

MDV/SLR/17



**SMALL STATES
CONFERENCE ON
SEA LEVEL RISE**
MALE, 14 - 18 NOVEMBER 1989

**AN AUSTRALIAN CONTRIBUTION
TO THE MONITORING OF SEA LEVEL RISE**

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The opportunity to comment upon the Australian contribution to the monitoring of sea level is appreciated.

Australia sees for itself a special role in this context. Whereas many of the Small States, almost by definition, are sited on plate boundaries or other regions of tectonic activity so that the observed sea level trend is confused, Australia provides a relatively stable platform so that the global ocean sea level signal may be estimated in its southern hemisphere expression. From such a base line, the local and more complex signals elsewhere may be better identified.

As in other countries an intensive study of the historic sea level record has been made although the instrumentation and its maintenance is somewhat less than adequate for the task. Against a background of long period oscillations and much "noise", it is not possible to place significant weight on the indication of a single station, however it is relevant to note that for the continent as a whole the mean result emerges as 1.22 mm per year, which is consistent with the findings in Northern Europe and North America. An appendix to this paper covers the survey. In particular the treatment of the longer available time series for Sydney (Ft. Denison), Perth (Fremantle) and Adelaide (Outer Harbour) shows surprisingly linear trends at some variance with the computations of the Global Climate Models. Future projections of such models are indicated and it is clear that great uncertainty prevails.

However, springing from this basis and with the conviction that a much more sophisticated monitoring system is the only responsible solution. Certain initiatives have been committed by the Federal Government.

The Mainland

In allocating funding for Greenhouse research, \$1 million has been earmarked for the installation and maintenance of a new base-line monitoring array of "super" tide gauges of high precision and with particular reference to datum stability. These systems will be supported by geodetic and geophysical survey and will telemeter their observations in near-real time to a National Tidal Facility established at Flinders University. Some seven or eight such stations are envisaged initially at sites indicated on an accompanying diagram although, it is anticipated that this number will increase significantly based upon State initiatives already in train.

The ASEAN Region

In a Development Aid Programme the Federal Government has funded the establishment of an array of 23 stations through the ASEAN region and, in association, training courses have been held in Singapore and in FIAMS. The ASEAN region has scientifically strategic attributes. In addition to presenting a large, mainly shallow, sea of much tidal variance it straddles the equatorial threshold between the Pacific and Indian Oceans and in its unique "through flow" is the key to the process of inter-annual climate

variability in ENSO time-scales. This feature is attracting increasing focus with the passage of time.

The Pacific Region

At the 1988 South Pacific Forum in Tonga, the Prime Minister of Australia announced an initiative to undertake a feasibility study into the establishment of a network of stations to monitor climatic change in the Pacific. At the Forum in Kiribati in July 1989, he announced that Australia would fund a core project over five years at a cost of \$ 6.25 million.

There is to be established a Regional Scientific/information expert who will serve as a link between project personnel and regional counterpart personnel, who will provide regular scientific and general reports for designated regional and Australian Agencies and who will communicate with the media on related issues.

There will also be a training element.

It is also understood that some eleven stations for sophisticated monitoring gear will be established at sites shortly to be identified in:

