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GRAVITY METER TIES TO NEW ZEALAND AND ANTARCTICA 1975

by

D.A. COUTTS

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SUMMARY

The Bureau of Mineral Resources, Geology & Geophysics made gravity ties from Australia to New Zealand and Antarctica in November and December 1973, using three LaCoste & Romberg gravity metres. Earlier, in December 1966, the Antarctic Division (of the then Department of External Affairs) made similar ties using two LaCoste & Romberg gravity meters. Gravity values calculated from the results of these two surveys are consistent, within experimental error, with the values of the International Gravity Standardization Net 1971 (IGSN-71) except the IGSN-71 value at Auckland B which appears to be about 0.1 mGal too high. The gravity intervals measured between McMurdo and Byrd, and McMurdo and the South Pole have standard deviations of 0.1 to 0.2 mGal.

INTRODUCTION

Until recently, gravity ties between Australia and Antarctica, and within Antarctica, were less accurate than those between and within other continents. This was because travel to Antarctica was mostly by sea and propeller aircraft, and air transport within the continent was very irregular. An additional and continuing problem is that of secular variation in the position of bases on the polar ice cap owing to ice accumulation and movement. In 1971, to strengthen Antarctic gravity ties, the XVth General Assembly of the International Union of Geodesy and Geophysics passed Resolution 14, recommending "the connection of all major Antarctic base stations to IGSN-71 as quickly as possible and with comparable precision". In 1972 jet aircraft started to be used for flights to Antarctica and this improved the situation considerably in terms of the reduced time interval between successive gravity observations. In 1973, in accordance with the IUGG resolution, the Bureau of Mineral Resources, Geology and Geophysics made gravity ties from Australia, through Christchurch, New Zealand, to the Antarctic bases McMurdo, Scott and South Pole. In 1966, the Antarctic Division of the then Department of External Affairs had carried out similar ties through Christchurch to McMurdo and Byrd bases. The results of both surveys have been integrated in this report.

The BMR work in December 1973 comprised gravity ties between Sydney and Christchurch, and Auckland and Melbourne, using commercial aircraft, and ties from Christchurch to McMurdo and South Pole, using air transport provided by the U.S. National Science Foundation. Three LaCoste & Romberg geodetic gravity meters were used; they had been calibrated in June 1973 by measurements with GAG-2 gravity meters along the Australian Calibration Line (Wellman et al., 1974b). A joint BMR/University of Wisconsin tie had been planned from McMurdo to Vostok, but could not be made because of bad weather.

A north-south calibration line was established in New Zealand as a co-operative project with the Geophysics Division of the N.Z. Department of Scientific and Industrial Research, and Victoria University, Wellington. There were two observers and five LaCoste & Romberg gravity meters; the meters were read at least four times at each of two sites in Auckland, Wellington, Christchurch, and Dunedin. The results of this co-operative work in New Zealand will be reported elsewhere.

REDUCTION OF RESULTS

Gravity meter readings for the 1973 ties to New Zealand and Antarctica are given in Appendixes 1, 2 & 3. Listed are the readings in scale divisions, earth tide corrections, calculated using a BMR computer program, and the milligal equivalent of the tide-corrected reading, calculated using the manufacturer's tables given in Wellman et al. (1974b).

Station descriptions can be found as follows:

Australia Stations:	Wellman et al. (1974b), and BMR Isogal sketches available on request.
Christchurch 48732 E,A	Cowan and Robertson, 1964
Christchurch 48732 F	IGSN-71 sketches (Morelli et al., 1971)
Auckland 45164 B	Cowan and Robertson, 1964
Auckland 45164 D	Plate 2
McMurdo 59676 D,C,N	IGSN-71 sketches (Morelli et al., 1971)
McMurdo (Observation Hill)	No sketch. Station survey maker
South Pole (old)	No sketch known
Byrd (Science Hut)	No sketch. Station under slip behind Science Hut; established 1.1.62 by University of Wisconsin

When air transport was used, the observations were made in a ladder sequence. Gravity meter drift has been assumed to be zero for these observations, and one estimate of the gravity interval has been calculated for each flight. Ground ties were made by alternate measurements between two sites; these intervals have been corrected for meter drift.

