1920.
NEW ZEALAND.

DEPARTMENT OF LANDS AND SURVEY.

SURVEYS

(ANNUAL REPORT ON).

Presented to both Houses of the General Assembly by Command of His Excellency.

CONTENTS.

The SURVEYOR-GENERAL to the Hon. MINISTER OF LANDS.

SIR,— Wellington, 14th July, 1920.

I have the honour to present herewith the report on survey operations for the year ended 31st March, 1920.

I have, &c.,

T. N. BRODRICK, Surveyor-General.

Hon. D. H. Guthrie, Minister of Lands.

REPORT.

THERE has been a steady increase in the volume of work handled by the Department during the year under report, as shown in the attached tables, which give a concise summary of the work completed. Full details are contained in the reports supplied by the Chief Surveyors, which are filed as departmental records.

Under the heading of "Rural Surveys," in Table B, an area of 613,810 acres is shown as completed work, consisting largely of land for soldier settlement. The area for last year was 302,369 acres, or less than one-half.

The area of Native lands surveyed shows a decrease from 241,927 acres to 122,248 acres.

The cost of rural surveys is 1s. per acre for the current year, against 1s. 6d. per acre last year. This apparent decrease is due to the large areas of pastoral land in Canterbury and Otago included in the total. Leaving out those pastoral areas, the average cost per acre of rural surveys has advanced from 1s. 6d. to 2s. per acre.

The cost per acre of Native surveys has also advanced from 1s. 7d. last year to 2s. 4d.

These figures show that the work is being done at a reasonable and satisfactory price as compared with the increase in the cost of all classes of work at the present time.

TABLE A.

Class of Work.	Area.	Average Cost.	Total Cost.
	Acres.		£ s. d.
Triangulation, by staff surveyors	55,920	1·83d. per acre	427 8 4
Topographical, by staff surveyors	114,675	3·85d. ,,	1,840 5 11
Rural, by staff surveyors	502,460	1·07s. ,,	27,053 9 6
Rural, by licensed surveyors	85,620	1·98s. ,,	8,506 12 3
Rural, by licensed surveyors (costs not available)	24,533	..	..
Village and suburban, by staff surveyors ..	928	13·07s. per acre	606 9 10
Village and suburban, by licensed surveyors ..	697	8·00s. ,,	279 3 7
Village and suburban, by licensed surveyors (costs not available)	..	..	..
Town, by staff surveyors	305 sec.	36·00s. per section	550 8 3
Town, by licensed surveyors	56 ,,	26·40s. ,,	73 19 7
Native Land Court, by staff surveyors ..	20,109	4·03s. per acre	4,058 15 8
Native Land Court, by licensed surveyors ..	102,139	2·35s. ,,	12,012 13 3
Native Land Court, by licensed surveyors (paid by applicants)	4,662	..	..
Coal areas, by licensed surveyors (paid by applicants)	584	..	..
Sawmill areas, by licensed surveyors (paid by applicants)	613	..	..
Roads, by staff surveyors	184·13 m.	£19·5 per mile	3,588 16 8
Roads, by licensed surveyors	14·45 m.	£12·4 ,,	179 1 11
Roads, by licensed surveyors (costs not available)	15·11 m.	..	..

TABLE B.

Land District.	Rural Surveys.	Native Land Court Surveys.
	Acres.	Acres.
North Auckland	38,619	19,526
Auckland	130,176	35,068
Hawke's Bay	59,032	25,701
Taranaki	11,777	6,570
Wellington	22,817	33,574
Marlborough	6,023	603
Nelson	21,270	..
Westland	3,276	..
Canterbury	204,377	530
Otago	109,047	..
Southland	7,396	676
Totals	613,810	122,248

MINOR TRIANGULATION.

An area of 55,920 acres is shown under this heading. The bulk of the work was undertaken as a check on the settlement surveys.

TOPOGRAPHICAL, FOR SELECTION.

Under this heading an area of 114,675 acres is shown, at a cost of 3·85d. per acre. This work is done as a preliminary to settlement surveys.

SETTLEMENT SURVEYS.

The settlement surveys comprise Crown lands, land for settlement, and land for discharged soldiers. The bulk appears in Table A under the head of "Rural," the acreage there shown being 618,810 acres, while the remainder includes village and suburban and town lands, totalling 1,481 acres.

NATIVE SURVEYS.

During the year staff surveyors completed the survey of 20,109 acres, while 102,139 was surveyed by private surveyors. The area surveyed in each land district is given in Table B.

GOLD-MINING SURVEYS.

No survey of gold-mining areas was made.

COAL-MINING SURVEYS.

A small area of 584 acres is shown under this head. The surveys were made by private surveyors and the fees paid by the applicants.

Major Triangulation.

This survey is held in abeyance, both as regards the field-work and the office computations. In an appendix will be found a report by the Chief Inspector of Surveys, making certain recommendations for conducting this work when it is resumed.

Standard Surveys.

Two experienced staff surveyors are at present engaged on these useful surveys—Messrs. C. A. Mountfort and H. M. Kensington—in the vicinity of Feilding and at Auckland respectively.

During the year under report Mr. Mountfort has completed a traverse of forty-two miles on the Kimbolton, Feilding, Halcombe, Feilding-Awahuri-Palmerston, and the Awahuri - Mount Stewart Roads, and has prepared an additional ten miles ready for measurement and observation.

Mr. Kensington returns forty-seven miles of streets in Arch Hill, Eden Terrace, Epsom, and Grey Lynn, of which the field-work has been completed.

The amount of reinstatement work was much larger than in previous years, as after five years the usual inspection was made of every block in the City of Auckland, and all blocks requiring adjustment or repairs were attended to. Good progress is being maintained with the plans of the survey by the staff at the Standard Survey Office. The plans of the portion of the Dunedin standard survey, of which the field-work was done by Mr. Neill, have now been completed. These comprise 112 sheets excellently drawn by Mr. A. H. Saunders.

The plans of the Napier standard survey are being made by the Head Office staff.

Topographical Survey.

An estimate of the cost of this survey for the Dominion has been prepared, based on experience gained on the work already done in this class of survey at Auckland, Dunedin, and Wellington. The work cannot be started until it is authorized by the Government and sufficient equipment is obtained to provide at least one party with the necessary instruments and apparatus for commencing the survey. Particulars of the instruments to be used in the performance of the topographical survey are given by the Chief Inspector of Surveys in Appendix I.

Inspections.

The inspection-work has of late been carried on by the Chief Draughtsmen and staff surveyors, but on account of the pressure of work in connection with settlement surveys not much of this very necessary work has been done during the past year.

It is important that more Inspectors should be appointed as soon as circumstances permit, so that a check can be kept on the work of the staff and private surveyors.

The increasing number of plans being received from surveyors in private practice creates a demand for more inspection-work in order to protect the public from inaccuracy in the field-work, as absence of inspections has a tendency to induce remissness in some surveyors.

Tidal Survey.

The work for the year comprised the preparation of the data to enable a tide-table for the year 1921 to be prepared by means of the tide-predicting machine at the National Physical Laboratory, Teddington, England, of the ports of Auckland, Wellington, Lyttelton, Dunedin, Bluff, and Westport.

The computations were carried out by Messrs. T. G. Gillespie and E. J. Williams until the end of August, when, owing to Mr. Gillespie's promotion to the position of Draughtsman in Charge of the Native Land Branch and his transfer to the Wellington District Office, the work was carried on by Mr. Williams with the temporary assistance of a cadet.

Tidal records and other meteorological data, together with the surface temperature of the sea, have been received regularly from New Plymouth.

Fresh analyses of the six ports for which predictions are required have been commenced, and will be continued during next year.

In the report of Mr. W. T. Neill, Chief Inspector of Surveys, appended hereto, are given details of the tidal work and a brief description of some of the tide-predictors.

Magnetic Observatory.

During the year the Christchurch Magnetic Observatory and the substation at Amberley have been in continuous operation, and records very valuable to terrestrial magnetism have been secured.

The illness and subsequent death of Mr. Thomas Maben, who had been connected with the Observatory for over eight years, led to the temporary appointment of Mr. W. J. Stacey, who resigned on the 13th March, 1920. Since then the Observatory has been without an assistant, but an understudy to Mr. Skey will be appointed at an early date; this will allow the Director to devote more time to the mathematical discussion of the annual data. A scheme for the construction of special measuring-scales has been devised by Mr. Skey for the purpose of reducing the time occupied in measuring curve ordinates.

In Appendix II is given the Director's report, which includes diagrams showing the magnetic curves and hourly values of the magnetic declination and horizontal force for the years 1919 and 1905.

Proposed Operations for 1920–21.

Triangulation.—This survey for the time being is discontinued, but it is hoped that a start may again be made some time during the coming year.

Standard Surveys.—A standard survey of the Gisborne Borough will be undertaken by Mr. H. M. Kensington, District Surveyor; and Mr. C. A. Mountfort, District Surveyor, will continue rural standard traverse-work in the Wellington District. He will also complete the standard survey of a portion of the Borough of Hamilton, which was commenced in 1907 and left in an incomplete state.

It is important that a staff be organized to conduct the standard survey, so that in the near future it may be undertaken in a more uniform and comprehensive manner.

Pressing demands for these surveys have been received from Auckland, Christchurch, Dunedin, Invercargill, and Wellington, principally in connection with the extension of the standard surveys into the newer suburbs. Whangarei and Petone have been promised standard surveys as soon as experienced surveyors can be spared from the more urgent settlement-work. There is agitation by local bodies and others to have this class of work carried out at Hawera, Picton, Nelson, Hokitika, and many other places. The Chief Inspector, in his report appended hereto, gives a description of the methods employed by him at Dunedin on the standard survey there.

Topographical Survey.—If it is approved by the Government it is proposed to start this work in a small way as soon as equipment arrives from England. A surveyor in charge of four assistants should constitute the first party. When these assistants become familiar with the work and have gained sufficient experience they could in turn be given charge of a party. By this means the full number of parties proposed to be engaged on this work would be made up in three or four years' time.

The map of the Dunedin centre extending along the coast from the Waikouaiti to the Taieri Rivers will be published early in the year. The field-work of this survey was done by Mr. W. T. Neill, District Surveyor, twenty years ago.

Settlement Surveys.—At the close of the year there were in the hands of the staff and private surveyors 669,231 acres of settlement lands, 162,487 acres of Native lands, 61·5 acres of town allotments, and 125 miles of road surveys. Table 4 shows the allocation of this work among the several land districts.

The work now on hand and the survey of estates that from time to time will be acquired for soldiers' settlements and for ordinary settlements, and of Crown lands to be offered for settlement, will fully occupy the staff surveyors for the ensuing year.

Head Office Drafting Branch.

The year in which peace has come has been rendered notable in the history of the Head Office of the Department by the retirement of the last two of the little band of first-class men who made the Department's map publications second to those of no other similar office in the world. As reported last year, the state of the map publications and the loss of staff made it necessary to face the whole subject of reorganizing this branch of the work. The volume of work requiring attention and the staff necessary to carry it out have been considered and decided upon, and several of the new appointments rendered necessary by the many losses of staff have been made, bringing the total up to nearly half the number of officers estimated necessary to carry out the work.

The volume of work required to bring the publications into line with the demands of the community is practically as follows: New drawings are required for 90 boroughs, 65 town districts, and 530 small centres; new drawings are required for over 400 survey districts; new drawings are required for 178 two-mile cadastral sheets.

None of the above numbers has ever been drawn at all, and no account is taken here of the numbers already drawn and requiring revision. The most useful map at present is the Department's one-mile county map, which is used in large quantities. Of the 130 counties in New Zealand, four or five are not more than about three or four years behindhand—the rest are from twenty years old upwards. This map, however, is to be superseded by the new series of two-mile cadastral on a better system and with more copious information.

Of the four cities, only Wellington and Dunedin are drawn, and neither is now up to date. The other two are in hand, and may take two years to finish.

