very low because of tidal fluctuations; two of the wells are fitted with cut-off valves to prevent excessive drawdown. The settlement has a septic-tank sewerage system, with effluent fed to outfalls on the west (ocean) beach.

There are several other wells on West Island, most of which are disused. Some were installed during the war for military establishments.

The northern part of West Island contains possibly the largest freshwater lens in the atoll (Plate 1). A detailed groundwater investigation by geophysical methods is recommended should the proposed quarantine station be sited here.

HORSBURGH ISLAND

There is a substantial freshwater lens on Horsburgh Island. Three wells were inspected and sampled, and the water from one was chemically analysed (Table 1); the water is of good quality, with electrical conductivity in the range 550-660 microsiemens/cm.

The water on Horsburgh Island was described by Wood-Jones (1912) as ' .... the best well water in the group, and ..... that used by the Ross family for drinking purposes. Under no conditions does it ever become brackish, doubtless because its use is restricted, and the well is situated in the centre of the island, and therefore far from the sea.'

The lagoon on the north side of the island is brackish (electrical conductivity 20 000 microsiemens/cm) and tidal.

SOUTH ISLAND

Although not visited during the present survey, the wider parts of South Island probably support several discrete freshwater aquifers. There are reported to be several wells on the island.

DIRECTION ISLAND

Direction Island is not wide enough to sustain a permanent freshwater lens, and this is probably so with most of the smaller islands. Rainwater catchment is the only feasible source of water supply, and was used when there was a cable station on the island.

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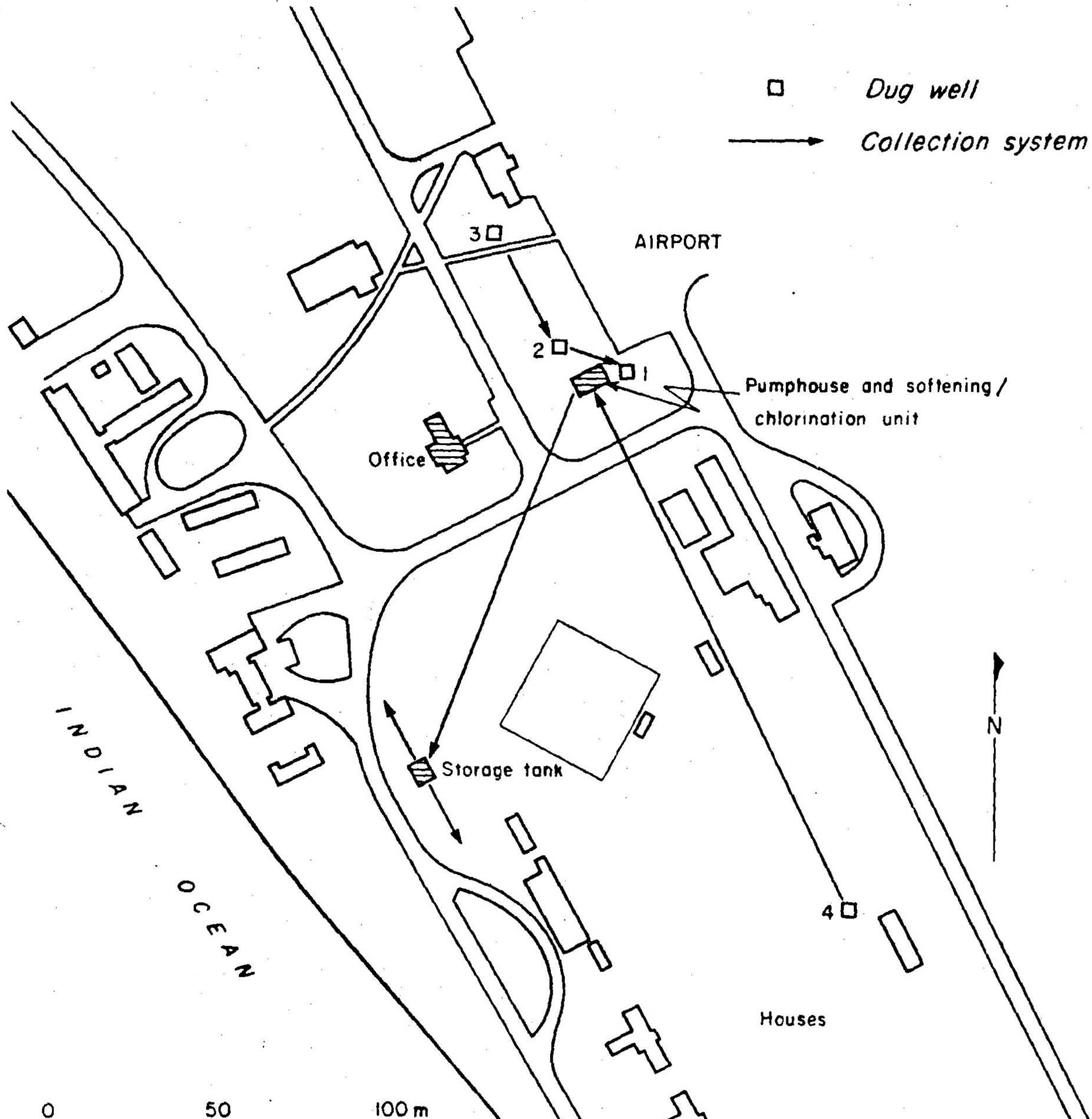

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Fig. 11 Well locations and collection system, West Island settlement

CONCLUSIONS AND RECOMMENDATIONS

1. On Home Island, levelling shows the average height of the water-table to be up to 0.5 m above mean tide-level. There are substantial tidal fluctuations in groundwater levels, and also a variation in monthly mean tide level.