Cook Islands

Fiji

Kiribati

Marshall Islands

Nauru

Papua New Guinea

Solomon Islands

Tonga

Tuvalu

Vanuatu

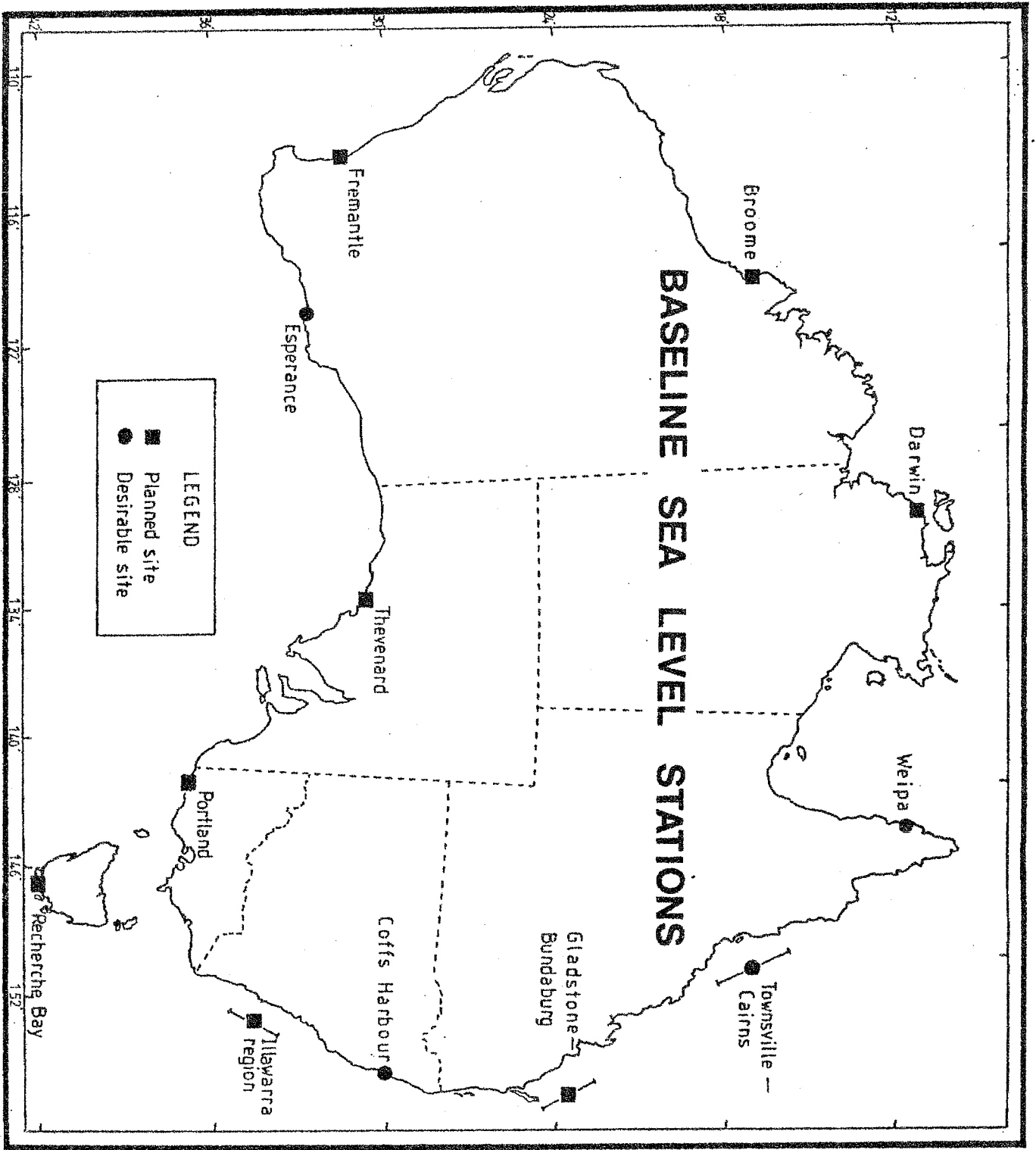
Western Samoa

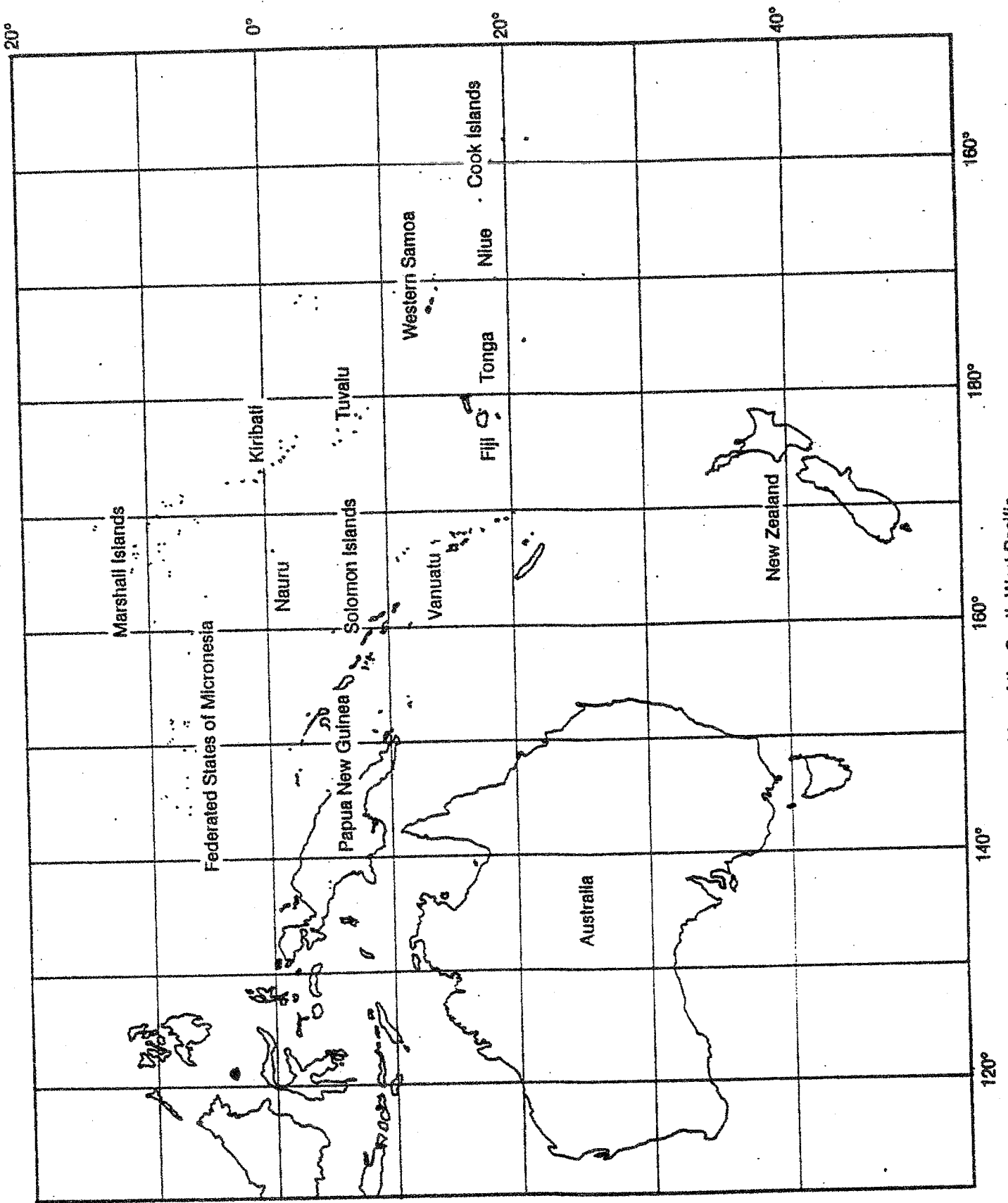
This array is scheduled to be defined by late March 1990.

The Southern Ocean

FIAMS is currently carrying out a feasibility study in response to a request from the GLOSS program with the object of setting up a sea level pilot project for the Southern Ocean.