General maps of New Zealand are fairly up to date, but several new scales and classes are required.

Of the four- and eight-mile maps, seven new drawings are required on the old system, but the new cadastral will supersede them. Six new drawings have been waiting the printer's convenience for nearly two years.

The most pressing work is the patching-up of the old county maps to meet the immediate call for statistical maps and other requirements, but permanent work is not proposed on them; their present condition is a danger and expense.

Briefly, over 1,250 quite new maps require to be drawn, and in addition the revision to date of many hundred more, merely in order to meet the ordinary demands made over the counters of the Department every day. It is estimated that twice the present staff might bring this work up in about five to seven years' time.

In addition, the topographical military survey maps—178 sheets—will require drawing when that survey is begun.

During the year very large numbers of maps of electorates were prepared, over £200 worth of lithographs being used for this purpose.

A preliminary part of the reorganization scheme is the preparation of an index to the map publications. The indexes to the survey districts and to the two-mile cadastral have been drawn, but not published. It is intended to have a published index to all sheets and classes of maps, with specimens of each kind.

During the year publication has been greatly hindered by the amount of sale-plan publication in connection with returned-soldier blocks, which necessarily take precedence. The Government Printer making no provision for the extra work, the regular publications are greatly delayed.

The descriptions, maps, &c., made for other Departments during the year amounted to £210.

Lithographs issued without charge to other Departments were about 900 to 1,000 in number and of considerable value.

Town schemes for the Minister's approval have, as was anticipated, increased in numbers.

Draughtsmen's Examination.

The annual examination was held in September, when eight candidates sat and six second-grade certificates were gained. Amendments have been made to the regulations, transferring most of the preliminary plan work to the examination-room, with a view to relieving candidates and equalizing the conditions of the test, and also remedying other defects which had become obvious in the working. As soon as any considerable number of men hold the certificates the staff will find that they have a weight and an assured position which will be a great advance on the conditions of former years.

Surveyors' Board.

The anticipations of an increased number of candidates owing to the cessation of war have been amply fulfilled. At the September examination twenty-two candidates sat, and only three passed; while at the March examination twenty-six sat and twenty-one passed. The numbers at this last examination were not far behind the total for all the Australian States put together, where the same examination is set on the same day under the reciprocity arrangement.

At the end of 1919 Messrs. Sadd and Simmonds were replaced by two new members of the Board: Messrs. Brook and Chambers.

General.

Extract from Report by H. M. Skeet, Chief Surveyor, Auckland.

"Two young Samoans who came to New Zealand under arrangement with the Samoan authorities to study our methods of field surveying and office routine proved very efficient and willing officers. Mr. Tauvela Hunter, the first of these, returned to Samoa after passing the preliminary survey examination. He was relieved by Mr. Melei, who after a short period in the office joined Mr. A. T. Leeds's survey party in the Waikato. The draughting-work done by both of these young men was consistently good, though modelled largely on a different method than that in vogue here."

Extract from Report by G. H. M. McClure, Chief Surveyor, Wellington.

"*Water-supplies to Soldiers' Settlements.*—During the past year water-supplies were installed in Kairanga, Cloverlea, and Putorino Soldier Settlements. So far as Kairanga and Cloverlea were concerned, the supply is derived from artesian wells in existence when the properties were purchased, and additional ones since put down. The necessary reticulation is now completed, and all the sections have a permanent supply of pure water, a most necessary requirement for dairy farms. This work, as well as the roading in these two settlements, was carried out in a very thorough and capable manner by Mr. A. H. M. Wright, Engineer to the Kairanga County Council, to whom the thanks of the Department are due.

"Owing to the area in the Putorino Settlement—some 922 acres, comprising fifteen dairy farms—and the impossibility of an artesian supply, it was found necessary to install a high-pressure water-supply. This entailed extensive engineering surveys and plans, as there were two possible sources of supply. After much consideration it was decided to utilize Rhodes Stream. This entailed the erection of a weir on Ngei Road, the construction of a reservoir, the laying-down of supply-pipes, and the reticulation of the settlement. These were works of some magnitude, as provision had to be made for a daily supply of at least 10,000 gallons, and it is gratifying to record that this indispensable work is now complete in spite of the difficulty of procuring material and labour. Although at the inception the question of providing Putorino with an adequate water-supply was beset with many engineering difficulties, these were successfully overcome by Mr. Sidney A. R. Mair, Engineer of the Rangitikei County Council, who initiated the scheme, made the engineering surveys and plans, and supervised the construction of the entire works free of cost to this Department. I wish to place upon record my appreciation of the valuable services rendered by Mr. Mair, and to thank him for the able assistance he has given me."

Full details of the personnel of the staff, both field and office, are given in the report by the Under-Secretary for Lands.

In conclusion, I am pleased to place on record the appreciation by the various Chief Surveyors of the manner in which their officers, both permanent and temporary, have carried out their duties during the year, and I desire to convey my thanks to the whole of the Survey staff for their good work.

Table 1.—Return of Field-work executed by Head Office Staff from 1st April, 1919, to 31st March, 1920.

Land District.	Standard Surveys.				Rural Standard Surveys.				Other Work.
	Completed.		In Progress.		Completed.		In Progress.		
	Miles.	Cost per Mile.	Miles.	Cost per Mile.	Miles.	Cost per Mile.	Miles.	Cost per Mile.	
		£		£				£	£ s. d.
Auckland	37·4	71·05	46·7	..	..	..	..	..	361 8 0
Hawke's Bay	..	..	33	50·86	..	..	43	30	..
Wellington	..	..	..	..	43	21·92	10	..	..
Otago	40	48·24	..	..	..	..	..	..	..

Table 2.—Return of Field-work executed by Staff and Contract Surveyors on Lands administered by Lands and Survey Department, from 1st April, 1919, to 31st March, 1920.

Land District.	Minor Triangulation.		Topography.		Rural.		Village and Suburban.			Town.			Roads, &c.		Other Work.	Total Cost of Completed Work from 1st April, 1919, to 31st March, 1920.
	Acres.	Cost per Acre.	Acres.	Cost per Acre.	Acres.	Cost per Acre.	Acres.	Number of Sections	Cost per Acre.	Acres.	Number of Sections	Cost per Section.	Miles.	Cost per Mile.		
		d.		d.		s.			s.			s.		£	£ s. d.	£ s. d.
North Auckland	..	..	..	..	37,339	2·36	705	172	11·00	5	8	110·06	20·00	28·84	1,212 2 2	6,631 2 8
Auckland	..	..	..	..	108,746	1·67	..	..	..	23	39	66·60	138·25	14·71	1,113 12 11	12,301 14 6
Hawke's Bay ..	..	..	13,100	1·31	59,032	1·87	..	..	..	..	..	..	9·25	30·68	917 15 6	6,796 6 4
Taranaki	11,220	3·20	..	..	11,777	3·71	..	..	..	20	55	20·79	2·60	39·31	22 0 0	2,513 3 1
Wellington	..	..	..	..	20,994	2·49	776	45	8·68	40	88	24·67	4·00	12·55	114 1 5	3,214 10 5
Nelson	43,200	1·50	79,300	4·30	20,787	2·65	..	..	..	..	..	..	15·23	33·00	457 18 1	5,420 13 4
Marlborough ..	..	..	17,000	1·90	6,023	2·32	..	..	..	..	..	..	0·22	68·18	126 0 8	972 2 5
Westland	..	..	5,275	9·80	3,276	5·88	14	3	31·50	..	..	..	1·95	20·00	40 2 7	1,279 16 4
Canterbury	..	..	..	..	204,377	0·44	..	..	..	..	..	..	4·00	11·50	87 17 4	4,592 17 11
Otago	1,500	1·30	..	..	109,047	0·39	105	7	10·55	..	..	..	..	..	24 0 0	2,223 14 10
Southland	..	..	..	..	4,496	2·82	21	15	78·07	46	136	32·98	1·08	72·30	166 13 0	1,185 6 6
Means and totals ..	55,920	1·83	114,675	3·85	585,894	1·76	1,621	242	..	134	326	34·60	196·58	18·97	4,282 3 8	47,131 8 4
Licensed surveyors (costs unobtainable)		..	..	..	24,533	..	..	..	..	..	..	..	11·50			
					610,427	..	..	..	..	..	..	..	208·08			

Table 3.—Return of Field-work executed by Staff and Contract Surveyors on Lands administered by other Departments from 1st April, 1919, to 31st March, 1920.

Land District.	Rural.		Village and Suburban.			Town.			Roads, &c.		Native Land Survey.			Mining.			Other Work.	Total Cost of Completed Work from 1st April, 1919, to 31st March, 1920.
	Acres.	Cost per Acre.	Acres.	Number of Sections.	Cost per Acre.	Acres.	Number of Sections.	Cost per Section.	Miles.	Cost per Mile.	Acres.	Number of Sub-divisions.	Cost per Acre.	Acres.	Number of Sections.	Cost per Acre.		
		s.			s.			s.		£			s.			s.	£ s. d.	£ s. d.
North Auckland	..	..	..	..	..	..	..	..	..	..	19,526	254	2·44	..	..	..	..	2,386 10 5
Auckland	..	..	..	..	..	..	..	..	..	..	35,068	297	1·62	..	..	..	..	2,925 11 11
Hawke's Bay	..	..	..	..	..	..	..	..	..	..	25,701	143	2·66	..	..	..	..	3,415 5 0
Taranaki	..	..	..	..	..	..	..	..	..	..	6,570	92	1·96	..	..	..	..	642 11 6
Wellington	..	..	4	1	50·00	2	15	47·20	2·0	19·07	33,574	240	3·83	..	..	..	12 0 0	6,527 17 0
Nelson	..	..	..	..	..	..	..	..	..	..	..	..	..	483	6	..	..	..
Marlborough	..	..	..	..	..	..	..	..	..	..	603	3	3·14	..	..	..	..	94 14 4
Canterbury	..	..	..	..	..	5	20	25·00	..	..	530	19	3·77	..	..	..	..	124 16 0
Otago	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Southland	2,186	1·34	..	..	..	..	..	..	..	..	676	12	2·20	714	..	..	..	221 13 11
Means and totals	2,186	1·34	4	1	50·00	7	35	34·52	2·0	19·07	122,248	1,060	2·63	..	..	..	12 0 0	16,339 0 1
Licensed surveyors (costs unobtainable)	..	..	..	..	..	..	..	..	..	..	4,662	..	..	1,197	..	..	..	..
	..	..	..	..	..	..	..	..	..	..	126,910	..	..	..	..	..	..	..

Table 4.—Return showing Surveyors employed and the Work on Hand on 1st April, 1920.

Names of Surveyors.	Surveyors employed.			Work on Hand.				
	Staff.	Temporary.	Contract.	District.	Settlement.	Native Blocks, &c.	Roads, &c.	Town.
					Acres.	Acres.	Miles.	Acres.
R. P. Greville, F.R.G.S.	5	1	..	North Auckland	35,512	..	2·2	
H. M. Skeet	12	..	..	Auckland	151,032	..	73·8	4·5
W. F. Marsh	4	..	14	Hawke's Bay	60,931	36,826	..	..
G. H. Bullard	4	..	6	Taranaki	45,587	2,860	5·5	47·0
G. H. M. McClure	4	..	16	Wellington	24,067	110,844	5·5	..
H. D. McKellar	3	..	3	Nelson	37,800	1,400	12·0	..
H. J. Lowe	1	..	2	Marlborough	1,181	3,412	..	..
R. S. Galbraith	1	..	..	Westland	14,820	6,306	7·0	..
H. D. M. Haszard, F.R.G.S.	2	..	..	Canterbury	445	..	1·0	..
R. T. Sadd	4	..	..	Otago	289,856	448	18·0	10·0
T. Brook	1	..	2	Southland	8,000	391	..	..
Total staff surveyors	41	1	43	..	669,231	162,487	125	61·5

Table 5.—Principal Classes of Office-work done from 1st April, 1919, to 31st March, 1920.