2. The thickness of the freshwater lens is from 10-19 m, with an average 15 m over an area of about 30 hectares.

3. Water quality is generally good, with electrical conductivity in the range 600-2000 microsiemens/cm.

4. The sustainable yield of the lens is estimated at about 200 000 litres per day, assuming evaporation is 1500 mm from a mean annual rainfall of 2000 mm. This is equivalent to about 400 litres per head per day.

5. The recommended pumping rate for infiltration galleries needs to be determined by pump tests.

6. A large-scale abstraction system will need careful management and monitoring to avoid salt-water intrusion by overpumping. There will also be problems of maintenance, and the people will have to be educated not to waste water.

7. The present system of abstraction by buckets from wells is safe, and ensures careful water usage and minimal risk of saltwater intrusion. The water supply could be improved at minimal cost by increasing rainwater storage capacity.

8. There are appreciable freshwater aquifers on Horsburgh Island, West Island and parts of South Island. Investigation by geophysical techniques is recommended should any further development be planned.

APPENDIX 1

HOPE ISLAND: DETAILS OF WELLS

WELL NO.	Type of well	Datum of measurements	Height of datum above ground level (m)	Depth of well below datum (m)	Internal diameter of well (m)	R.L. datum above mean tide level(m) on 11-12 December	Measured W.L. (m)	R.L. water table (m above) (mean tide level)	Conductivity (micromhos/cm)	Date of measurements time	date	Remarks
1	Brick lined, circular	Rim of well, southside	0.40	2.16	0.90	1.86	1.47-1.63	0.39-0.23	680		5.12.75	Tidal fluctuation monitored (Fig.7)
2	Brick lined, circular	Rim, southside		2.39	1.21	1.91	1.57-1.74	0.34-0.17	720 900	0930 -	8.12.75 5.12.75	Tidal fluctuation monitored (Fig.7)
3	Concrete lined covered	Rim, southside		3.09	1.30	2.66	2.27 2.14	0.39 0.52	650	0930 0930	4.12.75 9.12.75	Electric pump. Hospital supply
4	Brick lined, circular	Rim, northside		2.24	0.70	1.85	1.59 1.40	0.26 0.45	1130	0945 0915	4.12.75 9.12.75	
5	Brick lined, circular	Rim	0.45	1.96	0.82	-	1.45			1000	4.12.75	Sand 0.45-1.45m,coral 1.45-1.70m,sand 1.70-1.96m
6	Brick lined, circular	Rim, southside	0.60	2.14		2.02	1.59 1.45	0.43 0.57	900	1015 0930	4.12.75 10.12.75	Water table in coral, sand beneath.
7	Brick lined, circular	Rim	0.60	2.17	0.95	-	1.40			1030	4.12.75	" " " " " "
8	Brick lined, circular	Rim, eastside	0.70	2.07	0.90	1.89	1.71 1.50	0.18 0.39	800	1045 0945	4.12.75 10.12.75	Coral band below 1.48m. Sand bottom.
9	-	-	-	-	-	-	-	-	-	-	-	Same house as well 8
10	Brick lined, circular	Rim, eastside		1.59	0.80	1.58	1.37 1.15	0.19 0.41	920	1115 1015	4.12.75 10.12.75	Coral band below 1.29m. Sand bottom.
11	Brick lined, circular	Rim, northside		2.08	0.77	1.67	1.48 1.25	0.19 0.42	1190	1130 1030	4.12.75 10.12.75	Coral band below 1.39m. Sand bottom.
12	Brick lined, circular	Rim, northside		1.81	0.75	1.84	1.52 1.35	0.32 0.49	1000	1145 1530	4.12.75 9.12.75	Coral band below 1.42m. Sand bottom.
13	Concrete, circular	Rim, eastside	0.65	2.29	1.50	2.15	1.97 1.75	0.18 0.40	500	1300 1215	4.12.75 9.12.75	Coral band below 1.64m. Sand bottom.
14	Fibro lined, square	Rim, southwest corner	0.55	2.44	0.90	2.38	2.19 1.97	0.19 0.41	520	1315 1200	4.12.75 9.12.75	Coral band with sand bottom
15	Fibro lined, square	Rim, northeast corner	0.35	2.34	1.20	2.44	2.04 1.91	0.40 0.53	670	1330 1145	4.12.75 9.12.75	Water cloudy and not used. Water table in sand
16	Fibro lined, square	Rim, northeast corner	0.60	2.79	0.90	2.72	2.53 2.34	0.19 0.38	550	1345 1130	4.12.75 9.12.75	Coral band below 2.16m. Sand bottom.
17	Fibro lined, square	Rim, northeast corner	0.65	2.69	0.80	2.70	2.48 2.32	0.22 0.38	440	1400 1115	4.12.75 9.12.75	Coral band below 2.11m. Sand bottom.
18	Brick lined, fibro top	Rim	0.60	2.49	-	-	2.14			1415	4.12.75	-
19	Fibro lined, square	Rim, westside	0.50	2.83	0.70	2.80	2.31 2.15	0.49 0.65	870	1430 1100	4.12.75 9.12.75	-
20	Concrete, square	Rim, northside	0.70	3.00	0.75	2.96	2.67 2.58	0.29 0.38	1900	1445 1030	4.12.75 9.12.75	Coral below 2.51m. Sand bottom.
21	Concrete, square	Rim, northwest corner	0.50	2.69	0.70	2.56	2.34 2.15	0.22 0.41	720	1500 1015	4.12.75 9.12.75	-
22	Brick, square	Rim, northeast corner	0.45	2.30	0.80	2.25	1.81 1.97	0.44 0.33	570	0945 1515	9.12.75 4.12.75	-
23	Brick lined, circular	Rim, southside	0.90	2.24	1.03	1.95	1.61 1.50	0.34 0.45	670 1140	0900 1515	5.12.75 9.12.75	-
24	Brick lined, circular	Rim, southeast side	0.52	1.72	0.77	-	1.13	-	710	0910	5.12.75	Coral band with sand beneath.
25	lined with 44 gal.drum	-	-	-	-	-	-	-	-	-	-	Same house as well 24
26	Fibro lined, square	Rim, northwest corner	0.95	2.12	0.95	1.81	1.58 1.44	0.23 0.37	760 2000	0920 1100	5.12.75 10.12.75	-
27	Concrete,circular	Rim	0.35	1.84	0.78	1.29	0.99 0.88	0.30 0.41	710 1450	0930 1130	5.12.75 10.12.75	-
28	Brick lined, circular	Rim	0.80	2.18	0.75	-	1.56	-	720	0940	5.12.75	-
29	Brick lined, circular	Rim	0.60	2.46	0.60	1.82	1.51 1.40	0.31 0.42	680 620	0950 1145	5.12.75 10.12.75	-
30	lined with 44 gal. drum	Ground level	0.00	1.22	0.55	-	0.64	-	730	1000	5.12.75	