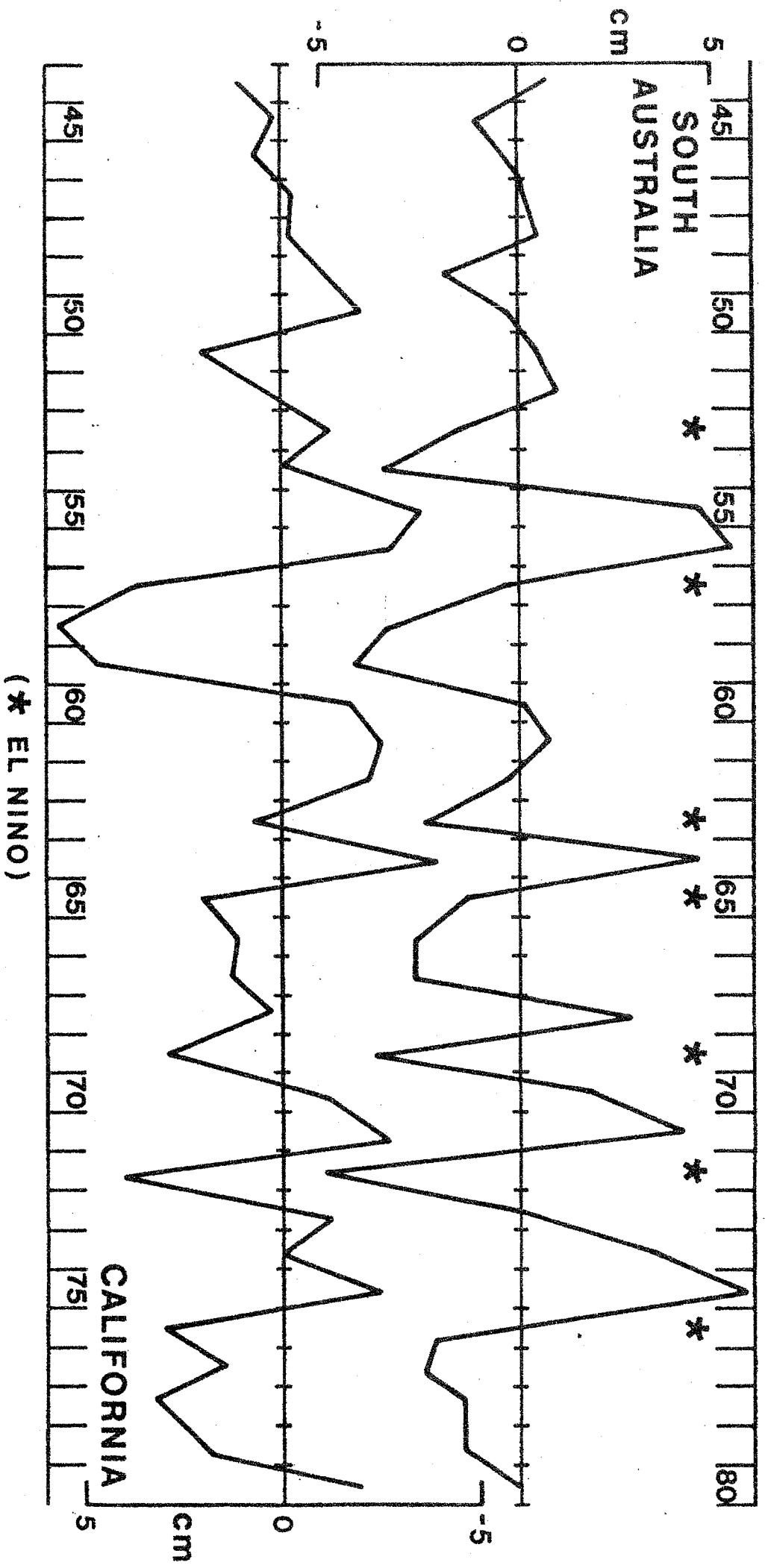
In addition to these initiatives the FIAMS group is actively involved in associated research with a special emphasis on inter annual signals. Australia's south coast has a special significance as the largest ice-free East/west expanse of coastline world-wide which also happens to be adjacent to the circumpolar Ocean and Current. This we see to be closely linked with the ENSO phenomenon in the interocean transport mechanism which eventually drives the Indonesian throughflow. Sea level in Australia is closely co-related with that of California, though in a negative sense, as is seen in an accompanying diagram, giving real prospects for the forecasting of El Nino events and Australian drought cycles. Other programs seek to monitor the accelerations of the circumpolar current through Coriolis gradient variations, using tide gauges on remote islands in the Southern Ocean.





Map of the South West Pacific

ANNUAL MEAN SEA LEVEL (1944 - 1980)



(* EL NINO)



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TIDAL LABORATORY

Secular Variations Study

The basic data set consists of all those ports on the databank that have a span of 10 years or greater, without regard to the amount of data in the span. The final column in Table 1 is the number of degrees of freedom in the regression equation and since the equation consists generally of 5 independent variables the column also represents the number of valid data points (those months without gaps) less 5. The beginning of the epoch is taken to be January 1966, so generally there is about a 21 year span for the more complete data sets.

The technique employed to derive the coefficients is described in Draper, N.R. and Smith, H. "Applied Regression Analysis", 1966, Chapter 6. It is a forward stepwise algorithm that selects the regression model. Optionally, selected variables may be forced into the model, a lack of fit test may be applied, and/or a partial F-test for each selected model term may be performed. The program (RLSEP) is contained in the IMSL Subroutine Package.

The independent variables chosen to represent the monthly means are the terms corresponding to sines and cosines of the tidal S_a (period one year) and S_{sa} (period 6 months) and a term representing the time. This variable is the time corresponding to the middle hour of the corresponding month and therefore sampling time intervals are variable.

In generating Table 1, the program was left to select those terms which satisfied the selection criteria at the 0.05 significance level. The Table also contains a column for the percentage of the variation explained by the regression, the standard deviation of the residuals, the F value for the F-test and the year that the records for each port start.

Generally, the higher the F value, the better the overall fit.