District.	Plans placed on Instrument of Title.			Deeds and other Instruments passed.	Plans examined and passed.	Deeds or other Instruments written.	Maps drawn for Lithography.		Lithographs published.	Lithographs sold.
	Leases and Licenses.	Freehold.	Miscellaneous.				Standard Publications.	Sale Plans.		£ s. d.
North Auckland	40	50	650	90	488	104	2	39	..	80 1 6
Auckland	508	7,419	..	3,661	815	..	..	91	..	326 8 5
Hawke's Bay	623	1,181	1,121	1,777	405	1,027	..	20	..	43 5 10
Taranaki	144	1,455	1,442	1,970	287	1,144	4	4	8	55 14 0
Wellington	645	5,192	831	3,146	468	745	2	39	..	65 14 0
Nelson	75	737	8	375	121	..	..	..	..	46 11 3
Marlborough	98	317	138	170	75	..	..	5	..	14 6 0
Westland	152	60	6	..	25	158	..	..	..	12 18 0
Canterbury	372	3,988	155	2,328	294	..	..	26	..	31 7 0
Otago	458	1,820	218	820	138	804	8	21	1,826	125 15 1
Southland	300	1,013	146	533	136	211	4*	13	..	64 14 8
Totals	3,415	23,232	4,715	14,870	3,252	4,193	20	258	1,834	866 15 9

* Revised.

APPENDIX I.

REPORT BY W. T. NEILL, CHIEF INSPECTOR OF SURVEYS.

Triangulation.

The field-work of the major triangulation, which was commenced in 1909 and continued until 1915, when it was stopped on account of the war conditions prevailing, has not yet been resumed.

Before the computation work can be proceeded with by the office staff it is essential that the tapes used in measuring the base-lines should be compared with the Imperial standard of length. A comparator and bar were obtained for this purpose, which is described in the Survey Report for 1912–13, but the apparatus is stowed away in the safe, and cannot be used until a suitable site is selected on which it can be permanently erected and housed.

There is also a pressing need for a suitable site to compare the tapes used by the staff and private surveyors with the Imperial standard band, as the erection of the new building for Base Records has covered one of the terminal blocks of the standard behind the Government Buildings which was previously used for this purpose. The acquisition of a site on which to erect the comparator and standard bar in a locality where it is unlikely that it will be disturbed by the extension of existing buildings or the erection of new ones is therefore a matter of importance in the ordinary routine work of the Department, besides providing a secure and reliable copy for all time of the Imperial standard of length now—through the well-directed efforts in 1904 of Mr. J. W. A. Marchant, Surveyor-General—uniformly used on all surveys throughout the Dominion.

In addition to the comparison of the tapes used on the base-lines, further field data will be required before a systematic reduction of the observations and the computation of the co-ordinates can be undertaken by the office staff. These field observations include a more precise determination of the meridian of the initial station than that hitherto used, and the measurement of some of the angles to complete the triangles in the northern portion of Wellington District.

The preparation of a number of auxiliary tables to facilitate the calculations was commenced at the beginning of the year, and was carried on at intervals whenever time was available, so as not to interfere with the more urgent work. It is proposed to continue this work at every opportunity until a complete set of geodetic tables applicable to the latitudes comprised within the Dominion is completed.

When the field-work of the triangulation is again resumed I would urge most earnestly that the work should be executed on correct and scientific principles; that only the most competent and highly trained assistants should be entrusted with this class of work, and that the apparatus and instruments used on the various operations connected with such an important survey should be subjected to adequate tests to ensure that they are capable of guaranteeing the requisite precision in the final results. A review of the methods used on the work already done and the accuracy attained in the past shows the absolute necessity for insisting on such a recommendation being enforced.

In a pamphlet entitled "An Exposition of Processes and Results of the Survey System of Otago," by J. T. Thomson, C.E., F.R.G.S., in 1875, are given the methods for conducting the triangulation that has already been completed in the Dominion, with the exception of a certain amount of work executed in Auckland and Wellington under the supervision of Captain T. Heale, Inspector of Survey, and Mr. H. Jackson, Chief Surveyor of Wellington Province, respectively. Again, in the Survey Report for the year 1912–13 (pages 59, 60) is given an historical review of the triangulation by Mr. J. McKenzie, Surveyor-General.

Notwithstanding the claims made in the early days, and frequently repeated, in favour of the original minor triangulation of the Dominion as being sufficiently accurate to control the section surveys on which titles were issued, it is now known by every surveyor who has made traverses connecting the trig. stations that the system has failed in regard to precision, and that the co-ordinate values of most of the triangulation stations of the original survey are not sufficiently accurate to check the values obtained by an ordinary traverse executed by an average 5 in. theodolite and the long band usually used by the staff surveyors. To a certain extent faulty measurements of the base-lines have accounted partly for the discrepancies in many cases. The theodolites usually used for the angular measurements were of the small 5 in. pattern, from which a high degree of accuracy could not be expected. It is probable that if a better class of theodolite had been used and more care taken to guard against mistakes in the base-line measurements the system would have been completely successful, and would have established the three desiderata of precision, rapidity, and cheapness claimed for it.

The Survey Report for 1914–15 contains an article in which the capabilities of the various instruments are discussed, and the limit of errors in surveying defined by mathematical demonstrations (Appendix VIII, page 66).

The report by Sir David Gill in the introduction of "The Geodetic Survey of Southern Rhodesia," published in Vol. iii of "The Geodetic Survey of South Africa," contains much that is useful to any one entrusted with the carrying-out of a triangulation, both as regards economy in adopting a sound system of survey as well as accuracy in deciding upon the apparatus by means of which the work can be efficiently performed.

With respect to the system to adopt, the following extract from a letter dated 28th January, 1897, addressed by Sir David Gill to Lord Grey, who then administered the Government, is worthy of citation: "With the universal experience of the civilized world at my back, I do not hesitate to say that it is waste and extravagance to postpone the commencement of a principal triangulation of your country. You have a comparatively clear field before you now, and the sooner you begin to base your land-tenure on a sound system of survey the sooner will you establish a system of sound title and sound evidence of title in the country, and the sooner will you stop the wasteful system of survey in proceeding from small to great instead of from great to small. . . . Every civilized country in the world has been, in the end, compelled to come to that, but not until a crop of legal troubles due to inaccurate surveys has been laid up which takes a century to set at rest—not until four or five times the cost of systematic survey has been spent in misdirected effort."

Sir David Gill, Astronomer Royal at the Cape, was entrusted with the direction of the Geodetic Survey of South Africa. The above extract is therefore the unbiased opinion of a competent authority.

With regard to the apparatus to employ on the triangulation, it appears that the measurement of the base-lines by Mr. J. Langmuir, Inspector of Surveys, by means of the invar steel bands, has been performed in a most careful and efficient manner, and should be satisfactory, provided that the bands were seasoned before being used on the base-line measurements, so that their lengths would remain sensibly constant in so far as the molecular stability of the metal is involved. Experience has shown a liability of these bands to shorten during a period of about two years succeeding their manufacture, after which the length can be relied upon and the bands will perform all that is claimed for them by the makers.

A careful scrutiny of the field results, and an examination of the circles of the two 8 in. theodolites with which the work was commenced, show that these instruments, although excellent and well finished in every respect, are not sufficiently powerful to give the degree of precision essential in work of this class. The instrument which has given uniformly good results and which has proved satisfactory on surveys of a similar kind in other countries, as Canada, United States of America, South Africa, India, &c., is the 12 in. theodolite. The latest models can be packed in three boxes, and are therefore more portable than the 8 in. size referred to above. Mr. Cox, a representative of Messrs. Watt and Sons, London, who visited Wellington recently, stated that twenty of these 12 in. theodolites were supplied by his firm for reconstruction surveys in Belgium and the north of France after the war.

Several auxiliary instruments, which have not been generally used before on triangulation work in the Dominion, but which are necessary in order that accurate differences in the heights of the stations may be determined, are barometers, hygrometers, and thermometers.

The permanent marking of the trig. stations, and the signals to be used while the observations are in progress, are matters that require careful consideration, and suitable designs should be prepared and adopted for the guidance of the staff officers to whom the field operations connected with the survey are entrusted. The work has an important scientific value also in connection with the determination of the size and shape of the earth.

The measurement of an arc of the meridian was contemplated in the Surveyor-General's report of 1877 (H.-17A, page 7), and again referred to in the report of 1900–1 (page xiii), but such a work as a separate survey will not be required, as all the data for determining the figure of the earth will be supplied by the triangulation, since the astronomical and geophysical observations for latitude, azimuth, and gravity measures are now recognized as part of the routine work of a modern survey of this kind.

STANDARD SURVEYS.

A standard survey of the Borough of Gisborne has been urgently needed for a long time, and a visit was made to discuss the details of the work with the municipal authorities in February, and satisfactory arrangements were concluded with them for commencing the survey at an early date, when the services of a staff surveyor experienced in that class of work will be available. Further standard surveys are required in all the cities and boroughs in the Dominion, and it is now indispensable that a uniform system should be inaugurated for the performance of this important work. A surveyor engaged in this work has many difficulties to contend with in investigating the original survey and subsequent subdivisions in order to decide the most probable position for the permanent blocks that indicate the street-intersections. He is to search for the original pegs, or for the places where they were originally located, and allow these to control, if he finds them. In many cases all the marks of the original survey have disappeared, and it becomes necessary to establish an alignment by reference to the occupation-lines. To do this satisfactorily the surveyor is all the better for a few years' experience, and should bring good sense and sound judgment to all questions with which he may have occasion to deal, as well as a knowledge of the correct principles to apply in deciding the position of the alignment from a multitude of preliminary measurements. After the permanent blocks have been located he is required to make a most precise measurement of each line and a refined observation of every angle.

It is therefore evident that the staff surveyors, before being entrusted with a standard survey, should receive additional instruction and training to that required to qualify for sectional work. In the past each surveyor has used his own judgment as to what instruments and apparatus should be used in performing the work; the various surveys therefore exhibit different standards of precision according to the power of the instruments employed. The instruments used in the operations connected with the standard survey of Auckland by Mr. J. Langmuir, Inspecting Surveyor, were described and illustrated in the Survey Report for the year 1909–10 (Appendix III, page 20 *et seq.*). A report on the methods and instruments used on the survey of Dunedin was prepared in 1916, but on account of the war conditions prevailing at that time the publication of it was postponed. That report is as under:—

Report on the Standard Survey of the City of Dunedin, by W. T. Neill, District Surveyor.

The operations connected with this work comprise three separate and distinct surveys—viz., (1) a preliminary survey, (2) a precise survey, and (3) an offset survey. A brief account of the salient points of each of these surveys, and a description of the instruments and apparatus used in performing the work, is given below:—

(1.) *Preliminary Survey.*—This work was undertaken to define the occupation of the various townships and subdivisions that had been made at different times, and often independently of each other, for the purpose of deciding the positions of the permanent monuments of the precise survey, of the area to be surveyed outside the boundary of the original city, and within the boundary of the original city to check the positions of the blocks of an earlier standard survey executed by J. A. Connell about forty years ago.

The accuracy observed in performing the work was similar to that enforced by the Survey Regulations under the Land Transfer Act. The survey was therefore effected by means of a 5-chain $\frac{1}{16}$ in. steel band and the standard pattern of 5 in. transit theodolite (No. 3 in Fig. 9). The temporary reference-points were marked with second-hand bolts and spikes obtained from the Railway Engineer's Department, driven slightly below the surface of the street, the exact centre being shown by a centre-punch mark. The alignment was established by taking offsets to both sides of the street from a trial line and computing the most probable line by an application of the "method of least squares" in most cases where the original pegs had disappeared.