The gravity intervals for both air and ground ties were adjusted to the GAG-2 Australian Calibration Line (ACL) scale by multiplying them by the following factors, determined by Wellman et al. (1974b) for the June 1973 observations,

Meter No	GAG-2 ACL milligal / maker's table milligal
G20A	1.0003782
G101	1.0026897
G252	1.0005338

Table 1 lists the gravity intervals on the GAG-2 scale measured by BMR in 1973. Intervals measured by the Antarctic Division in 1966 are given in Table 2, both as listed by Carter (1967), and as intervals on the GAG-2 ACL scale, corrected using the following factors from Wellman et al. (1974a, b).

Meter No	GAG-2 ACL milligal maker's table milligal
G20	1.00056
G104	1.00025

Plate 1 summarizes the ties made in 1966 and 1974, and gives sufficient additional ground ties to allow comparison of these results with earlier work. The additional ground-tie intervals are from Wellman et al. (1974b) for Melbourne A to M, M to V, and Sydney J to U; IGSN-71 values of Morelli et al. (1971) for Christchurch E to F, and the unpublished 1973 co-operative BMR/New Zealand Geophysics Division work for Auckland B to D.

DISCUSSION OF RESULTS

In Table 3, the IGSN-71 gravity values (Morelli et al., 1971) for the principal stations are compared with values calculated from the 1966 and 1973 observations. Values have been calculated for the 1966 and 1973 observations using the GAG-2 ACL scale and IGSN-71 values at Sydney and Melbourne, and IGSN-71 values at Christchurch and McMurdo. The three sets of values agree within experimental error.

Agreement of the derived gravity values at Christchurch E is pleasing, as the IGSN-71, 1966, and 1973 ties are strong. Agreement at McMurdo is not as good, but well within experimental error.

The IGSN-71 value at Auckland is based on low-accuracy ties made by the U.S. Navy and the Dominion Observatory of Canada. A better Auckland value can be established by measuring the Melbourne/Auckland gravity interval, as the Melbourne gravity value is accurately known and the gravity interval is small. In Table 4, estimates of the Auckland B/Melbourne A gravity interval are compared. The intervals agree within experimental error. The best tie is from the 1973 BMR work; this gives a value for Auckland B of 979 934.005 $\pm$ .022 mGal (IGSN-71 system). However this value is based on only three single ties without drift control. The precision of this Melbourne-Auckland interval could easily be improved by more measurements with LaCoste & Romberg gravity meters. This would be a very useful contribution to the world gravity network.

Table 5 gives gravity intervals for McMurdo A to South Pole from Behrendt (1967), Bentley (1971), and the 1973 BMR work. Bentley (1971) shows that the clear decrease in gravity at the pole station, shown by the 1957-1967 work, can be attributed to sinking of the South Pole gravity station relative to basement. The December 1973 BMR tie confirms the decrease in gravity, at the previously determined rate of 0.1 $\pm$ 0.01 mGal per year. Numerous gravity observations have been made since 1967 between McMurdo and South Pole but none have been reported, and so a detailed analysis has not been made at this stage.

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APPENDIX 1. GRAVITY READINGS ON METER G20A, 1973