Table 2 comprises the results of forcing the independent variables into the regression equation (with a resultant decrease in F values). Table 3 is the result for those stations surveyed in the original seasonal variations study for the Division of National Mapping. This subset of stations are deemed to be more reliable since they are generally better quality. Note however that the larger trends for three of the final four stations are also associated with the smaller numbers of complete months.

Overall the average trend is found to be 1.22 mm/year for all those stations in Table 3. For the same subset of stations but using the trends of Table 1 the figure is 0.86 mm/yr.

The same procedure was applied to the longer sets of data for Fort Denison Fremantle and Port Adelaide (Outer Harbor). The results are displayed in Figures 1 and 2. Figure 1 shows in the lowest box the observed monthly means. These are then adjusted by any datum changes to give the series in the corrected box. These are then analysed for the Sa and Ssa and trend components which are then resynthesized to obtain the series plotted in the predicted box. Finally, the difference between the corrected series and the predicted series are plotted as residuals.

The secular trend of the three longer term observation sets derived from the above analysis are given on Figure 2 together with the annual means as points.

TABLE 1

PORT	Z0 m	H mm	Sa g	H mm	Ssa g	H mm	Ssa g	trend mm/yr	° varn expt.	res s.d. cm.	F value	Records Start	deg Of freedom
CAIRNS	1.409	91.25	0.0	17.17	0.0	0.0	0.0	3.20	69.4	4.6	98.3	1960	128
TOWNSVILLE	1.629	98.89	352.8	21.44	0.0	0.0	0.0		72.3	4.5	200.7	1950	229
MACKAY	2.902	111.25	348.8	0.00	0.0	0.0	0.0	5.59	64.7	6.0	86.3	1960	139
(ADJUSTED)	2.948	110.68	349.0	0.00	0.0	0.0	0.0	2.76	5.9	5.9	84.2	1960	139
BUNDABERG	1.354	75.79	347.5	0.00	0.0	0.0	0.0		55.7	4.8	115.0	1966	180
BRISBANE	1.183	59.95	15.0	0.00	0.0	0.0	0.0	2.92	40.9	5.7	34.3	1966	147
LORD HOWE ISLAND	1.184	0.00	0.0	0.00	0.0	0.0	0.0		0.0	0.0	0.0	1958	67
NEWCASTLE	0.982	41.56	32.8	22.02	127.5	0.0	0.0		26.4	5.7	19.6	1957	217
CAMP COVE	0.920	35.92	44.4	25.16	133.1	0.0	0.0	1.69	31.7	4.8	12.2	1966	131
FORT DENISON	0.944	42.56	47.0	24.88	139.5	0.0	0.0		35.4	4.8	30.6	1886	222
POINT LONSDALE	0.853	50.39	90.0	29.05	142.4	0.0	0.0	1.98	33.0	6.1	26.7	1962	216
GEE LONG	0.466	55.26	90.0	24.82	142.9	0.0	0.0		39.1	5.3	28.1	1965	129
BURNIE	2.202	57.87	90.0	0.00	0.0	0.0	0.0	-11.03	37.9	9.6	32.0	1952	102
(VISUALLY CORR'D)	1.947	38.47	90.0	0.00	0.0	0.0	0.0		16.9	5.9	21.6	1952	102
GEORGETOWN	1.994	40.92	90.0	0.00	0.0	0.0	0.0		18.0	6.1	34.5	1965	153
HOBART	1.313	0.00	0.0	0.00	0.0	0.0	0.0		0.0	0.0	0.0	1960	160
(LESS YEARS 74 AND 75)	1.199	32.84	135.8	0.00	0.0	0.0	0.0		6.2	9.2	4.7	1960	137
WILLIAMSTOWN	0.525	34.88	90.0	24.86	140.0	0.0	0.0	1.29	23.1	5.8	18.3	1966	243
PORT MACDONNELL	0.620	66.24	90.0	34.20	127.7	0.0	0.0		44.3	6.1	46.3	1962	173
VICTOR HARBOUR	0.614	82.27	90.0	29.30	143.5	0.0	0.0		39.7	7.8	40.8	1964	184
PORT ADELAIDE(OUTER)	1.581	72.68	90.0	20.03	180.0	0.0	0.0	3.44	30.0	8.1	51.0	1940	235
PORT ADELAIDE(INNER)	1.415	75.94	90.0	20.84	180.0	0.0	0.0		41.3	7.3	51.0	1933	215
PORT LINCOLN	1.027	82.91	90.0	32.49	155.7	0.0	0.0	1.53	54.3	5.9	64.7	1964	217
THEVENARD	0.988	84.51	90.0	16.40	180.0	0.0	0.0	1.69	47.1	6.6	55.2	1964	184
ESPERANCE	0.719	80.51	76.3	26.41	146.9	0.0	0.0	1.82	54.8	5.6	50.6	1965	209
ALBANY	0.772	92.71	75.4	27.77	145.5	0.0	0.0		63.8	5.2	93.4	1960	211
BUNBURY	0.649	111.71	70.9	28.80	180.0	0.0	0.0		64.6	6.0	128.4	1963	209
FREMANTLE	0.722	101.09	69.1	28.99	147.8	0.0	0.0		60.8	6.1	88.9	1897	228
GERALDTON	0.865	109.26	54.8	33.28	150.5	0.0	0.0		66.7	5.6	110.8	1963	220
CARNARVON	0.828	94.83	19.2	24.53	141.0	0.0	0.0	3.39	63.1	5.8	47.8	1965	140
DAMPIER	2.673	87.73	0.0	0.00	0.0	0.0	0.0		26.8	10.0	49.3	1966	131
(LESS YRS 76, 77, 78)	2.693	92.16	0.0	0.00	0.0	0.0	0.0		48.1	6.7	103.0	1966	107
PORT HEDLAND	4.164	101.37	343.7	0.00	0.0	0.0	0.0		54.6	6.5	84.9	1960	138
BROOME	4.478	173.12	0.0	40.52	90.0	0.0	0.0		15.7	14.1	12.7	1966	133
(LESS MTHS 7, 8, 9 1977)	4.484	62.97	0.0	34.07	90.0	0.0	0.0		13.1	13.3	10.0	1966	130
WYNDHAM	4.224	148.09	324.0	54.59	0.0	0.0	0.0	3.04	68.1	7.7	66.2	1966	123
DARWIN	3.997	108.17	316.8	14.98	90.0	0.0	0.0		56.0	6.9	92.5	1966	216
MILNER BAY	0.644	271.05	316.2	36.41	0.0	0.0	0.0	-6.72	80.2	10.1	96.2	1966	94
CENTRE ISLAND	3.051	296.36	310.2	37.12	0.0	0.0	0.0		78.3	11.3	122.5	1966	100
WEIPA	1.642	306.32	310.7	63.51	304.6	0.0	0.0	3.74	86.3	9.2	131.0	1966	104
BOOBY ISLAND	2.744	278.51	320.1	0.00	0.0	0.0	0.0	-16.54	74.4	11.6	45.4	1970	45