(2.) *Precise Survey.*—As its name implies, the object of this work is to obtain a high degree of precision in the linear and angular measurements of all the distances and angles between the points fixed by the preliminary survey, and in addition to erect permanent monuments that will securely mark these positions. The lengths of the lines were measured in the following manner: A telescopic tripod is placed over the initial point. A scale, divided to $\frac{1}{200}$ of a link, capable of being adjusted within a range of $1\frac{1}{2}$ in., is carried by the tripod, to which is attached a heavy plummet, the point of which is adjusted exactly over the initial mark. A similar tripod, scale, and plummet is placed over a centred bolt at a number of chains in advance, and supports aligned on the grade are placed at each chain-mark. An $\frac{1}{8}$ in. invar steel tape equal in length to the distance between the tripods is placed on the supports, with one end at each tripod. The zero end of the tape is adjusted over the centre of the scale at the initial point by means of a tape-stretcher. A second similar tape-stretcher carrying a spring-balance is attached to the forward end of the tape. The standard tension is then applied—viz., 15 lb.—and the exact distance between the centres of the initial and the forward bolts is read off the leading scale and entered in the field-book. The vertical angles are observed from each end of the measured distance by setting the theodolite over each chaining-tripod and sighting to a division on a graduated scale at the same height above the other tripod as the horizontal axis of the theodolite is above the tripod under it. Fig. 2 shows the chaining-scales, plummets, spring-balances, centre-punches, graduated grade-scales, spring tapes, and a small telescope for aligning the tape-supports at each chain-mark. Fig. 3 shows the chaining-tripods, supports which are usually placed at each chain-mark, and the tape-stretchers. In windy weather these tape-stretchers are also used to protect the plummets from the effects of air-currents when they are being adjusted over the exact centre of the bolts. The invar steel ribbon was imported and made up into tapes of lengths of 1, 2, 3, 4, and 5 chains each. The leading chain length of each tape is graduated to 10 links, and the balance to chains. Fig. 1 shows five of these tapes in their cases, also two 5-chain $\frac{1}{16}$ in. steel tapes on Littlejohn's patent drums, and a form of wind-shade on the right, which was used when the work was commenced, but is now superseded by using the tape-stretcher as a breakwind.

The performance of the invar tapes in the field has been very satisfactory. They were controlled by monthly comparisons with No. 11 Imperial standard band. These comparisons showed that a new tape contracted about $\frac{1}{10}$ in. per chain before it was seasoned, but that after a time it settled to a constant length at a constant temperature. The coefficient of expansion between 32° and 70° F., derived from the monthly comparisons, is about one-fifteenth of that of a steel band, and is fairly well represented by Dr. Glazebrook's formula, which in the centigrade scale is $L_t = L_0 (1 + 0{\cdot}00000074T - 0{\cdot}0000000089T^2)$. A length of 1 chain of the tape is altered by $\frac{1}{100}$ in. for a difference of temperature of 30° F., and, as this represents nearly the extreme variation of temperature during the year, it is obvious that the length of the tape obtained at each comparison will be sufficiently accurate for practical use without any further correction, excepting on a few days when the temperature is abnormal.

Fig. 4 shows the micrometer microscope used for the most refined comparisons; the instrument labelled 1 is a Beck microscope fitted with a Grayson micrometer reading to $\frac{1}{1000}$ in.

A valuable report was issued by the International Bureau of Weights and Measures, Breteuil, in 1906, giving details of the experiments conducted by M. Benoit and Dr. Guillaume on the use of invar for rapid base-line measurements.

At the commencement of the work the angular measurements were made by a special 5 in. repeating theodolite, shown on the right in Fig. 5. The horizontal circle is graduated from 0° to 180° in opposite directions, and it is fitted with a double vernier. The telescope carries an eye-piece micrometer and has anallatic lenses. This proved to be an excellent form of instrument for alignment purposes and for setting off right angles, but it was not powerful enough to give satisfactory results for the bearings of irregular traverses or for long lines. An 8 in. vernier theodolite was supplied by the Department (shown on the left in Fig. 5) to accomplish this purpose. The results obtained by the 8 in. instrument over long lines were excellent, but, on account of the plummet being suspended from the tripod instead of from the vertical axis, it was unreliable for short lines. The specification of a special 7 in. micrometer theodolite designed for work of this class was sent to Messrs. Troughton and Simms with an order for the instrument. On the arrival of this instrument, about a year after the work started, all the bearings were revised, and the results were entirely satisfactory.

The instrument as used for horizontal angles is shown in Fig. 6, and in Fig. 7 it is shown with its auxiliary telescope with vertical circle, micrometer, eye-piece, and Talcott level. An examination of the horizontal circle and an analysis of the results gave the mean error of a set of six readings $\pm 0{\cdot}5''$. Such accuracy cannot be expected from the results of actual observation, on account of the uncertainty arising from the effects of lateral refraction, which vitiate the measurement of all angles to a certain extent. The correction for refraction is so important that it will be made the subject of a separate investigation. The formulæ for the computation of the alignment and the corrections to reduce the field measurements to their horizontal value at sea-level will also be the subject of a separate report.*

The theodolite on the right in Fig. 9 is a standard pattern of the 5 in. micrometer size, and was found useful for observing the bearings of irregular traverses with very short lines.

(3.) *Offset Survey.*—This work consists of a rapid measurement with a $\frac{1}{4}$ in. steel tape, 1 chain long, of the distances between the permanent monuments along each street, and noting the offsets to buildings, fences, &c. It also serves as a check by disclosing any mistakes that may have been made in the precise measurement or in building the permanent mark in an erroneous position. In most cases both sides of the streets are measured, and the offsets obtained by readings from the staff. Fig. 8 shows a portion of the offset staff, which is 15 links long, and the large aperture dumpy telescope capable of reading it to distances of 10 chains.

* The first part of this article was published in the *Journal of the New Zealand Institute of Surveyors*, Vol. xi, No. 7, Sept.-Dec., 1919.

Tidal Survey.

The tide-gauges at all of the seaports for which tide-tables are prepared by the Department are under the control of the Harbour Board authorities at the various places, and as they are attended to in a satisfactory manner it was considered unnecessary to make an inspection of the tidal stations each year, but only to check the levels between the standard gauges and the permanent bench-marks at intervals of from three to five years.

The tidal station at Lyttelton, however, was visited on account of the records from the automatic tide-gauge not being entirely satisfactory, and an inspection of the tide-gauge was necessary in order to discover the cause of the discrepancy. It was found that the total range of the recording-pencil differed from the time scale on the printed record sheet. Although this error can be corrected when the sheets are measured in the office, yet if the best results are to be obtained for the predictions at this important port it is essential that the automatic tide-gauge at present in use there should be replaced by a better one.

All the computations pertaining to the work required to evaluate the harmonic constants for the six standard ports have been completed.

The amplitudes (R) and the epoch (ζ) for the various components have been found for each station by an harmonic analysis of the measured hourly heights of the tide-gauge records extending over periods of 370 days each: from these have been deduced the values of H and κ, which are connected with R and ζ through the various astronomical quantities involved in the positions of the sun and moon, in such a way that H and κ should come out the same from the reduction of each period.

On account of the tidal observations not being exactly consistent from year to year it is necessary to extend observations over a number of years and to accept the mean of the values of H and κ from each analysis as the best result. Accordingly the data in the appended table were prepared and supplied to the Director, National Physical Laboratory, Teddington, England, for the purpose of having the curve for the year 1921 run off by the tide-predicting machine. The information was sent to England on the 1st July, 1919, and the tide-tables for 1921 were received in Wellington on the 17th January, 1920.

During the year under report the computation forms were revised and recast where experience showed that improvements could be made, with the result that fully a week's work is saved on the analysis of each period for each port, or a saving of the work of two computers for six weeks annually. The computations were carried out by Messrs. T. G. Gillespie and E. J. Williams from the beginning of the year until the 31st August, when Mr. Gillespie was promoted to the position at the Wellington District Office of Draughtsman in Charge of the Native Land Branch. Mr. Gillespie was a careful and reliable computer, and was continuously engaged on the tidal reductions for the last nine years. Since then the work has been carried on by Mr. Williams, who was appointed successor to Mr. Gillespie last December, with the temporary assistance of a cadet.

Complete and continuous records have been obtained at the New Plymouth tidal station of the tide curve from the self-registering tide-gauge, and other meteorological data, together with the surface temperature of the sea.

The mean values for each month of the temperature of the air, the height of the barometer, and the surface temperature of the sea, from the date when the observations were commenced to the end of the year under report, are given below:—

New Plymouth Tidal Station.—Mean Monthly Values.

Date.	Barometer.	Attached Thermometer.	Temperature of Air.	Temperature of Sea.
1918.	In.	Deg. (F.)	Deg. (F.)	Deg. (F.)
September	30·17	52·57	53·24	52·17
October	29·96	56·26	57·82	54·46
November	29·96	58·50	61·94	56·77
December	29·94	60·07	61·74	55·58
1919.				
January	29·95	62·07	62·42	57·42
February	30·22	65·86	67·46	61·11
March	30·13	61·32	62·77	58·94
April	30·18	56·33	57·00	56·37
May	30·25	53·00	51·77	53·77
June	29·99	51·90	50·30	52·40
July	30·11	50·03	49·07	50·42
August	30·03	51·65	50·32	51·00
September	29·95	52·50	52·60	51·53
October	30·07	56·42	57·13	53·19
November	29·99	57·57	58·03	54·37
December	30·10	60·71	61·90	55·55
1920.				
January	30·07	63·10	65·29	59·00
February	30·06	66·14	67·35	62·90
March	30·11	62·52	64·65	61·65

STANDARD SURVEY OF THE CITY OF DUNEDIN.

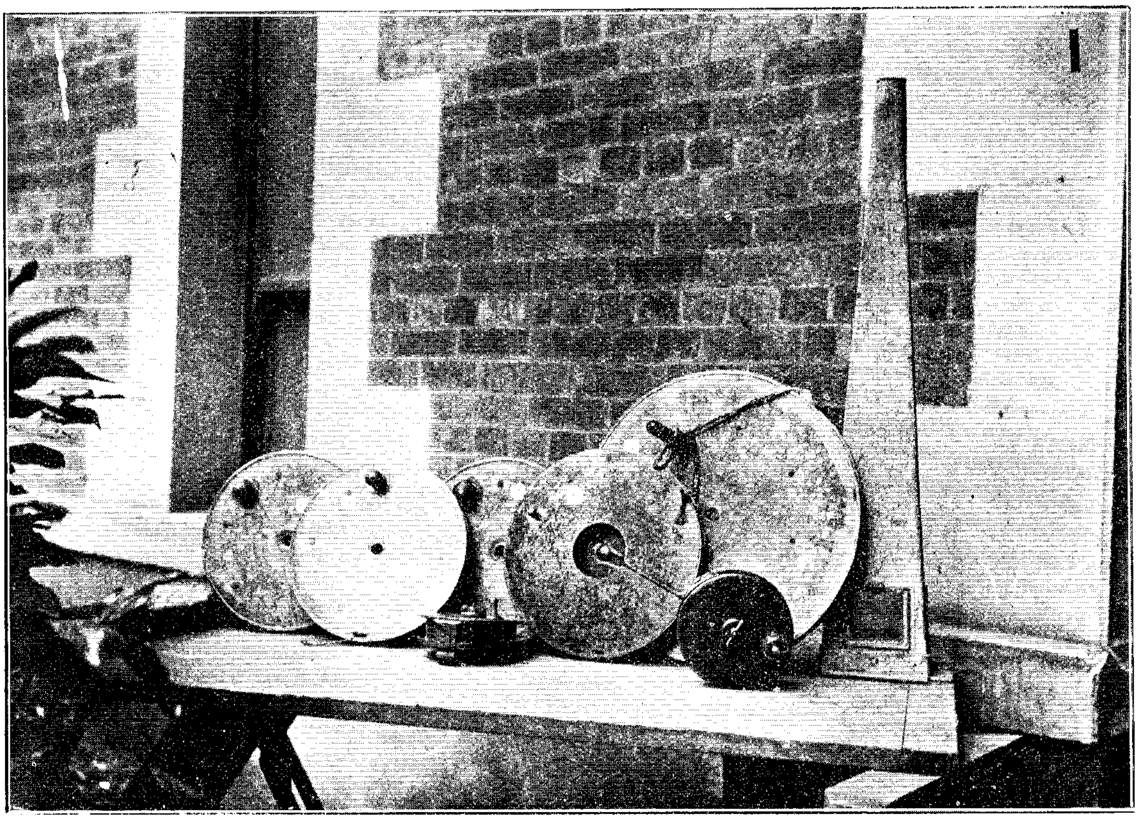


FIG. 1. Invar and steel tapes; wind-shade on right.