WELL NO.	Type of well	Datum of measurements	Height of datum above ground level (m)	Depth of well below datum (m)	Internal diameter of well (m)	R.L. datum above mean tide level(m) on 11-12 December	Measured W.L. (m)	R.L. water table (m above) (mean tide level)	Conductivity (micromhos/cm)	Date of measurements time	date	Remarks
31	Brick lined, circular	Rim	0.60	1.91	0.80	-	1.39	-	700	1010	5.12.75	-
32	Fibro lined at top	Rim, northside	0.60	2.07	0.90	1.87	1.52 1.42	0.35 0.45	710 880	1020 1445	5.12.75 9.12.75	Sand overlying coral
33	Concrete lined	Rim, northwest corner	0.20	1.54	0.75	1.97	-	0.45	580 870	1020 1500	5.12.75 9.12.75	-
34	Bricklined, square	Rim, westside	0.60	2.26	0.75	1.90	1.62 1.46	0.28 0.44	700 880	1040 1045	5.12.75 10.12.75	-
35	Brick lined, circular	Rim	0.45	1.94	0.72	-	1.59	-	660	1050	5.12.75	-
36	Brick lined, square	Rim, northwest corner	0.70	2.24	0.80	1.97	1.74 1.50	0.23 0.47	720 1130	1100 1100	5.12.75 10.12.75	-
37	Fibro lined, square	Rim	0.80	2.44	1.00	-	1.85	-	660	1110	5.12.75	-
38	Concrete pipe	Rim, westside	0.67	2.15	0.75	2.06	1.78 1.62	0.28 0.44	650 850	1120 0915	5.12.75 10.12.75	Coral band with sand below.
39	Brick lined, circular	Rim	0.50	2.28	0.80	-	1.84	-	650	1130	5.12.75	-
40	Brick top, square, lined with 44 gallon drum at bottom.	Rim, westside	0.65	2.45	0.85	1.81	1.98 2.08	-0.37 -0.47	800 1200	1140 1045	5.12.75 11.12.75	-
41	Brick lined, circular	Rim	0.55	2.72	0.65	-	2.19	-	640	1150	5.12.75	-
42	Brick lined, circular	Rim, eastside	0.70	2.44	0.75	2.45	2.23 1.97	0.22 0.48	640 1700	1200 1015	5.12.75 11.12.75	Coral band with sand below
43	Concrete pipe at top, drum below	Rim, northwest corner	0.20	2.19	0.75	2.68	-	-	640 820	1210 1000	5.12.75 11.12.75	-
44	Brick lined, circular at top, drum below	Rim, southside	0.35	2.21	0.70	2.23	1.95 1.90	0.28 0.33	630 850	1220 0930	5.12.75 11.12.75	-
45	Fibro lined	Rim, eastside	0.65	2.51	0.70	2.46	2.22 2.08	0.24 0.38	640 910	1230 0915	5.12.75 11.12.75	-
46	Fibre lined	Rim	0.85	2.57	0.65	2.64	2.39 2.26	0.25 0.38	680 530	1240 1400	5.12.75 9.12.75	Coral band with sand below
47A	Brick lined, circular	Rim	0.40	1.96	0.75	2.01	1.69 1.58	0.32 0.43	620 640	1300 1345	5.12.75 9.12.75	Coral below 1.56m
47B	-	-	-	-	-	1.88	1.46	0.42	580	1415	9.12.75	
48	Concrete pipe, circular	Rim, northside	0.37	2.11	1.20	2.14	1.78 1.53-1.65	0.36 0.61-0.49	640 - 630	1310 - 1430	5.12.75 12.12.75 9.12.75	Mosque well. Tidal fluctuation monitored (Fig. 7)
49	Brick lined, circular	Rim, southside	0.50	1.82	0.80	-	1.53	-	610	1320	5.12.75	
50	Fibro lined, square	Rim, westside	0.65	2.30	0.80	-	2.01	-	630	1330	5.12.75	
51	Concrete lined, circular	Rim, westside	0.60	2.25	0.60	-	1.90	-	640	1340	5.12.75	
52	Lined with drum	Rim, eastside	0.95	2.32	0.80	2.36	1.99 1.99	0.37 0.37	770 660	1515 1350	10.12.75 5.12.75	
53	Fibro lined, square	Rim, southside	0.80	2.34	0.90	2.34	2.17 1.96	0.17 0.38	690 890	1400 1430	5.12.75 10.12.75	
54	Concrete, circular	Rim, northside	0.65	2.14	0.75	2.00	1.82 1.60	0.18 0.40	680 880	1410 1400	5.12.75 10.12.75	
55	Concrete, circular	Rim, westside	0.75	2.24	0.75	1.62	1.92 1.70	-0.30 -0.08	670 700	1420 1300	5.12.75 10.12.75	
56	Brick lined, circular	Rim, northside	0.40	1.74	0.85	1.57	1.38 1.14	0.19 0.35	640 490	1430 1245	5.12.75 10.12.75	
57	Fibro, square	Rim, northside	0.55	1.78	0.75	-	1.53	-	620	1440	5.12.75	
58	Brick lined, circular	Rim, northside	0.45	1.84	0.75	-	1.47	-	640	1450	5.12.75	
59	Brick lined, circular	Rim, northside	0.70	2.14	0.90	-	1.70	-	670	1500	5.12.75	
60	Brick lined, circular	Rim, eastside	0.90	2.00	0.75	1.86	1.76 1.55	0.30 0.41	640 640	1510 1230	5.12.75 10.12.75	
61	Brick, square	Rim	0.70	1.79	0.70	-	1.12		650	1520	5.12.75	Coral band with sand below