TABLE 2

PORT	ZO m	H mm	Sa g	H mm	Ssa g	H mm	trend mm/yr	varn expl.	res s.d. cm.	F value	Records Start	deg of freedom
BOOBY ISLAND	2.749	282.24	319.4	46.55	331.2		-17.35	76.8	11.3	29.8	1970	45
CAIRNS	1.409	91.58	3.1	17.35	9.4		3.24	69.7	4.6	58.8	1960	128
TOWNSVILLE	1.628	98.93	352.8	21.59	351.5		0.08	72.3	4.5	119.8	1960	229
MACKAY	2.948	110.14	349.1	11.49	2.3		2.75	64.9	5.9	51.3	1960	139
BUNDABERG	1.359	75.63	347.3	4.41	137.5		-0.51	56.0	4.8	45.9	1966	180
BRISBANE	1.183	59.55	15.2	12.21	131.0		2.91	42.3	5.6	21.6	1966	147
LORD HOWE ISLAND	1.119	29.27	46.8	38.33	112.4		4.85	8.6	13.1	1.3	1958	67
NEWCASTLE	0.976	41.55	32.8	22.08	127.9		0.31	26.5	5.7	15.7	1957	217
CAMP COVE	0.920	35.92	44.4	25.16	133.1		1.69	31.7	4.8	12.2	1966	131
FORT DENISON	0.867	42.87	46.6	24.86	139.4		0.86	36.2	4.8	25.1	1886	222
POINT LONSDALE	0.854	50.35	92.1	29.05	142.3		1.97	33.0	6.2	21.3	1962	216
GEE LONG	0.459	55.51	86.1	25.00	142.5		0.65	39.5	5.3	16.8	1965	129
WILLIAMSTOWN	0.525	35.21	82.3	24.89	140.0		1.31	23.4	5.8	14.8	1966	243
BURNIE	1.983	38.05	75.6	11.27	124.9		-0.83	20.2	5.9	5.2	1952	102
GEORGETOWN	1.984	41.18	96.0	12.42	173.5		0.95	20.4	6.1	7.8	1965	153
HOBART	1.228	34.09	137.9	9.41	217.2		-2.18	8.2	9.2	2.4	1960	137
PORT MACDONNELL	0.605	66.46	95.1	33.78	128.9		1.26	45.2	6.0	28.5	1962	173
VICTOR HARBOUR	0.616	82.29	92.0	29.30	143.4		-0.17	39.8	7.8	24.3	1964	184
PORT ADELAIDE(OUTER)	1.551	72.87	91.8	24.34	145.0		0.84	31.4	8.1	21.5	1940	235
PORT ADELAIDE(INNER)	1.027	83.31	92.1	24.65	148.5		3.38	42.3	7.2	31.5	1933	215
PORT LINCOLN	1.027	83.31	84.5	32.45	155.6		1.53	54.7	5.9	52.4	1964	217
THEVENARD	0.988	84.60	84.6	20.16	145.2		1.72	48.2	6.6	34.3	1964	184
ESPERANCE	0.719	80.51	76.3	26.41	146.9		1.82	54.8	5.6	50.6	1965	209
ALBANY	0.769	92.76	75.4	27.84	145.5		0.21	63.8	5.2	74.4	1960	211
BUNBURY	0.643	111.98	70.9	29.83	163.4		0.42	65.0	6.0	77.7	1963	209
FREMANTLE	0.692	101.19	69.1	28.97	147.8		0.39	60.9	6.1	71.0	1897	228
GERALDTON	0.862	109.32	54.7	33.27	150.5		0.20	66.8	5.7	88.3	1963	220
CARMARVON	0.828	94.83	19.2	24.53	141.0		3.39	63.1	5.8	47.8	1965	140
DAMPIER	2.677	93.37	353.9	15.51	106.5		2.10	51.1	6.6	22.4	1966	107
PORT HEDLAND	4.165	101.08	343.5	14.91	112.6		-0.07	55.9	6.5	34.9	1960	138
BROOME	4.480	68.84	337.4	35.90	111.1		-0.69	15.4	13.3	4.7	1966	130
WYNDHAM	4.223	147.49	324.1	54.80	6.5		3.08	58.2	7.7	52.8	1966	123
DARWIN	3.990	107.81	316.9	18.19	55.8		0.68	56.6	6.9	56.4	1966	216
MILNER BAY	0.644	271.97	316.4	38.85	340.5		-6.73	80.4	10.1	77.0	1966	94
CENTRE ISLAND	3.035	292.80	310.1	45.72	331.7		1.75	78.9	11.2	74.9	1966	100
WEIPA	1.642	306.32	310.7	63.51	304.6		3.74	86.3	9.2	131.0	1966	104