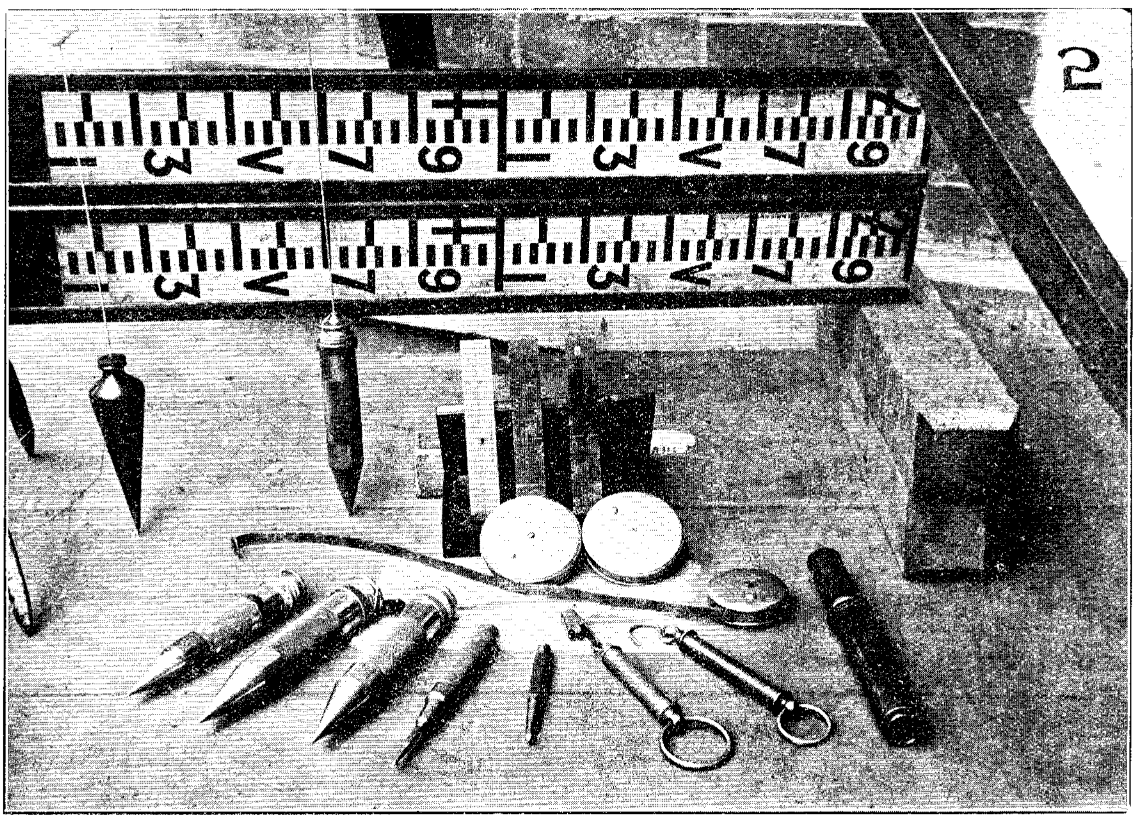


FIG. 2. Chaining-scales, plummets, spring-balances, centre-punches, grade-scales, spring tapes, and small telescope.

[*To face page 12.*

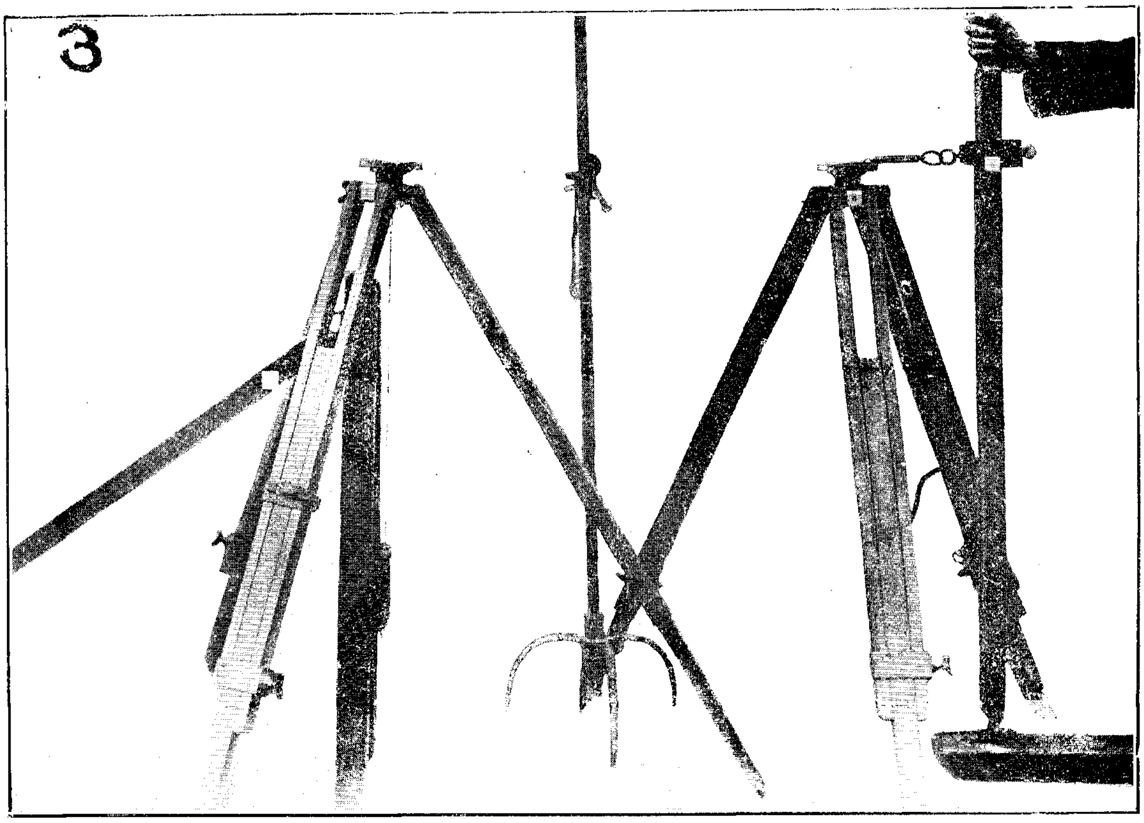


FIG. 3. Chaining-tripods, supports for tape, and tape-stretchers.

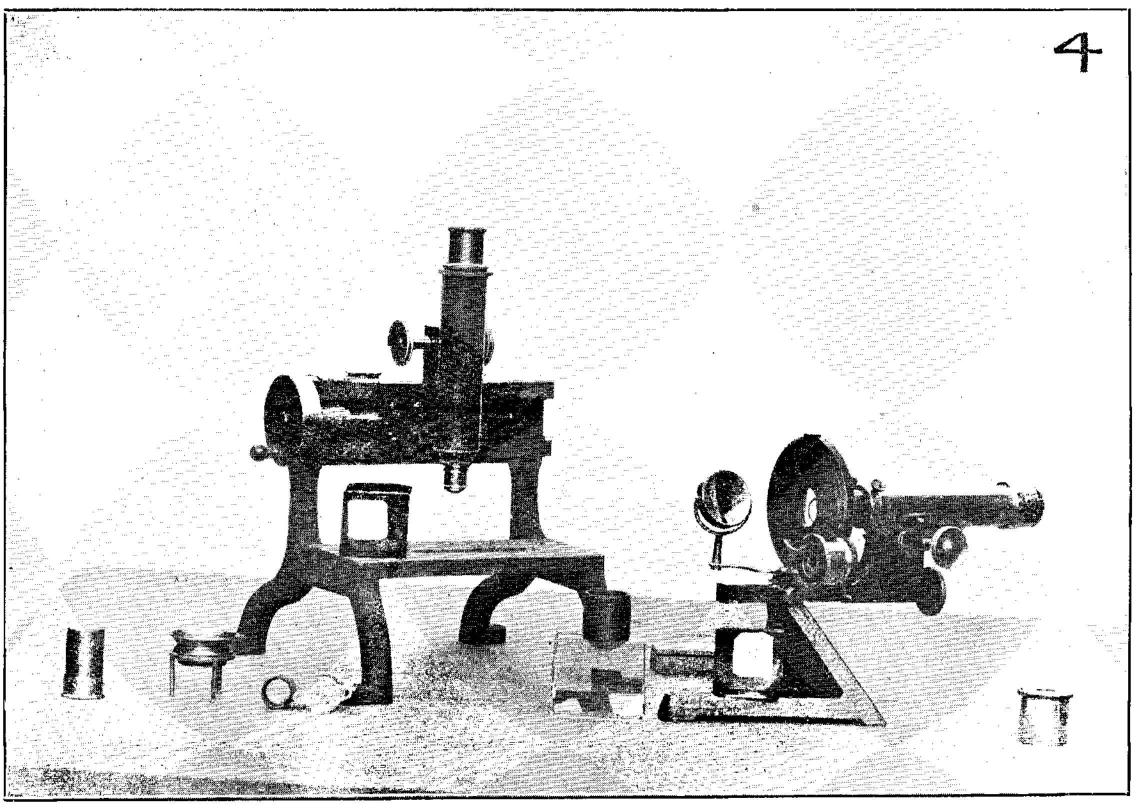


FIG. 4.—Micrometer microscopes.

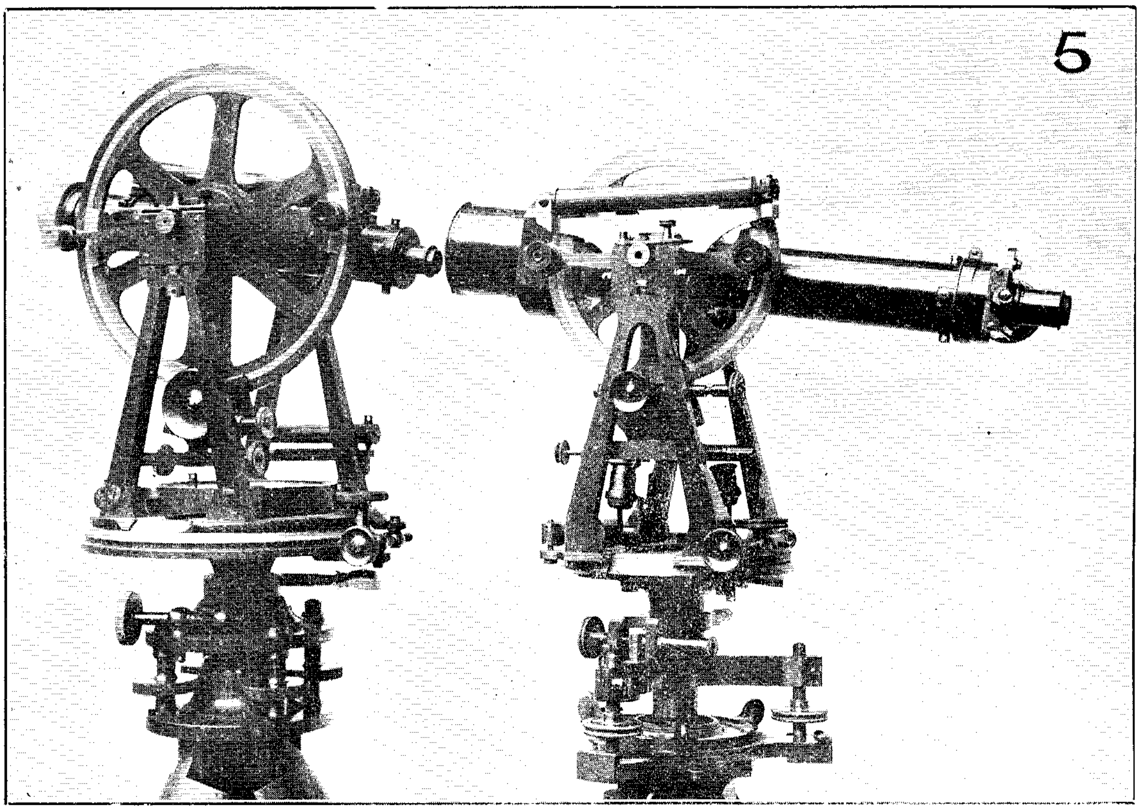


FIG. 5.—An 8 in. and a 5 in. transit theodolite.