WRL NO.	Type of well	Datum of measurements	Height of datum above ground level (m)	Depth of well below datum (m)	Internal diameter of well (m)	R.L. datum above mean tide level(m) on 11-12 December	Measured W.L. (m)	R.L. water table (m above) (mean tide level)	Conductivity (micromhos/cm)	Date of measurements time	date	Remarks
62	Brick lined, circular	Rim	0.65	2.35	0.70	-	1.50	-	670	1530	5.12.75	
63	Fibro, square	Rim, southwest corner	0.75	2.19	0.85	1.93	1.69	0.24	760	1540	5.12.75	
							1.51	0.42	850	1200	10.12.75	
64	Cemented brick,circular	Rim	0.55	2.31	1.02	-	1.73	-	730	0930	8.12.75	Coral band below 1.75m
65	Steel pipe, circular	Rim	0.78	2.76	0.88	2.74	2.24	0.50	600	0940	8.12.75	Coral band below 2.38 m. Sand bottom.
							2.36	0.38	530	1000	9.12.75	
66	Concrete, circular	Rim, southside	0.70	2.80	1.05	2.80	2.44	0.36	820	0950	8.12.75	Coral band below 2.14 m
							2.41	0.39	770	1045	9.12.75	
67	Concrete, circular	Rim	0.20	2.09	0.85	2.13	1.70	0.43	820	1000	8.12.75	
							1.88	0.25	730	1100	11.12.75	
68	Brick lined, circular	Rim	0.30	2.06	0.75	-	1.60	-	2200	1010	8.12.75	
69	Brick lined, circular	Rim	0.45	2.24	0.70	-	1.99	-	2000	1020	8.12.75	
70	Lined with 44 gal. drum	Rim, eastside	0.50	2.39	0.55	2.31	2.04	0.27	1950	1030	8.12.75	
							2.10	0.21	840	1030	11.12.75	
71	Fibro, rectangular	Rim	0.80	2.49	-	2.64	2.24	0.40	1400	1040	8.12.75	
							2.31	0.33	850	0945	11.12.75	
72	Brick lined, circular	Rim, eastside	0.23	2.04	0.85	2.14	1.82	0.32	880	0900	11.12.75	
							1.72	0.42	1300	1050	8.12.75	
73	Brick lined, circular	Rim	0.45	2.23	0.75	-	1.82	-	770	1100	8.12.75	
74	Brick lined, circular	Rim, southside	0.65	2.54	0.75	2.47	2.06	0.41	1400	1110	8.12.75	
							2.05	0.42	800	1300	9.12.75	
75	Cemented brick, circular	Rim, eastside	0.45	2.09	0.75	1.80	1.38	0.42	920	1120	8.12.75	
							1.38	0.42	720	1330	9.12.75	
76	Brick lined, circular	Rim, southside	0.47	1.86	0.75	1.63	1.21	0.42	850	1130	8.12.75	Hardpan(cemented sand and coral)below 1.[illegible]
							1.41	0.21	810	1530	10.12.75	
77	Steel lined	Rim, southside	0.85	2.23	0.90	2.05	1.63	0.42	840	1140	8.12.75	
							1.70	0.35	1200	1500	10.12.75	
78	Steel lined	Rim, northside	0.85	2.21	0.95	2.02	1.59	0.43	890	1150	8.12.75	Coral hardpan below 1.68m
							1.72	0.30	740	1445	10.12.75	
79	Brick lined, circular	Rim, northside	0.47	1.81	0.80	1.62	1.19	0.43	1600	1200	8.12.75	
							1.24	0.38	1100	1415	10.12.75	
80	Brick lined, circular	Rim, northside	0.65	2.09	0.75	-	1.45	-	800	1210	8.12.75	Coral band below 1.45m
81	Fibro lined, square	Rim, southwest corner	0.41	1.99	0.90	1.75	1.35	0.40	900	1220	8.12.75	
							1.38	0.37	1200	1345	10.12.75	
82	Fibro lined, square	Rim, northwest corner	0.60	1.81	0.85	1.86	1.45	0.41	950	1230	8.12.75	Coral below 1.43m
							1.49	0.39	1200	1330	10.12.75	
83	Cemented brick, circular	Rim, west side	0.80	1.83	0.80	1.55	1.15	0.40	680	1240	8.12.75	
							1.17	0.38	720	1315	10.12.75	
84	Brick lined, circular	Rim	0.46	1.67	0.80	-	1.90	-	700	1750	8.12.75	Coral below 1.10m
85	-	Rim	0.50	1.90	-	-	1.23	-	800	1300	8.12.75	Coral below 1.29m. Sand bottom.
86	Concrete, circular	Rim	0.85	2.06	0.75	-	1.50	-	680	1310	8.12.75	Coral below 1.56m. Sand bottom.
87	Concrete, circular	Rim	0.25	1.72	1.05	-	1.03	-	840	1320	8.12.75	Coral below 1.03m. Sand bottom.
88	Lined with 44 gal.drum	Rim	0.15	1.35	0.55	-	0.85	-	900	1330	8.12.75	
89	Brick lined, circular	Rim	0.20	1.19	0.80	-	0.92	-	510	1330	8.12.75	
90	Brick lined, circular	Rim	0.45	2.18	0.80	-	1.42	-	750	1340	8.12.75	
91	Cemented brick, circular	Rim	0.50	2.18	0.80	-	1.42	-	750	1350	8.12.75	Coral below 1.34m
92	Concrete pipe	Rim	1.00	2.18	0.77	-	1.69	-	730	1400	8.12.75	
93	Concrete pipe	Rim	0.62	2.23	0.75	-	1.81	-	730	1400	8.12.75	Coral below 1.62m
94	Brick lined	-	-	-	-	-	-	-	640	1410	8.12.75	
95	Concrete pipe	Rim	-0.20	1.64	0.75	-	1.34	-	650	1420	8.12.75	