PORT ADELAIDE (OUTER) - MONTHLY MEANS

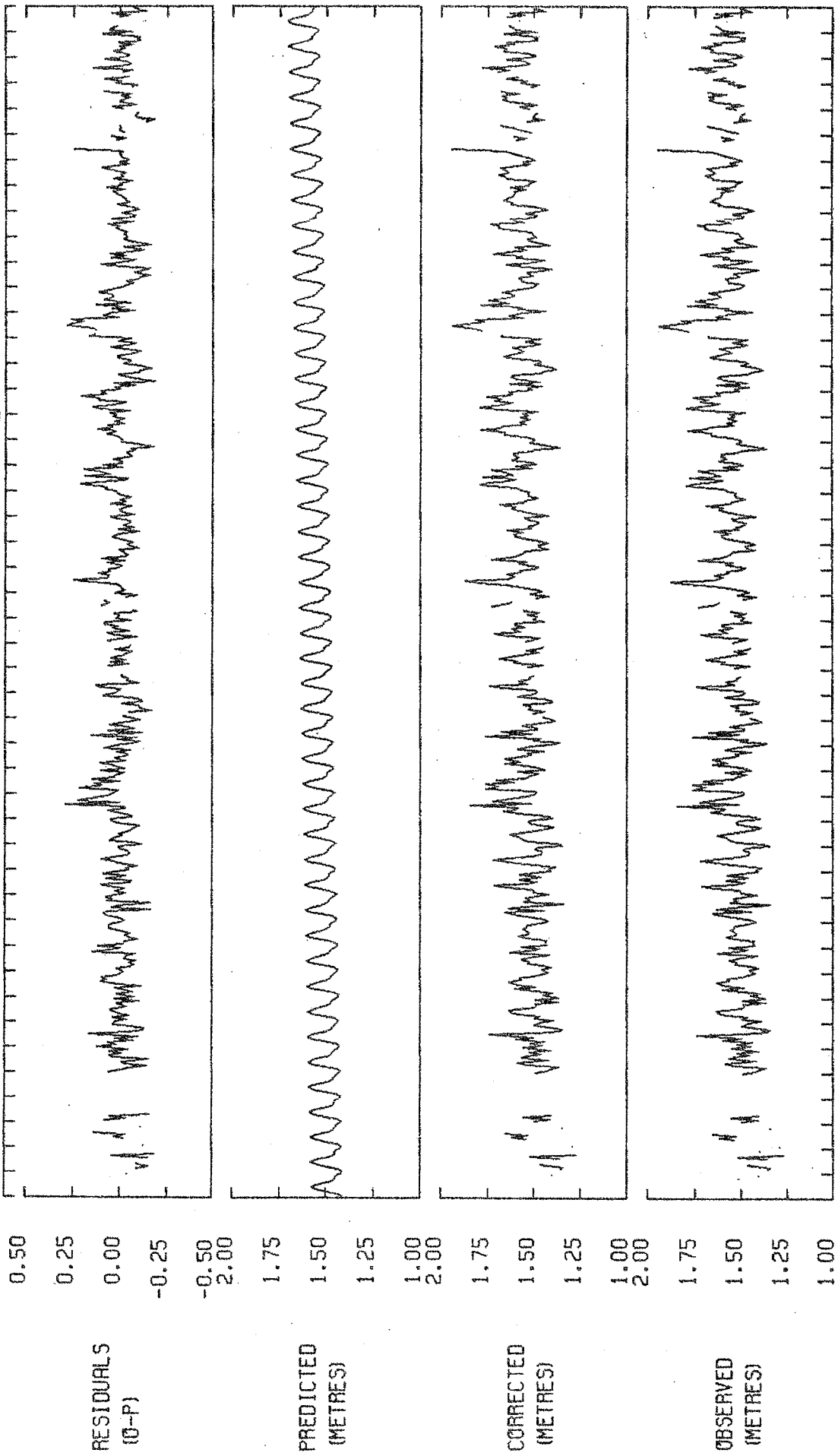


TABLE 3

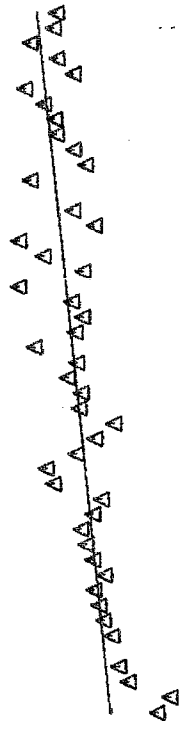
PORT	ZO m	Sa H mm	Sa g	H mm	Ssa g	trend mm/yr	varn expl.	res s.d. cm.	F value	Records Start	deg of freedom
TOWNSVILLE	1.628	99.93	352.8	21.59	351.5	0.08	72.3	4.5	119.8	1960	229
BUNDABERG	1.359	75.63	347.3	4.41	137.5	-0.51	56.0	4.8	45.9	1966	180
NEWCASTLE	0.976	41.55	32.8	22.08	127.9	0.31	26.5	5.7	15.7	1957	217
CAMP COVE	0.920	35.92	44.4	25.16	133.1	1.69	31.7	4.8	12.2	1966	131
FORT DENISON	0.867	42.87	46.6	24.86	139.4	0.86	36.2	4.8	25.1	1886	222
POINT LONSDALE	0.854	50.35	92.1	29.05	142.3	1.97	33.0	6.2	21.3	1962	216
WILLIAMSTOWN	0.525	35.21	82.3	24.89	140.0	1.31	23.4	5.8	14.8	1966	243
GEORGETOWN	1.984	41.18	96.0	12.42	173.5	0.95	20.4	6.1	7.8	1965	153
PORT MACDONNELL	0.605	66.46	95.1	33.78	128.9	1.26	45.2	6.0	28.5	1962	173
VICTOR HARBOUR	0.616	82.29	92.0	29.30	143.4	-0.17	39.8	7.8	24.3	1964	184
PORT ADELAIDE(OUTER)	1.551	72.87	91.8	24.34	145.0	0.84	31.4	8.1	21.5	1940	235
PORT ADELAIDE(INNER)	1.417	76.33	92.1	24.65	148.5	3.38	42.3	7.2	31.5	1933	215
PORT LINCOLN	1.027	83.21	84.5	32.45	155.6	1.53	54.7	5.9	52.4	1964	217
THEVENARD	0.988	84.60	84.6	20.16	145.2	1.72	48.2	6.6	34.3	1964	184
ESPERANCE	0.719	80.51	76.3	26.41	146.9	1.82	54.8	5.6	50.6	1965	209
ALBANY	0.769	92.76	75.4	27.84	145.5	0.21	63.8	5.2	74.4	1960	211
BUNBURY	0.643	111.98	70.9	29.83	163.4	0.42	65.0	6.0	77.7	1963	209
FREMANTLE	0.692	101.19	69.1	28.97	147.8	0.39	60.9	6.1	71.0	1897	228
GERALDTON	0.862	109.32	54.7	33.27	150.5	0.20	66.8	5.7	88.3	1963	220
CARNARVON	0.828	94.83	19.2	24.53	141.0	3.39	63.1	5.8	47.8	1965	140
DAMPIER	2.677	93.37	353.9	15.51	106.5	2.10	51.1	6.6	22.4	1966	107
PORT HEDLAND	4.165	101.08	343.5	14.91	112.6	-0.07	55.9	6.5	34.9	1960	138
WYNDHAM	4.223	147.49	324.1	54.80	6.5	3.08	68.2	7.7	52.8	1966	123