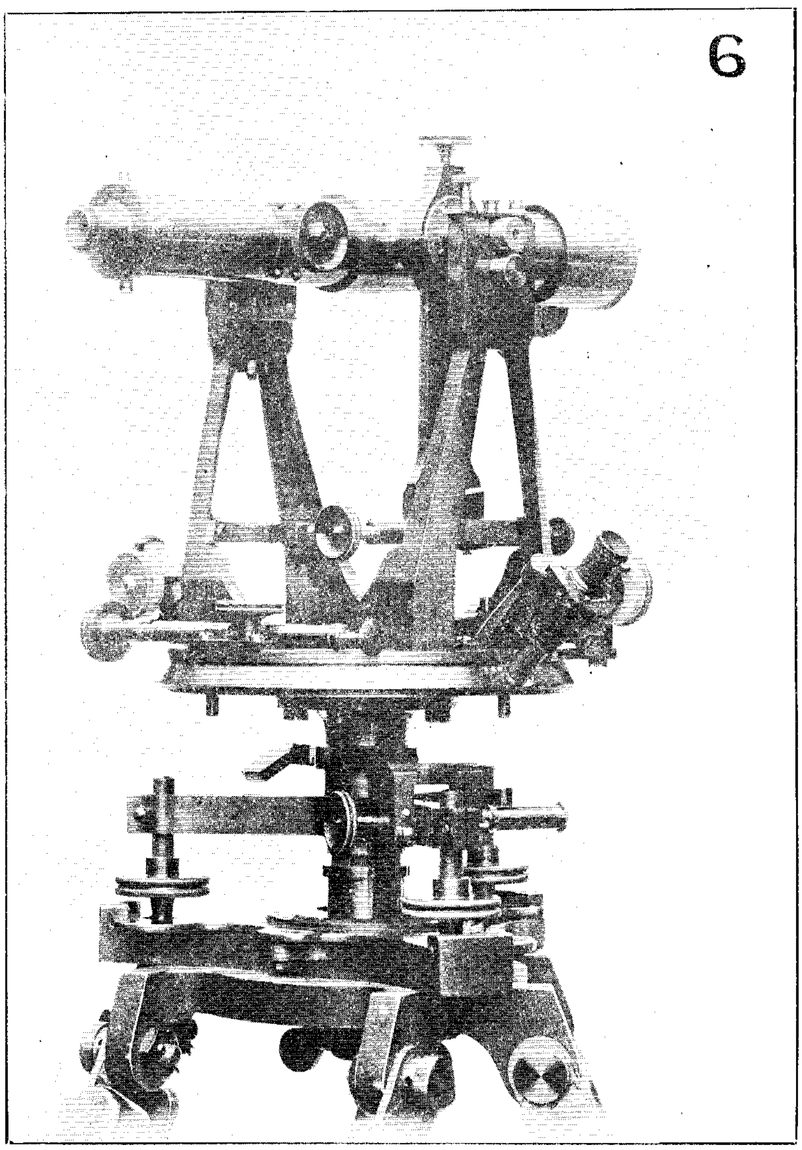


FIG. 6.—A 7 in. micrometer transit theodolite as used for observing bearings.

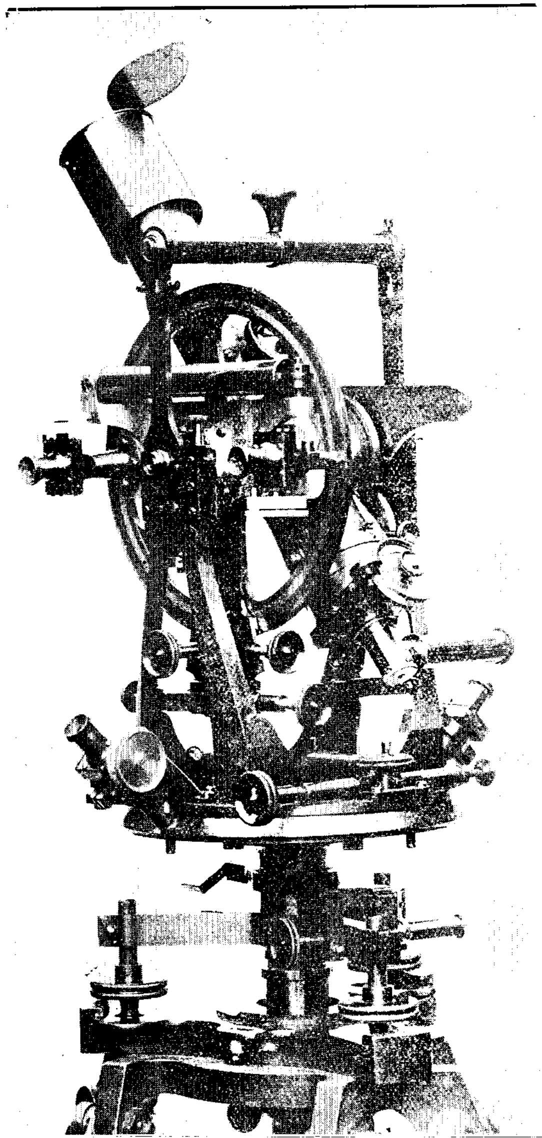


FIG. 7.—A 7 in. micro-transit theodolite with micrometer eye-piece and Talcott level.

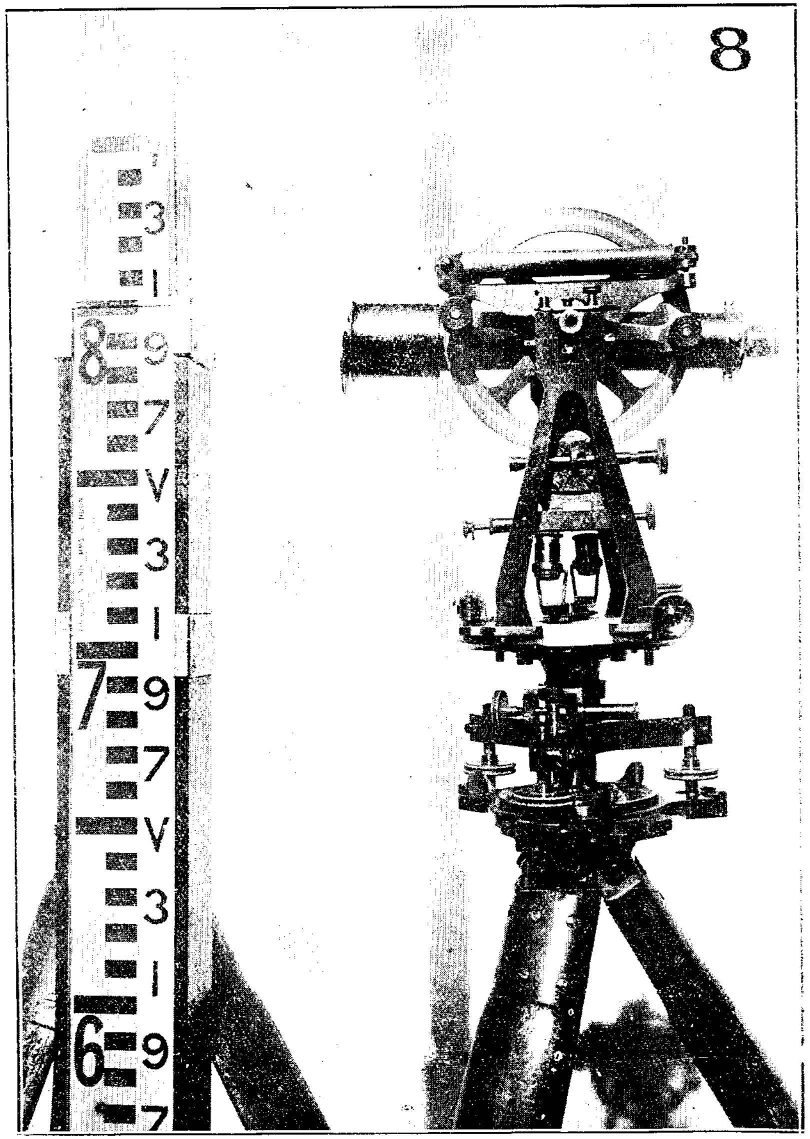


FIG. 8.—5 in. transit theodolite and offset staff. The staff is divided to $\frac{1}{20}$ link.

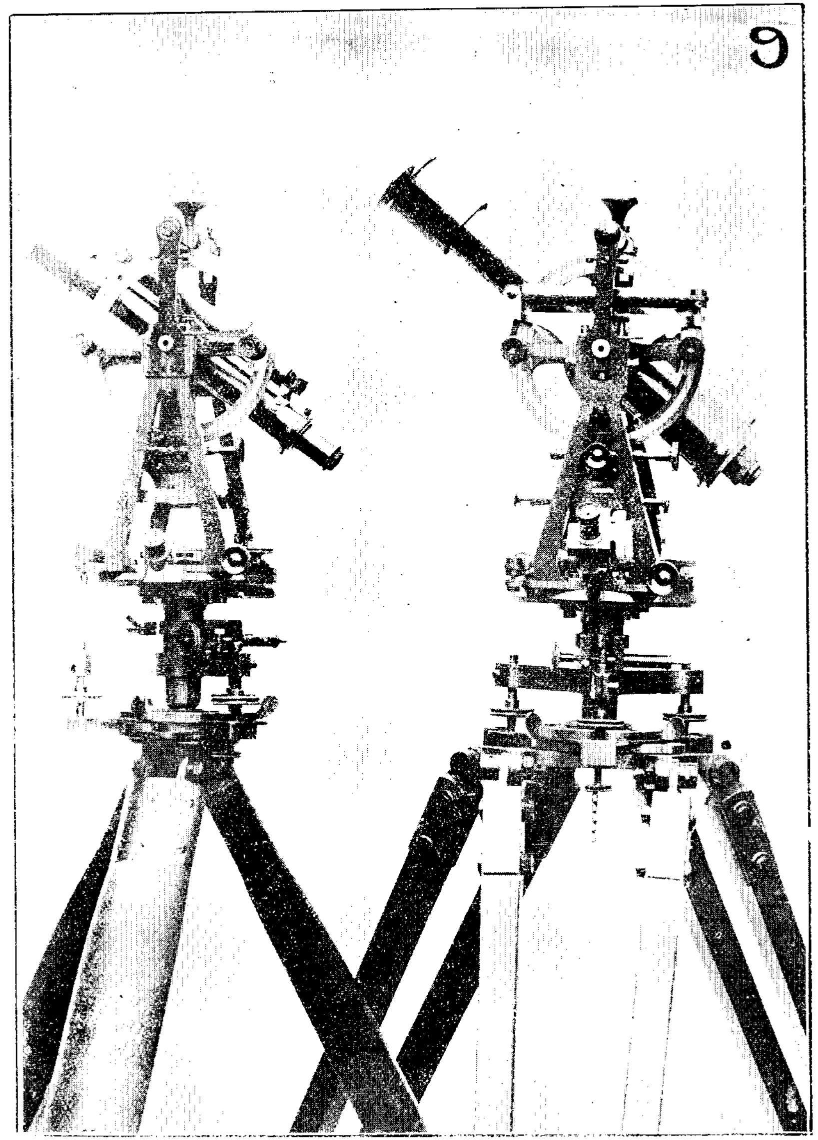


FIG. 9. Instrument labelled 3 is a 5 in. transit used on the preliminary survey. Instrument labelled 4 is a 5 in. micro-transit used on portions of the precise survey.