WELL NO.	Type of well	Datum of measurements	Height of datum above ground level (m)	Depth of well below datum (m)	Internal diameter of well (m)	R.L. datum above MTL (m) on 11-12 December	Measured W.L. (m)	P.L. water table (m above MSL)	Conductivity (micromhos/cm)	Date of measurements time	date	Remarks
96	Concrete pipe	Rim, northside	0.80	2.32	1.05	2.17	1.77	0.40	600	1230	9.12.75	Coral below 1.66m
							1.86	0.31	670	1430	8.12.75	
97	Brick lined, circular	Rim	0.55	1.86	0.90	-	1.08	-	730	1430	8.12.75	
98	Brick lined	Rim	-	1.46	-	-	1.19	-	-	1440	8.12.75	Disused
99	Brick lined, circular	Rim	0.56	2.10	1.00	-	1.21	-	450	1450	8.12.75	
100	Brick lined, circular	Rim	0.40	1.78	0.75	-	1.23	-	740	1500	8.12.75	
101	Brick lined, circular	Rim	0.23	1.34	0.85	-	0.84	-	780	1500	8.12.75	
102	Brick lined, circular	Rim	0.50	1.79	0.88	-	1.24	-	760	1510	8 12.75	
103	Brick with steel liner	Rim	0.55	1.84	1.37	-	1.26	-	740	1520	8.12.75	
104	Cemented brick	Rim	0.63	2.44	1.42	-	1.49	-	820	1530	8.12.75	Electric pump - Residence supply
105	Cemented pipe	Rim	0.75	2.19	1.05	-	1.52	-	700	1530	8.12.75	
106	Cemented brick	Rim	0.55	1.59	0.80	-	1.09	-	620	1540	8.12.75	
107	Brick, circular	Rim	0.43	1.75	1.00	-	1.03	-	580	1115	10.12.75	
							1.09	-	540	1550	8.12.75	
108	Brick, circular	Rim	0.60	1.89	0.80	1.49	1.03	0.48	740	1600	8.12.75	Electric pump- supply for manager's hou

APPENDIX 2.