AVERAGE 1.22 mm/year

ANNUAL MEAN SEA LEVEL

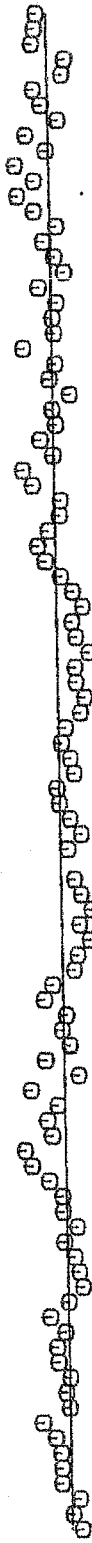
2.00
1.67
1.33
1.00
0.67
0.33
0.00

ADELAIDE (OUTER HARBOR) 2.85 mm/yr Δ

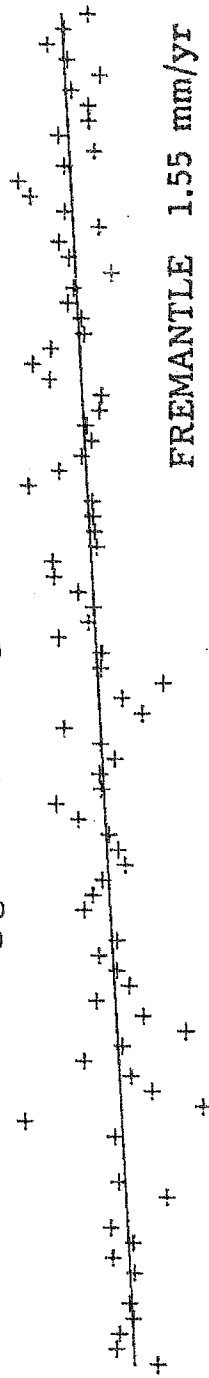


SEA LEVEL (M)