Station IGC Name	Date and Time (UTC) Month	Day	Hour	Minute	Reading Sc.Div.	Earth Tide Correction mGal	Corr'd Equiv. mGal
Canberra M	11	28	01	23	3025.140	+.093	3171.646
Sydney U	11	28	03	10	3097.520	+.135	3247.739
Sydney U	11	28	20	12	3097.770	-.059	3247.808
Christchurch E	11	29	02	00	3857.000	+.104	4046.250
Christchurch E	12	07	17	45	3857.030	-.041	4046.137
McMurdo D	12	08	03	20	6222.710	-.035	6536.901
South Pole	12	08	11	35	5595.980	-.063	5877.093
South Pole	12	08	23	04	5596.160	-.061	5877.285
McMurdo D	12	09	04	15	6222.580	-.037	6536.762
McMurdo D	12	10	20	44	6222.500	-.043	6536.672
McMurdo N	12	10	22	07	6222.230	-.025	6536.406
McMurdo D	12	10	22	36	6222.450	-.019	6536.643
McMurdo D	12	11	00	45	6222.460	-.002	6536.671
McMurdo N	12	11	01	38	6222.190	-.002	6536.387
McMurdo D	12	11	02	08	6222.470	-.003	6536.680
McMurdo D	12	12	01	00	6222.440	-.015	6536.637
McMurdo C	12	12	01	30	6219.010	-.013	6533.030
McMurdo D	12	12	01	45	6222.450	-.013	6536.649
McMurdo C	12	12	02	02	6219.040	-.012	6533.062
McMurdo D	12	12	02	17	6222.460	-.012	6536.661
Christchurch D	12	12	11	50	3856.350	-.081	4045.381
Christchurch E	12	14	02	47	3856.320	+.098	4045.529
Sydney U	12	14	10	28	3097.155	-.080	3247.141
Sydney U	12	14	20	27	3097.130	-.023	3247.171
Christchurch E	12	15	02	26	3856.490	+.049	4045.659
Christchurch A	12	15	02	52	3868.57	+.056	4058.374
Christchurch E	12	15	03	15	3856.47	+.060	4045.649
Christchurch A	12	15	03	40	3868.57	+.062	4058.380
Christchurch E	12	15	04	04	3856.47	+.064	4045.653
Christchurch A	12	15	04	28	3868.56	+.061	4058.368
Christchurch E	12	15	04	54	3856.47	+.058	4045.647
Auckland D	12	18	08	37	3343.070	-.016	3505.666
Melbourne V	12	18	13	00	3333.930	-.063	3496.011
Melbourne V	12	18	18	00			Meter off heat
Canberra M	12	18	21	09	3024.670	+.071	3171.130

APPENDIX 2. GRAVITY READINGS ON METER G101, 1973

Station IGC Name	Date and Time (UTC) Month	Day	Hour	Minute	Reading Sc. Div.	Earth Tide Correction mGal	Corr'd Equiv. mGal
Canberra M	11	28	01	26	3191.16	+.095	3335.689
Sydney U	11	28	03	14	3263.74	+.134	3411.643
Sydney U	11	28	20	15	3263.94	-.059	3411.659
Christchurch E	11	21	02	10	4025.29	+.104	4208.260
Christchurch E	12	07	17	50	4025.45	-.038	4208.285
McMurdo D	12	08	03	45	6402.40	-.046	6692.878
South Pole	12	08	10	30	5772.63	-.064	6035.275
South Pole	12	08	23	08	5772.66	-.061	6035.309
McMurdo D	12	09	04	24	6402.38	-.039	6692.864
McMurdo D	12	10	20	49	6402.43	-.042	6692.913
McMurdo D	12	11	00	48	6402.42	-.002	6692.943
McMurdo N	12	11	01	41	6402.15	-.002	6692.661
McMurdo D	12	11	02	12	6402.39	-.003	6692.911
McMurdo D	12	12	01	06	6402.42	-.015	6692.930
McMurdo C	12	12	01	32	6398.95	-.013	6689.311
McMurdo D	12	12	01	48	6402.41	-.013	6692.921
McMurdo C	12	12	02	05	6398.95	-.012	6689.312
McMurdo D	12	12	02	20	6402.42	-.013	6692.932
Christchurch E	12	12	12	04	4025.55	-.074	4208.366
Christchurch E	12	14	02	51	4025.33	+.099	4208.297
Sydney U	12	14	10	41	3264.12	-.082	3411.824
Sydney U	12	14	20	17	3264.09	-.021	3411.854
Christchurch E	12	15	02	31	4025.42	+.050	4208.342
Christchurch A	12	15	02	55	4037.59	+.057	4221.080
Christchurch E	12	15	03	20	4025.42	+.060	4208.352
Christchurch A	12	15	03	43	4037.55	+.062	4221.043
Christchurch E	12	15	04	07	4025.42	+.063	4208.355
Christchurch A	12	15	04	31	4037.58	+.060	4221.072
Christchurch E	12	15	04	58	4025.43	+.057	4208.359
Auckland D	12	18	08	40	3510.61	-.017	3669.722
Melbourne V	12	18	13	03	3501.43	-.062	3660.074
Melbourne V	12	18	18	48	3501.29	+.073	3660.062
Canberra M	12	18	21	15	3191.40	+.070	3335.915