MONTHLY TIDE LEVELS, WEST ISLAND, 1968–71

(Information from CSIRO Division of Fisheries & Oceanography, Cronulla, NSW)

Year	Month	Monthly Highest High Water (m)	Monthly Lowest Low Water (m)	Monthly Mean Sea Level (m)	
1968	April	1.41	0.13	0.67	
	May	1.47	0.13	0.67	
	June	1.59	0.31	0.83	
	July	1.59	0.34	0.83	
	August	1.51	0.35	0.87	
	September	1.55	0.45	0.91	
	October	1.65	0.40	0.90	
	November	1.77	0.40	0.97	12 days missing
	December	1.71	0.37	0.93	9 days missing
1969	January	1.49	0.21	0.80	8 days missing
	February	1.54	0.35	0.86	
	March	1.33	0.26	0.75	
	April	1.45	0.23	0.79	
	May	1.61	0.33	0.85	
	June	1.64	0.30	0.84	
	July	1.71	0.42	0.97	
	August	1.65	0.43	0.99	
	September	1.62	0.46	0.97	
	October	1.63	0.54	0.98	
	November	1.67	0.36	1.19	
	December	1.88	0.54	1.01	
1970	January	1.66	0.44	0.87	
	February	1.64	0.30	0.81	
	March	1.41	0.24	0.81	

APPENDIX 2 (continued)

	April	1.41	0.29	0.78	
	May	1.50	0.24	0.78	
	June	1.49	0.25	0.82	
	July	1.58	0.34	0.84	
	August	1.67	0.45	0.95	
	September	1.81	0.52	1.01	
	October	1.81	0.58	1.09	
	November	1.80	0.37	0.98	
	December	1.66	0.41	0.92	
1971	January	1.55	0.50	0.95	7 days missing

Gauge was on the Jetty at the north end of West Island.

Datum is a plane 2.41 m below "Dr Bradfield's Bench Mark".

APPENDIX 3

WEST ISLAND : MONTHLY AND YEARLY RAINFALL (in mm)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1901	-	-	-	-	-	-	-	-	-	-	-	199	-
1902	296	197	137	315	51	35	216	57	18	8	39	29	1398
1903	130	88	157	218	109	458	213	48	87	35	479	20	2043
1904	382	75	11	533	328	38	322	177	21	4	54	60	2008
1905	12	176	548	298	383	267	213	46	19	57	5	5	2028
1906	106	68	169	39	205	430	257	199	151	250	24	65	1962
1907	54	252	284	136	118	247	158	99	48	5	14	443	1857
1908	53	394	316	58	89	136	886	96	36	93	162	90	2407
1909	27	172	95	365	324	261	365	41	542	102	61	48	2403
1910	243	189	174	278	96	176	361	289	97	816	241	19	2918
1911	63	170	225	319	172	320	145	79	265	46	13	333	2151
1912	88	302	201	245	288	240	117	107	103	79	349	102	2165
1913	221	50	714	221	70	244	154	233	40	41	40	79	2108
1914	82	93	293	213	77	39	302	130	26	-	-	-	-
1915	-	-	-	-	-	-	-	-	-	-	-	-	-
1916	135	326	280	212	342	368	273	359	16	190	110	188	280
1917	54	283	263	135	148	275	559	161	19	96	190	167	234
1918	172	152	170	88	136	88	31	62	50	36	40	74	110
1919	19	75	124	287	564	350	61	54	417	57	158	95	226
1920	225	216	165	155	166	161	127	425	59	46	65	88	189
1921	196	278	409	175	61	235	146	116	100	57	58	239	206
1922	172	222	94	237	190	162	81	47	14	35	27	512	179
1923	3	75	310	378	104	109	86	95	93	22	0	46	132
1924	18	175	207	201	320	442	246	124	81	31	118	6	197
1925	226	487	103	146	552	165	439	40	24	27	17	67	229
1926	97	264	123	476	121	95	167	85	12	18	87	25	157
1927	356	168	308	431	75	165	523	100	190	38	76	3	243
1928	95	73	255	396	75	346	59	66	11	292	57	227	196
1929	18	114	179	168	249	367	273	42	32	5	12	75	153
1930	286	61	150	204	183	213	313	49	42	15	50	37	160
1931	12	37	90	357	281	208	95	197	168	82	24	160	171
1932	198	65	172	234	63	251	148	258	46	11	129	28	160
1933	290	164	174	194	255	419	125	54	65	170	490	126	252
1934	216	164	150	576	79	211	106	50	87	8	114	112	187
1935	80	660	87	131	16	155	42	29	14	8	20	141	138
1936	206	266	337	259	166	192	176	123	47	189	137	108	220
1937	33	50	166	275	243	173	65	206	18	14	100	51	139
1938	94	255	323	333	315	192	224	232	5	9	164	75	222
1939	199	232	213	574	208	34	48	98	40	145	262	319	237

[redacted]

[redacted]