SYDNEY (FORT DENISON) 0.51 mm/yr \circ



FREMANTLE 1.55 mm/yr $+$



1880

1905

1930

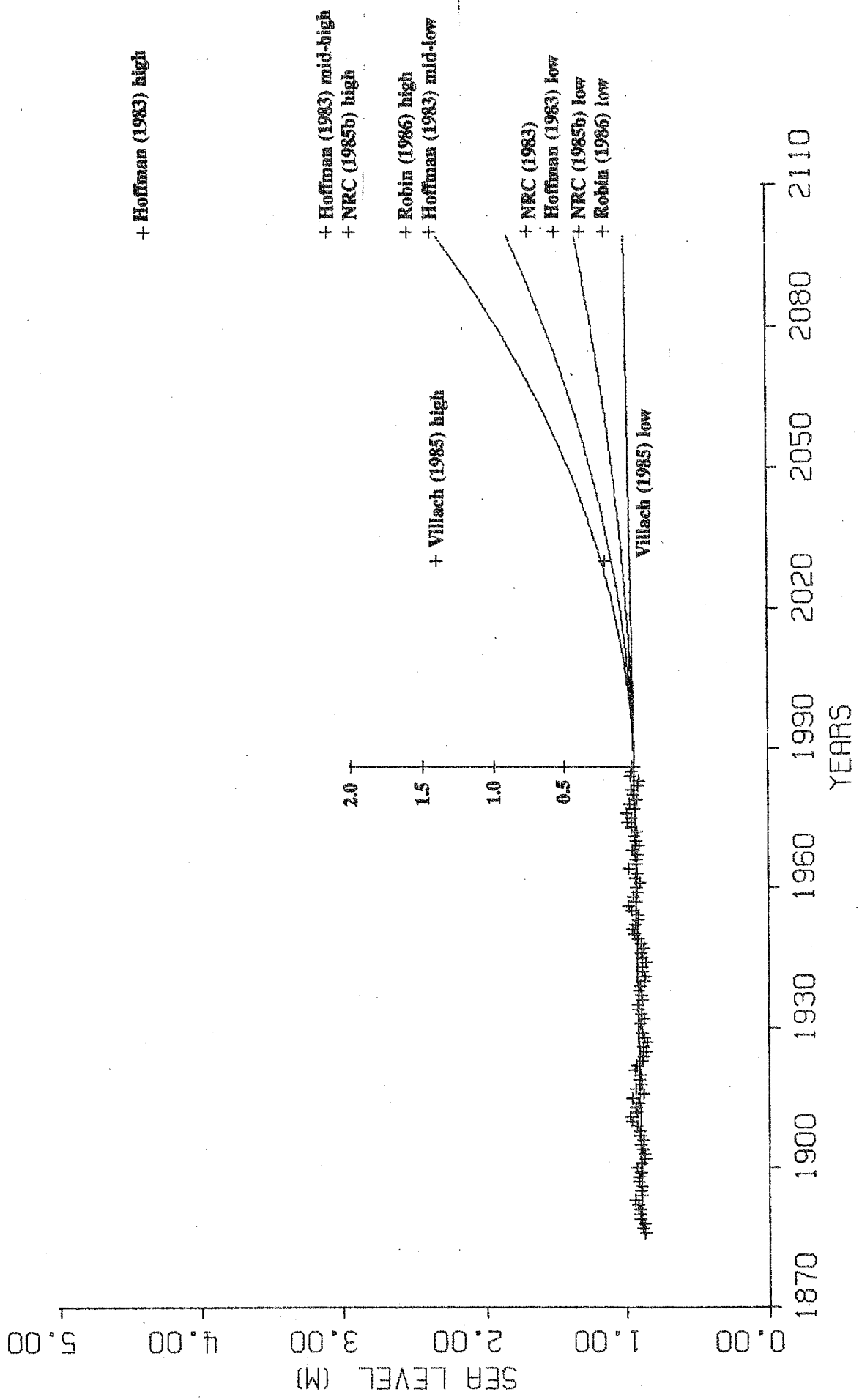
1955

1980

YEARS

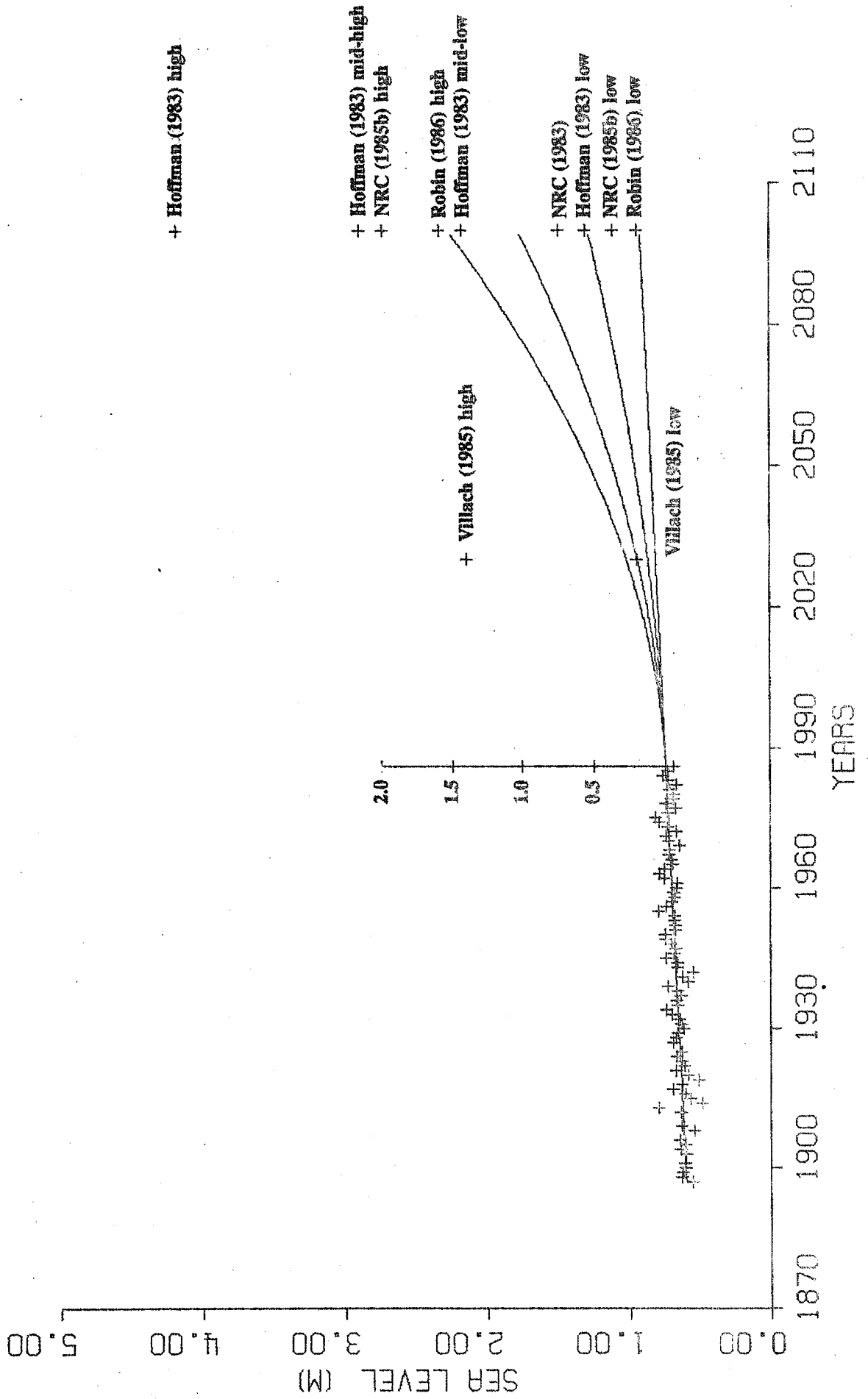
OBSERVED AND PROJECTED MSL

FORT DENISON



OBSERVED AND PROJECTED MSL

FREMANTLE



OBSERVED AND PROJECTED MSL
 PORT ADELAIDE (OUTER HARBOR)