APPENDIX 3. GRAVITY READINGS ON METER G252, 1973

Station IGC Name	Date and Time (UTC) Month	Day	Hour	Minute	Reading Sc. Div.	Earth Tide Correction mGal	Corr'd Equiv. mGal
Canberra M	11	28	01	30	3165.44	+.098	3327.778
Sydney U	11	28	03	18	3237.78	+.132	3403.868
Sydney U	11	28	20	18	3238.01	-.058	3403.920
Christchurch E	11	29	02	17	3996.98	+.104	4202.126
Christchurch E	12	07	17	55	3997.19	-.035	4202.208
McMurdo D	12	08	04	00	6368.71	-.049	6693.925
South Pole	12	08	10	45	5740.20	-.063	6034.390
South Pole	12	08	23	13	5740.22	-.061	6034.413
McMurdo D	12	09	04	38	6368.78	-.042	6694.006
McMurdo D	12	10	20	53	6368.82	-.041	6694.049
McMurdo N	12	10	22	10	6368.52	-.024	6693.751
McMurdo D	12	10	22	43	6368.80	-.017	6694.052
McMurdo D	12	11	00	53	6368.79	-.002	6694.056
McMurdo N	12	11	01	45	6368.55	-.002	6693.804
McMurdo D	12	11	02	15	6368.81	-.003	6694.076
McMurdo D	12	12	01	11	6368.86	-.014	6694.118
McMurdo C	12	12	01	35	6365.43	-.013	6690.522
McMurdo D	12	12	01	50	6368.86	-.013	6694.118
McMurdo C	12	12	02	07	6365.44	-.012	6690.533
McMurdo D	12	12	02	23	6368.88	-.013	6694.140
Christchurch E	12	12	12	16	3997.32	-.074	4202.306
Christchurch E	12	14	02	55	3997.28	+.100	4202.438
Sydney U	12	14	10	21	3238.11	-.079	3404.004
Sydney U	12	14	20	22	3238.07	-.022	3404.019
Christchurch E	12	15	02	34	3997.34	+.051	4202.452
Christchurch A	12	15	02	58	4009.42	+.057	4215.161
Christchurch E	12	15	03	23	3997.32	+.060	4202.440
Christchurch A	12	15	03	46	4009.40	+.063	4215.146
Christchurch E	12	15	04	10	3997.30	+.063	4202.422
Christchurch A	12	15	04	34	4009.41	+.060	4215.154
Christchurch E	12	15	05	02	3997.32	+.056	4202.436
Auckland D	12	17	08	43	3483.91	-.018	3662.498
Melbourne V	12	17	15	06	3474.77	-.061	3652.845
Melbourne V	12	17	20	52	3474.64	+.074	3652.843
Canberra M	12	17	23	19	3165.66	+.069	3327.980

TABLE 1. GRAVITY INTERVALS MEASURED BY BMR IN 1973

Gravity Stations	Meter	Interval (GAG-2 mGal)			Mean	st.dev.	st.dev.of mean
Sydney U	G20A	798.744	798.721	(799.281)	798.732	0.016	0.012
to	G101	798.744	798.621	798.612	798.659	0.074	0.043
Christchurch E	G252	798.632	798.863	798.856	798.784	0.131	0.076
	Mean of eight intervals				798.72	0.099	0.035
Christchurch E	G20A	2491.706	2492.222		2491.964	0.365	0.258
to	G101	2491.276	2491.249		2491.263	0.020	0.014
McMurdo D	G252	2493.047	2493.164		2493.106	0.083	0.059
	Mean of six intervals				2492.111	0.849	0.346
McMurdo D	G20A	660.014	659.747		659.944	0.278	0.196
to	G101	659.367	659.326		659.347	0.029	0.021
South Pole (old)	G252	659.907	659.927		659.917	0.014	0.010
	Mean of six intervals				659.715	0.298	0.122
McMurdo D	G20A	0.245	0.290		0.268	0.032	0.022
to	G101	-	0.260		0.260	-	-
McMurdo N	G252	0.300	0.265		0.283	0.025	0.017
	Mean of five intervals				0.272	0.023	0.010
McMurdo D	G20A	3.615	3.594		3.605	0.015	0.010
to	G101	3.623	3.626		3.625	0.002	0.001
McMurdo C	G252	3.598	3.598		3.598	0.0	0.0
	Mean of six intervals				3.609	0.014	0.006
Auckland D	G20A	9.659					
To	G101	9.674					
Melbourne V	G252	9.658					
	Mean of three intervals				9.664	0.009	0.005
Christchurch E	G20A	12.720	12.729	12.718	12.722	0.006	0.003
to	G101	12.733	12.690	12.715	12.713	0.022	0.012
Christchurch A	G252	12.715	12.715	12.725	12.718	0.006	0.003
	Mean of nine intervals				12.718	0.012	0.004