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1940	66	349	219	78	126	74	371	59	41	12	8	68	1471
1941	70	103	110	258	407	362	176	67	404	54	33	106	2149
1942	266	234	405	207	74	306	202	82	862	322	58	270	3288
1943	532	164	393	89	284	408	220	183	119	120	294	94	2900
1944	134	138	106	288	113	198	94	66	16	58	78	71	1359
1945	137	231	555	119	23	82	0	50	27	8	218	123	1573
1946	55	379	490	-	280	370	279	62	63	1	2	111	-
1947	214	279	325	413	209	148	226	222	70	72	19	49	2244
1948	3	359	77	405	111	339	268	106	211	4	91	244	2218
1949	7	436	286	284	243	197	57	73	8	28	177	42	1838
1950	182	242	262	210	69	416	207	16	83	289	140	5	2121
1951	152	223	215	383	189	210	442	184	15	59	15	73	2160
1952	107	14	138	143	261	55	226	122	103	148	50	87	-
1953	222	96	84	209	42	132	172	141	24	14	38	13	1186
1954	134	25	247	40	165	237	158	107	65	49	373	368	1967
1955	139	182	84	215	185	265	643	468	120	512	182	61	3054
1956	213	97	189	316	646	388	234	378	46	230	73	32	2858
1957	373	168	219	21	311	80	218	286	16	9	11	40	1751
1958	25	102	225	172	123	216	304	101	96	152	63	117	1696
1959	123	206	250	121	80	121	177	61	31	134	3	20	1327
1960	339	106	251	551	308	203	377	192	213	21	129	221	2910
1961	138	372	39	384	38	88	87	34	15	38	21	15	1268
1962	90	149	87	123	42	120	209	81	76	41	135	119	1273
1963	140	267	349	108	78	230	150	50	28	53	10	7	1470
1964	189	224	196	129	300	290	146	113	27	63	25	191	1892
1965	561	191	107	104	124	206	124	164	46	37	45	146	1854
1966	250	121	336	283	156	176	96	32	27	10	90	447	2024
1967	178	132	295	346	68	211	110	86	24	9	31	270	1759
1968	487	135	630	250	56	89	152	177	142	99	27	214	2458
1969	153	72	181	385	263	99	108	48	73	4	9	100	1494
1970	307	301	269	406	98	196	221	234	185	51	284	211	2764
1971	404	332	387	301	185	116	295	60	244	66	89	33	2601
1972	120	126	195	184	174	647	99	192	25	54	48	34	1878
1973	72	94	79	385	354	172	300	456	197	80	575	275	3041
1974	155	199	109	479	203	109	388	196	129	196	119	100	2382
1975	348	189	302	210	390	298	384	62	251	61	199	-	-