It is desirable that the temperature of the sea should be observed at a number of stations, so that data can be obtained to make charts of the Dominion which will show the variations of the sea-temperatures for the different seasons of the year, and from which predictions will be obtainable that will have an important influence in assisting to forecast the climatic conditions. These sea-temperatures are also invaluable to the various acclimatization societies which are interested in the introduction of edible species of fish for the improvement of the fishing industry.

Since tide-tables are now prepared for the ports of Auckland, Bluff, Dunedin, Lyttelton, Wellington, and Westport, the tidal work has become an important function of the Department. The inclusion of four extra ports for which predictions of the times and heights of high and low water for the year 1921 will be published, without an increase to the computing staff, was accomplished by making use of the tide-predicting machine at the National Physical Laboratory, Teddington, England, to run off the tide curve for the year from the data supplied for setting the machine, instead of computing the tide-tables in this office as previously, when the predictions for only two ports could be done. These six ports are now available as standard ports, and give indirectly, by means of an auxiliary table which can be prepared, the information as to the time and height of high and low water of all the intermediate ports within the Dominion where tidal observations have been taken.

A study of the tides of the South Pacific Ocean promises to throw a great deal of light on the tidal theory, in which, notwithstanding the enormous increase in the power of the mathematical resources at our disposal, but little advance has been made, and the problem has remained in very much the same condition as it was left by Laplace over a hundred years ago. The great extent of the South Pacific and Antarctic Oceans furnishes conditions more nearly resembling the ideal tides, upon a sphere covered completely by water of uniform depth, and which can be foretold from astronomical data alone, than are met with on any of the other oceans. But even in the South Pacific Ocean the continents, islands, and the great differences in its depth, modify the theoretical conclusions as regards both time and magnitude, so that before the height and time of future tides can be computed it is necessary to resort to observation to determine the characteristic elements of any place. Nevertheless some striking results have been disclosed—as, for instance, at Papeete, on the Island of Tahiti, the lunar tide appears to be totally eliminated, and a tide of about 10 in. in height occurs about one hour after noon daily, there being a night tide about the same time after midnight. Again, the principal solar tide vanishes in the vicinity of Lyttelton, so that the luni-tidal intervals at that port are sensibly constant. Further, when high water of this component, considered separately, occurs at Wellington it is low water at the same time at Lyttelton. These peculiarities of the tides at a port have to be carefully considered when such port is used as a standard of reference for other ports by means of the tidal differences, since it is obvious that only such stations as have similar characteristic elements should be referred to each other.

The tidal observations are made mainly by the self-registering tide-gauges, in which a curve is traced which shows the height of the water at any time above an arbitrary datum. This curve is decomposed by a process devised by Lord Kelvin, and known as "harmonic analysis," into its harmonic elements.

All the important theoretical components due to the varying motions of the sun and moon in their elliptical orbits inclined to the plane of the Equator were carefully determined and published by the British Association for the Advancement of Science. In the reports for 1872 and 1876 are given the values of the components as determined by Lord Kelvin. Later, in 1883, they were extended and improved by Sir George H. Darwin, who introduced a notation, partly adopted from the Tidal Survey of India, by which each harmonic component is known by a symbol, and this system is adopted for convenience the world over by all who have to do with tidal computations.

Sir George Darwin also prepared computation forms and an apparatus for facilitating the reduction of tidal observations. The manufacture of this apparatus, or abacus, has been discontinued, as it was never entirely satisfactory. A substitute will be devised during the coming year for use in this office by the computing division, as the abacus procured when the tidal work was initiated about ten years ago is very much worn.

When the amplitudes and epochs of the various components entering into the tides have been determined for any port the tide can be computed in advance by a general principle of dynamical theory that the tidal elevation at any place for a given time is equal to the sum of a series of simple harmonic functions of the time whose periods are known—that is, by the summation of the formula—

$$H = A_0 + A_1 \cos (n_1 t + a_1) + A_2 \cos (n_2 t + a_2) + A_3 \cos (n_3 t + a_3) + \dots\dots\dots\dots (1)$$

in which H is the height sought; A_0 is a constant expressing the height of mean sea-level above a datum-line, which usually represents the plane to which the soundings given on the charts are referred (this datum should have a scientific definition, and should consist of the sum of the amplitudes of a certain number of the principal tides); A_1, A_2, A_3 . . . are the amplitudes of the successive components, expressed in feet; and n_1, n_2, n_3, . . . the hourly speeds of the same components in degrees of arc; t is the time in mean solar hours from the beginning of the prediction to the instant for which the height is required; a_1 is the interval from the beginning of the prediction back to the preceding high water of the component A_1, expressed in degrees; a_2, a_3 being like intervals for the components A_2, A_3.

The computation of the tides by the above formula involves an enormous amount of labour of a kind particularly tedious and subject to error. The performance of the work mechanically, therefore, soon suggested itself, both for reasons of economy as well as accuracy, and was accomplished by the construction of various tide-predicting machines.

The first was the British Association tide-predicting machine, or tide-predictor No. 1, the designing of which was due to Lord Kelvin in 1873. It is described in Thomson and Tait's "Natural Philosophy," second edition, Part I, pages 479, 481. This machine combines the following ten component tides: (1) The mean lunar semi-diurnal; (2) the mean solar semi-diurnal; (3) the larger elliptic semi-diurnal; (4) the luni-solar diurnal declinational; (5) the lunar diurnal declinational; (6) the luni-solar semi-diurnal declinational; (7) the smaller elliptic semi-diurnal; (8) the solar diurnal declinational; (9) the lunar quarter-diurnal, or first shallow-water tide of mean lunar semi-diurnal; (10) the luni-solar quarter-diurnal shallow-water tide. Having been little used, it was deposited in the South Kensington Museum.

A second tide-predictor was designed in 1897 by Mr. E. Roberts, of the "Nautical Almanac" office, which was at first used for the prediction of the tides for India, under Mr. Roberts's supervision. In 1903 it was removed to the National Physical Laboratory, and is now available to predict the tides for all parts of the Empire. This tide-predictor has twenty-four components.

Two other tide-predictors were constructed, from designs of Lord Kelvin, by Kelvin and White, of Glasgow. One of them, containing sixteen components, is now used by the Hydrographic Service of the French Government, and the other, upon the same model, differing only in the number of components, of which twelve are provided, was constructed for the Brazilian Government.

In 1906 Mr. E. Roberts designed for his private use a tide-predictor in which provision was made for forty components, thirty-three of which are actually geared up, and vacant places for the gearing of the remaining seven have been left for the insertion of compound tides if required. It is known as "Roberts's Universal Tide-predictor," and was exhibited in 1908 at the Franco-British Exhibition in London, where it was awarded the Grand Prix.

In the United States, where tidal work has been an important function of the U.S. Coast and Geodetic Survey, two machines have been constructed. The first, called by Professor W. Ferrel, its designer, "The Maxima and Minima Tide-predicting Machine," is described in the Coast and Geodetic Survey Report, 1883. It is provided with nineteen cranks, and consequently combines nineteen component tides. In addition to the set of cranks summing the cosine series of equation (1), there is another set of cranks, pulleys, and chain for summing simultaneously the first derivative of equation (1), namely—

$$A_1 n_1 \sin (n_1 t + a_1) + A_2 n_2 \sin (n_2 t + a_2) + A_3 n_3 \sin (n_3 t + a_3) +$$

which, by an ingenious device, points out upon a dial the time when the value of the derived series is zero, and consequently that of the cosine series, a maximum or a minimum; and thus it gives the heights and times of high and low water without any measurement of the curves, as is required in the other machines described above.

The second tide-predictor of the Coast and Geodetic Survey has been in use for predicting the tides since 1910. Provision is made for combining thirty-seven component tides. It traces a curve of the predicted tides as well as shows the time and height of the tide upon dials, and therefore combines both features of the British tide machines and the Ferrel machine. It is described in Special Publication No. 32 of the U.S. Coast and Geodetic Survey, 1915. This publication contains illustrations and a description of each of the tide-predictors referred to above.

The ports of the Dominion for which tide-tables are prepared and published in advance—viz., Auckland, Bluff, Dunedin, Lyttelton, Wellington, and Westport—were chosen by the Nautical Adviser. Auckland is suitable as a standard port of reference of the ports lying between the East Cape and the North Cape. Bluff, Dunedin, and Lyttelton can be used as standard ports on which to base the times and heights of high and low water for the intermediate ports in the vicinity of each. To what extent the Port of Wellington can be used as a standard of reference is at present doubtful. The tides in the Marlborough Sounds and along the coast of Cook Strait would be better based on New Plymouth than on either Auckland or Wellington; while either Napier or Gisborne would make a good standard port of reference for the intermediate ports and bays on the east coast of the North Island as far north as East Cape. Westport, situated about a mile up the Buller River, is a suitable standard port for Greymouth, Hokitika, and other similarly situated ports on the west coast of the South Island. The diurnal inequality of the tides at the Westport tidal station is masked by the diurnal variation of the height of the Buller River, caused in summer by the rapid melting of the snow on the mountains, and in winter by the great rainfall.

For a more complete knowledge of the tides and their peculiarities or characteristic features within the boundaries of the Dominion it is desirable that observations should be made on the outlying islands whenever there is an opportunity of obtaining records.

In 1840 Sir J. C. Ross, in his "Voyage of Discovery," Vol. i, page 153, reports that remarkable oscillations were observed in the tides at Rendezvous Harbour, in the Auckland Islands, and also at South Harbour, in Campbell Island. When near high water, after rising to nearly its highest, the tide would fall 2 in. or 3 in. and then rise again 3 in. or 4 in. This irregular movement occupied rather more than an hour. A similar tendency to a double high and low water is generally exhibited on the Lyttelton tidal records.

Mean Values of the Harmonic Constants used in preparing the Tide-tables for 1921.