TABLE 2. GRAVITY INTERVALS MEASURED BY ANTARCTIC DIVISION (CARTER, 1967)

Gravity Station	Meter	Maker's Table mGal	GAG-2 mGal	Mean	st.dev.	st.dev. of mea
Melbourne M	G104(1)	534.04	534.176			
to	(2)	534.17	534.306	534.241	0.091	0.065
Christchurch F	G20 (1)	533.76	534.058			
	(2)	533.71	534.009	534.033	0.035	0.024
	Mean of four intervals			534.137	0.133	0.066
Christchurch F	G104(1)	2491.40	2492.035			
to	(2)	2491.48	2492.115	2492.075	0.056	0.040
McMurdo D	G20 (1)	2490.49	2491.885			
	(2)	2489.96	2491.354	2491.619	0.375	0.265
	Mean of four intervals			2491.847	0.342	0.171
McMurdo D	G104(1)	380.46	380.557			
to	(2)	380.75	380.847	380.702	0.205	0.145
Byrd (Science Hut)	G20 (1)	380.36	380.573			
	(2)	380.79	381.003	380.788	0.304	0.215
	Mean of four intervals			380.745	0.217	0.109
McMurdo D	G104(1)	(52.585	52.598)			
to	(2)	52.600	52.613			
McMurdo (Observation	(3)	52.585	52.598			
Hill)	(4)	(52.525	52.538)			
	G20 (1)	(52.405	52.434)			
	(2)	(52.500	52.529)			
	(3)	52.490	52.519			
	(4)	(52.520	52.549)			
	Mean of three intervals			52.577	0.051	0.029

TABLE 3. GRAVITY VALUES

Gravity Station	Values based on GAG-2 scale & IGSN-71 values Sydney and Melbourne (mGal) (1973)	Values based on scale and datum given by IGSN-71 values of Christchurch & McMurdo (mGal) (1966)	IGSN-71 values and quoted errors (mGal)
Sydney U	979 682.82 ± .02 *	979 682.871 ± .099	979 682.82 ± .02
Melbourne M	979 947.35 ± .02 *	979 947.542 ± .092	979 947.35 ± .02
Auckland B	979 934.005 ± .022	979 934.193 ± .092	979 934.11 ± .05
Christchurch E	980 481.531 ± .036	980 481.58 ± .03 *	980 481.58 ± .03
McMurdo D	982 973.251 ± .140**	982 973.45 ± .04 *	982 973.45 ± .04
Byrd (Science Hut)	982 592.506 ± .180	982 592.69 ± .10	-
South Pole	982 313.536 ± .180	982 313.799 ± .090	-

* Assumed value

** G252 results not included

TABLE 4. GRAVITY INTERVAL AUCKLAND 45164B TO MELBOURNE 45474A

Tie and year		Interval ± s.d. mGal
BMR 1959 +	W140	31.08 ± .05 *
	W169	30.98 ± .11 **
IGSN-71 (1962-67 indirect ties)		31.070 ± .055
BMR 1973		31.175 ± .030

* W140 calibration constant used = 55.68 mGal/499.77 ± .08 sc. div.