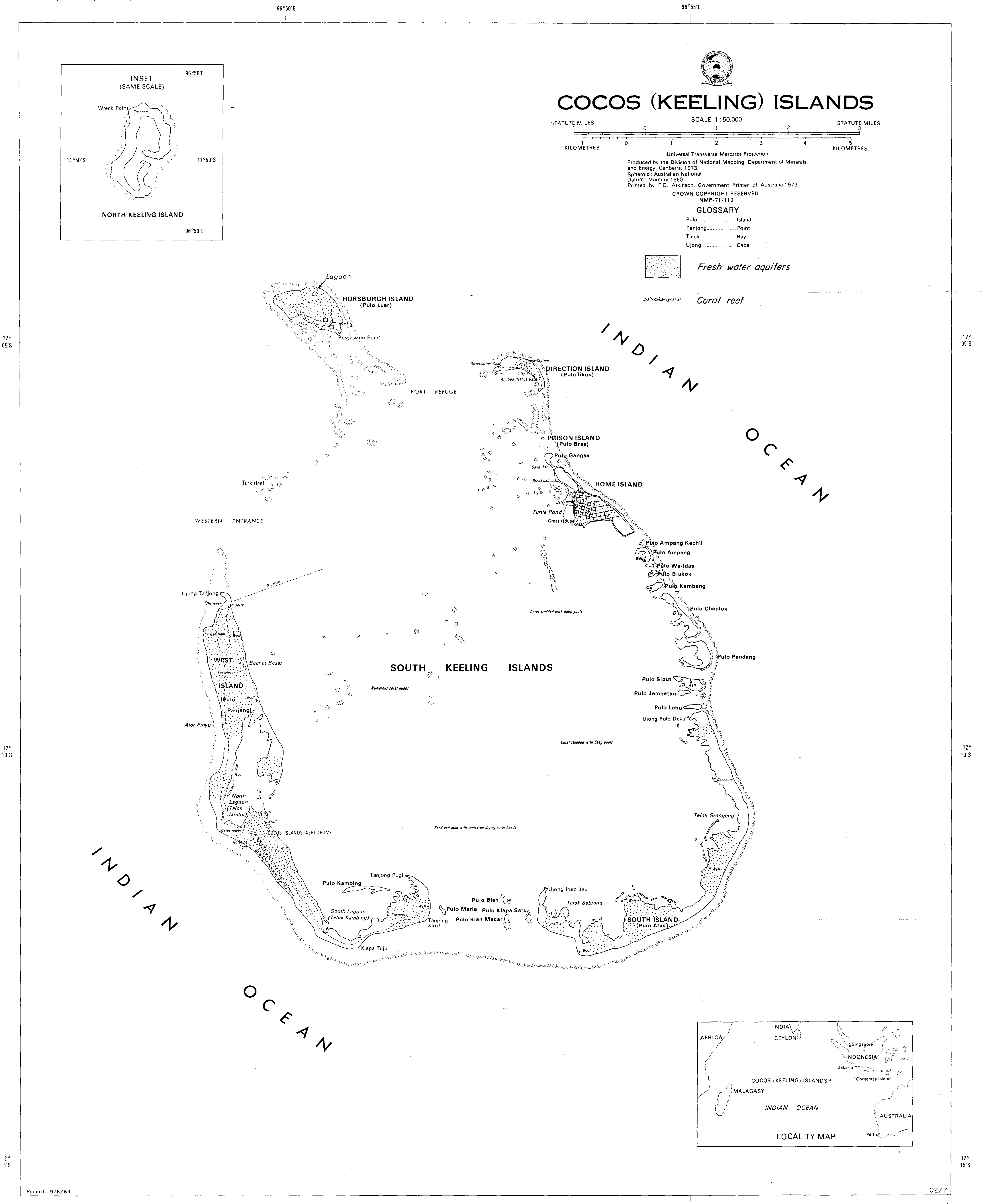
MEANS AND MEDIANS FOR THE PERIOD 1901 TO 1973 USING ALL AVAILABLE DATA

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN RAINFALL (MM)	167	196	232	252	186	222	214	127	95	86	99	121	2009
MEDIAN RAINFALL(MM)	138	174	210	234	165	207	177	98	47	46	58	88	1986
NO.OF RAINFALL OBS.	71	70	70	69	70	70	70	70	70	69	69	70	66

APPENDIX 4

TIDAL PREDICTIONS, PORT REFUGE, DECEMBER 1975

DECEMBER	Time(hrs)	Height(m)	DECEMBER	Time(hrs)	Height(m)
4	0006	0.3	5	0046	0.3
	0542	0.8		0623	0.8
	1108	0.4		1148	0.4
	1754	1.3		1843	1.3
6	0125	0.3	7	0202	0.3
	0703	0.6		0743	0.8
	1227	0.4		1308	0.4
	1915	1.2		1949	1.2
8	0239	0.4	9	0316	0.4
	0825	0.8		0910	0.8
	1350	0.4		1436	0.5
	2026	1.1		2105	1.1
10	0355	0.4	11	0436	0.4
	1001	0.8		1059	0.9
	1530	0.5		1635	0.6
	2149	1.0		2238	0.8
12	0522	0.4	13	0612	0.4
	1201	0.9		1304	0.9
	1756	0.6		1922	0.6
	2339	0.9			
14	0050	0.8	15	0203	0.8
	0704	0.4		0756	0.4
	1401	1.0		1452	1.1
	2038	0.5		2139	0.5
16	0308	0.8			
	0846	0.4			
	1538	1.1			
	2231	0.4			


96°50'E
96°55'E
INSET
(SAME SCALE)
Wreck Point
Coconuts
11°50'S
NORTH KEELING ISLAND
COCOS (KEELING) ISLANDS
SCALE 1 : 50,000
STATUTE MILES
KILOMETRES
Universal Transverse Mercator Projection
Produced by the Division of National Mapping, Department of Minerals and Energy, Canberra, 1973.
Spheroid: Australian National
Datum: Mercury 1960
Printed by F.D. Atkinson, Government Printer of Australia 1973.
CROWN COPYRIGHT RESERVED
NMP/71/119
GLOSSARY
Pulo .... Island
Tanjong .... Point
Telok .... Bay
Ujong .... Cape
Fresh water aquifers
Coral reef
12° 05'S
12° 10'S
12° 15'S
INDIAN OCEAN
Lagoon
HORSBURGH ISLAND
(Pulo Luar)
Wells
Possession Point
PORT REFUGE
DIRECTION ISLAND
(Pulo Tikus)
PRISON ISLAND
(Pulo Bras)
Pulo Gangsa
HOME ISLAND
Turtle Pond
Great House
Turk Reef
WESTERN ENTRANCE
Pulo Ampang Kechil
Pulo Ampang
Pulo Wa-idas
Pulo Blukok
Pulo Kambang
Pulo Cheplok
Pulo Pandang
Pulo Siput
Pulo Jambatan
Pulo Labu
Ujong Pulo Dekat
Ujong Tanjong
Oil tanks
Jetty
Bechet Besar
SOUTH KEELING ISLANDS
WEST ISLAND (Pulo Panjang)
Alor Pinyu
North Lagoon (Telok Jambu)
Water tower
COCOS ISLANDS AERODROME
Telok Grongeng
Pulo Kambing
Tanjong Pugi
South Lagoon (Telok Kambing)
Tanjong Klikil
Klapa Tuju
Pulo Blan
Pulo Maria
Pulo Klapa Satu
Pulo Blan Madar
Ujong Pulo Jau
Telok Sabrang
SOUTH ISLAND
(Pulo Atas)
INDIA
AFRICA
CEYLON
Singapore
INDONESIA
Jakarta
Christmas Island
COCOS (KEELING) ISLANDS
MALAGASY
INDIAN OCEAN
AUSTRALIA
Perth
LOCALITY MAP
Record 1976/64
02/7