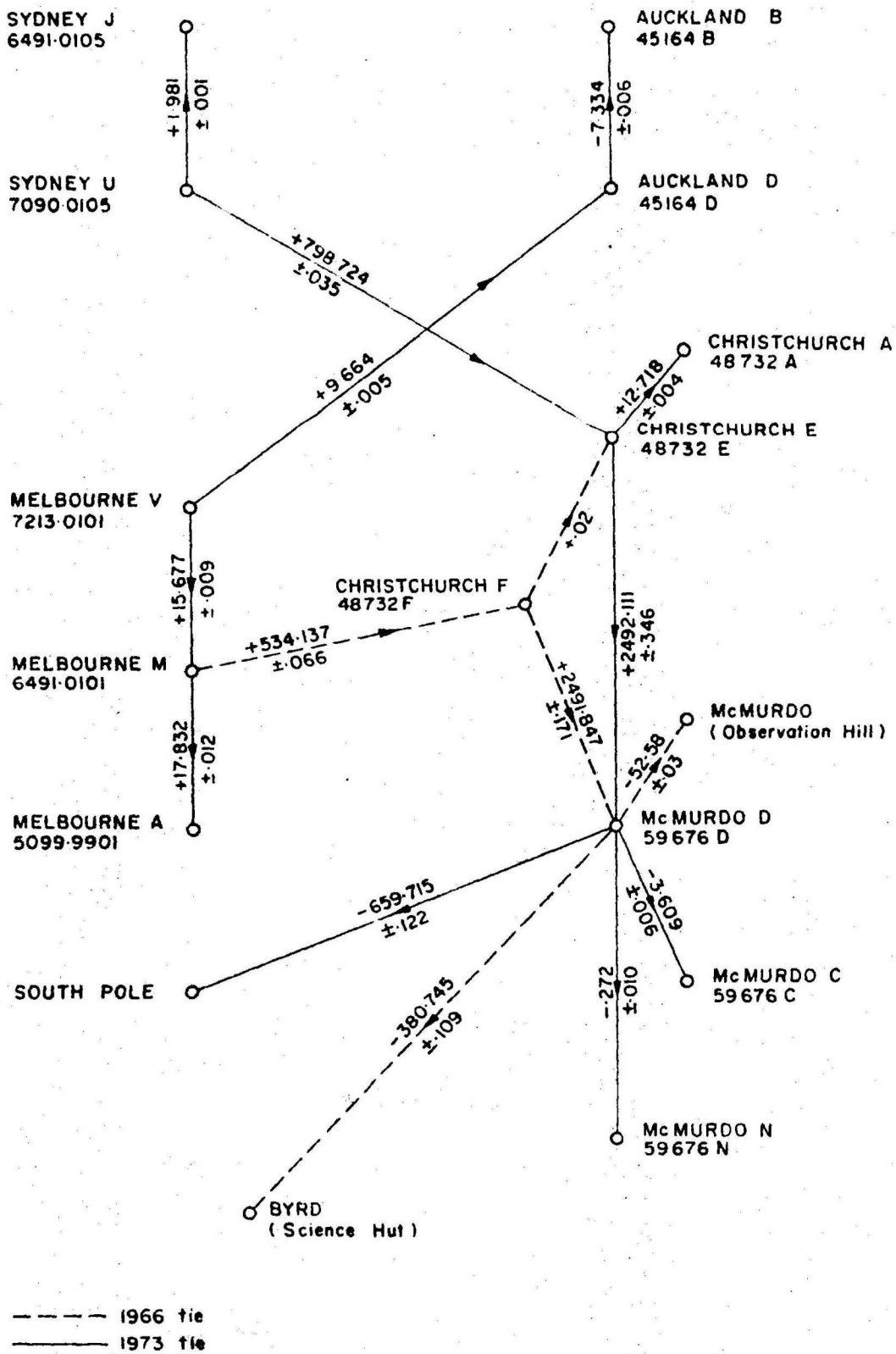
** W169 calibration constant used = 55.68 mGal/525.05 ± .2 sc. div.

\+ From Williams et al., 1961

TABLE 5. GRAVITY INTERVAL McMURDO 59676A TO SOUTH POLE

Date	Gravity Interval (mGal)	Number of Drift-corrected Intervals measured
Dec 1957	664.22	1
Feb 1961	663.99 ± .02	2
Dec 1961	664.01 ± .06	5
Nov 1962	663.73	½
Dec 1962	663.93	1
Jan 1965	663.52	1
Jan 1965	(?)663.32	1
Jan 1966	663.51	1
Dec 1967	663.40	?1
Dec 1973	663.075 ± .122	2 (GAG-2 milligal)
	663.011 ± .070	2 (ICSN-71 milligal)

Using McMurdo A - McMurdo D = 3.36 ± .01 mGal (Behrendt, 1967)

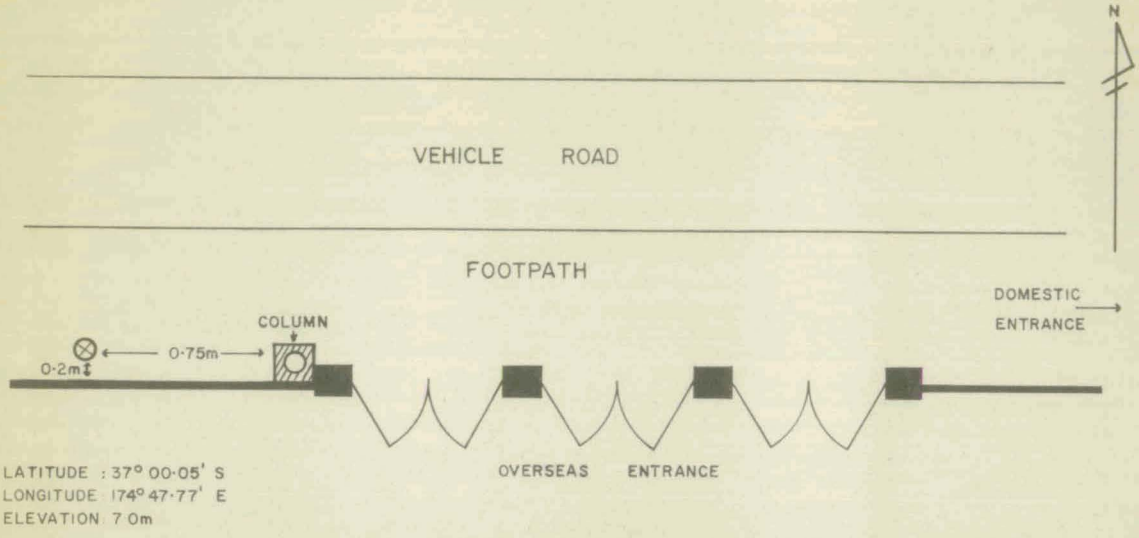
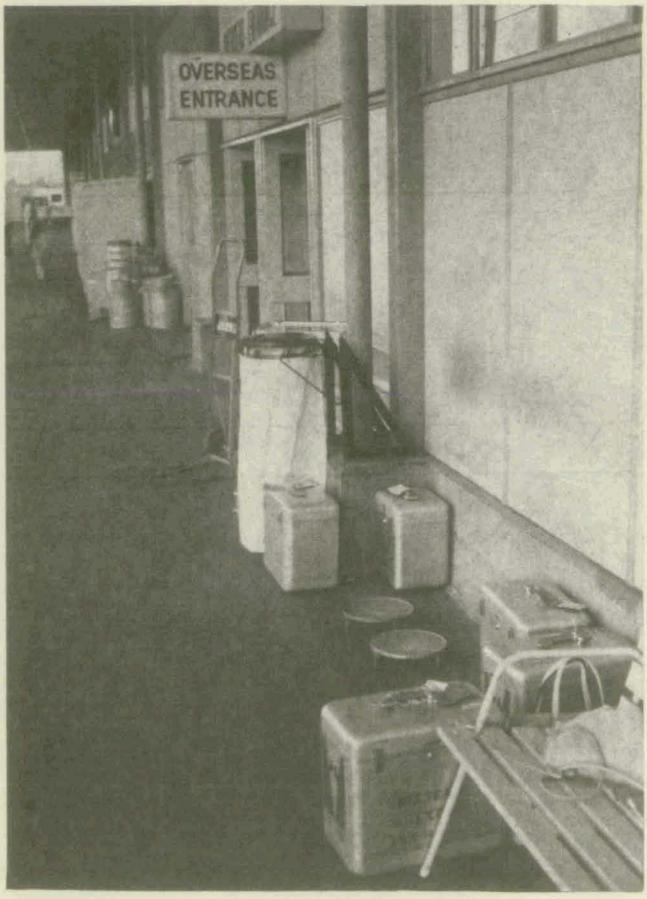


SCHEMA OF GRAVITY TIES

Intervals in GAG-2 ACL milligals

AUCKLAND 45174D
(NEW ZEALAND)

The station is on the footpath, near the overseas passenger entrance to Auckland International Airport. The site is 0.75m from the column outside and west of the doors and 0.2m from the wall.



LATITUDE : 37° 00·05' S
LONGITUDE 174° 47·77' E
ELEVATION 7·0m