Tide Symbol.	Auckland. $A_0 = 5·74$ ft.		Bluff. $A_0 = 5·38$ ft.		Dunedin. $A_0 = 3·23$ ft.		Lyttelton. $A_0 = 3·20$ ft.		Wellington. $A_0 = 2·93$ ft.		Westport. $A_0 = 5·00$ ft.	
	H	κ.	H.	κ.	H.	κ.	H.	κ.	H.	κ.	H.	κ.
Short Period.	Ft.	°	Ft.	°	Ft.	°	Ft.	°	Ft.	°	Ft.	°
S1	0·009	11·03	0·005	37·07	0·016	294·24	0·036	13·01	0·005	228·48	0·013	78·91
S2	0·597	263·50	0·500	49·67	0·251	125·38	0·156	140·07	0·098	329·46	0·973	333·10
S4	0·019	336·59	0·008	219·59	0·006	318·00	0·013	141·61	0·005	188·20	0·007	74·38
S6	0·002	50·98	0·005	167·31	0·005	60·60	0·012	358·98	0·005	309·32	0·001	284·91
M1	0·011	141·89	0·011	55·20	0·004	177·98	0·015	89·84	0·006	49·45	0·009	274·27
M2	3·794	204·00	2·876	35·00	2·535	121·48	2·893	122·20	1·597	135·35	3·772	304·60
M3	0·048	204·02	0·005	257·21	0·019	276·94	0·014	121·43	0·025	192·86	0·019	205·02
M4	0·110	127·80	0·098	230·63	0·255	174·01	0·009	82·32	0·037	286·46	0·066	43·12
M6	0·023	294·55	0·085	76·46	0·082	355·52	0·021	62·21	0·016	100·77	0·025	42·14
O1	0·062	136·62	0·106	77·38	0·088	74·47	0·080	58·82	0·105	34·45	0·100	54·47
K1	0·234	167·74	0·064	110·78	0·062	90·01	0·153	85·34	0·086	79·98	0·078	191·46
K2	0·142	251·27	0·080	79·73	0·086	130·04	0·047	91·54	0·046	340·07	0·267	325·79
P1	0·073	167·06	0·025	117·25	0·030	34·20	0·037	88·90	0·030	67·31	0·032	135·24
J1	0·016	214·22	0·002	292·73	0·004	128·89	0·010	57·78	0·006	140·90	0·017	292·16
Q1	0·011	59·44	0·028	38·97	0·029	279·75	0·016	33·31	0·029	22·22	0·034	26·98
L2	0·190	212·64	0·132	35·76	0·116	102·80	0·115	116·54	0·055	140·74	0·093	266·68
N2	0·781	169·09	0·670	14·55	0·540	104·75	0·659	89·04	0·389	99·67	0·715	287·35
ν2	0·202	180·03	0·068	65·08	0·043	166·56	0·095	146·37	0·108	109·38	0·077	346·77
μ2	0·104	168·04	0·073	349·29	0·017	329·09	0·109	47·85	0·081	86·45	0·104	268·47
T2	0·077	103·24	0·026	84·48	0·027	66·95	0·027	201·80	0·040	308·20	0·027	356·59
(MS)4	0·176	193·71	0·083	1·08	0·113	140·70	0·103	145·33	0·036	134·61	0·104	299·09
(2SM)2	0·063	307·32	0·036	132·91	0·026	357·73	0·102	23·32	0·033	5·18	0·063	187·69
Long Period.												
Mm	0·123	211·63	0·087	139·98	0·072	39·56	0·034	174·87	0·087	308·38	0·019	172·56
Mf	0·055	258·88	0·062	153·21	0·073	181·16	0·054	190·93	0·065	158·15	0·031	343·12
MSf	0·075	153·37	0·025	286·79	0·106	105·36	0·138	161·38	0·098	13·79	0·057	138·62
Sa	0·230	54·00	0·137	318·95	0·099	213·18	0·107	305·82	0·158	192·55	0·099	181·17
Ssa	0·107	293·67	0·143	80·87	0·046	77·44	0·193	152·05	0·073	191·54	0·058	67·82

Magnetic Survey and Observatory.

The Magnetic Observatory was visited on the 16th March, and next day, accompanied by the Director, Mr. H. F. Skey, B.Sc., a visit was made to the substation at Amberley.

The work of the Observatory has been performed in a satisfactory manner during the past year, and good progress has been made in overtaking arrears of work, so that the hourly values of the magnetic elements of declination and horizontal force for the year 1905, in addition to those for 1919, have been measured, and will be published in Appendix II of the annual report, which is bound separately and issued only to the institutions and scientists interested in this field of work.

A suitable assistant has not yet been appointed to the Observatory staff, on account of the difficulty experienced in finding a youth with sufficient technical knowledge and a bent for the work. A pressing need in connection with the Magnetic Survey is a redetermination of the magnetic elements at the principal seaports, as soon as the Director is free to undertake this work. The results are required to control the information supplied to the Marine Department and the Admiralty for publication in the "New Zealand Nautical Almanac" and Admiralty charts respectively.

The publication of the results of the Milne seismograph at the Magnetic Observatory has been through the medium of the annual report of the Department since its inception in 1901; and, as it is desirable that the results of this instrument and the only other one in the Dominion at Hector Observatory should appear simultaneously, the late Mr. G. Hogben, C.M.G., Government Seismologist, was consulted with a view to this end, and also to adopt, for the convenience of other workers in this domain, the symbols of the international notation. Forms are now being prepared so that the earthquake records, commencing from the 1st January, 1920, will be uniformly presented, and more frequently than in the past.

A resolution of the Science Congress, 1919, "That, in view of the great scientific value of a knowledge of the variations of the electrical state of the atmosphere, this Congress desires to urge upon the Government of New Zealand the desirability of the establishment of an electrograph at the Christchurch Magnetic Observatory," opens up the question of the consolidation of the scientific work of the Department. It is inadvisable to install any more instruments at Hagley Park, as the electro-magnetic effect caused by the electric haulage adopted on the Christchurch tram system interferes with the records, and the removal of the magnetic pavilion to Amberley, or both stations to a more suitable locality, is now under consideration.

A reply to a request for an estimate of a duplicate of the atmospheric electric equipment proposed to be installed at Watheroo, Western Australia, from the Department of Research in

Terrestrial Magnetism, Carnegie Institution of Washington, is to the effect that, owing to interruptions and delays incident to the war, it is not at present possible to purchase on the market equipment such as they propose to install at their observatories.

The mean annual values of the magnetic elements as far as they are available at present are shown in the following table:—

Table of Mean Values of the Magnetic Elements at Christchurch Observatory.

Date.	Declination E. of N.	Annual Change.	Horizontal Force.	Annual Change.	Vertical Force.	Annual Change.	Inclination South.	Annual Change.	Date.
	° ′	′	C.G.S. Unit.	γ	C.G.S. Unit.	γ	° ′	′	
1902 ..	16 15·1	+3·2	0·22694	−25	0·55277	+9	67 40·8	+1·50	1902
1903 ..	16 18·3	+3·5	0·22669	−25	0·55286	+21	67 42·3	+1·80	1903
1904 ..	16 21·8	+3·6	0·22644	−16	0·55307	+41	67 44·1	+1·70	1904
1905 ..	16 25·4	+2·4	0·22628	−23	0·55348	+28	67 45·8	+1·80	1905
1910 ..	16 37·6	+1·4	0·22515	−27	0·55485	+12	67 54·8	+1·40	1910
1911 ..	16 39·0	+2·5	0·22494	−23	0·55497	−9	67 56·2	+1·00	1911
1913 ..	16 44·0	+0·8	0·22449	−35	0·55478	−13	67 58·2	+1·60	1913
1914 ..	16 44·8	+2·2	0·22414	−27	0·55465	+7	67 59·8	+1·67	1914
1915 ..	16 47·0	+2·8	0·22387	−32	..	..	..	..	1915
1916 ..	16 49·8	+3·2	0·22355	−27	..	..	..	..	1916
1917 ..	16 53·0	+2·7	0·22328	−24	0·55486	+30	68 4·8	+1·90	1917
1918 ..	16 55·7	+2·9	0·22304	−24	0·55516	−9	68 6·7	+1·10	1918
1919 ..	16 58·6	..	0·22280	..	0·55507	..	68 7·8	..	1919

The mean variation of the declination for the period 1902–19 is found to be at the rate of $+2{\cdot}56'$ per annum, increasing easterly.

Topographical Survey.

An estimate of the cost of a topographical survey of the Dominion was given in my report of the 25th October, 1919. The instrumental outfit was carefully considered, and the details of the organization of the field parties decided. The conclusions arrived at were based on the experience gained on the surveys that have been made on similar lines to the proposed work by Mr. K. Graham, District Surveyor at Auckland and Wellington, and my own survey of the Dunedin centre.

In the open country it is proposed to use the plane table in connection with a hand-level, pocket-compass, aneroid, &c., and to have recourse to the tacheometer when forest or scrub is encountered. On the broken and mountainous parts of the country it is proposed to introduce the photo-theodolite. In recent years stereo-photogrametric methods have become of great practical and economic advantage in such work, where the ordinary methods of topography are difficult, if not impossible. Its chief advantage lies in the permanency and accuracy of the records made, and the comparative rapidity of the field-work, particularly where climatic conditions are severe, for one need not enter much of the territory that is being surveyed, and measurements can be taken to and from objects that are inaccessible to the surveyor or his assistant. The photo-theodolite, however, is not intended to compete with the plane table on the flat or undulating open country. According to the opinions, founded on extensive experience, of many surveyors, the plane table is the most economical instrument in use at the present time for most classes of topographical surveys.

A co-ordinate scheme of map reference is being prepared for the maps to be supplied to the Defence Department, based on the Allied system as described in Appendix 3 of the "History of Survey Operations" which is in preparation at the War Office, and a copy of which was kindly forwarded by Lieut.-Colonel R. B. Smythe. The mean sea-level is the datum to which all heights are to be referred, and lines of levels on the main roads are recommended in order to pick up and co-ordinate a great amount of work done in the past by the Departments of Roads, Public Works, and the various County Councils. These levels will be invaluable as checks on the contouring, and for future use when internal improvements involving engineering surveys are undertaken.

Office Appliances.

A Layton's improved arithmometer was installed for the use of the Computing Division during the year under report. It is claimed by the maker that this is the best machine on the market, either British or foreign. The performance of this arithmometer has been satisfactory, and it has been found very useful in doing the drudgery connected with the work of the division.

APPENDIX II.

THE MAGNETIC OBSERVATORY.

ANNUAL REPORT OF THE DIRECTOR.

DURING the past year this Observatory has operated as previously in all branches, and an exceedingly valuable series of records has been obtained.

Before dealing with the more interesting details of the work it is necessary first to give those mean values of the magnetic elements for the year which are looked upon as exceedingly valuable by magneticians in other parts of the world, because this Observatory is the most southern outpost of the group of observatories surrounding this globe.

We must then epitomize the year's magnetic work in the following table :—

	Mean Values for the Year 1919.	Change since 1918.
Magnetic declination	16° 58·6′ E. of N.	+2·8′
Horizontal magnetic force	0·22280 C.G.S. unit	−24 γ
Magnetic inclination	68° 7·8′ S.	+1·1′
Northerly component	0·21309 C.G.S. unit	−28 γ
Easterly component	0·06505 „	+10 γ
Vertical component	0·55507 „	−9 γ
Total magnetic force	0·59812 „	−16 γ

The values of these elements for the year 1905 have also now become available for publication. They are included in the table of the mean values of magnetic elements at Christchurch Observatory, published herein.

Full tables of hourly values of magnetic declination (D) and of magnetic horizontal force (H) are published herewith, also the vector diagrams of diurnal horizontal disturbing forces for the three seasons and the year, and diagrams showing the average monthly diurnal variation of D and H. Diagrams are also given showing the monthly diurnal range in D and H throughout the year.

ANNUAL VARIATION OF HORIZONTAL FORCE AT CHRISTCHURCH.

The diurnal change in H is obviously connected with the apparent daily revolution of the sun around our earth from east to west. The change of seasons throughout the year is accomplished by the apparent partial revolution of the sun around the earth from south to north and back again, the sun apparently oscillating through an angle of about 47°, or just over one-eighth of a revolution, in a direction, of course, at right angles to that of the sun's apparent daily revolution. It might be expected, then, that some annual inequality should exhibit itself in the mean monthly values of the magnetic elements. It might further be expected that the daily and annual inequalities might have some relation, and perhaps that the curve of annual inequality in H should be somewhat similar to the midday portion of the curve of daily variation in D, and similarly for annual D and diurnal H variations.

It is surmised that one reason why this effect is not always evident is that the secular change proceeds irregularly throughout any individual year. It may happen, however, that for a considerable portion of a year the secular change may go on uniformly, or that for a large part of one year the irregularity of secular change may balance the irregularity of the change for a large part of another year, and when the mean results for the two years are considered, the seasonal changes, after allowing for a uniform secular change, may be exhibited by a symmetrical curve. This might more reasonably be expected to happen in the case of two years separated by half a sun-spot period, or about five years and a half.

Taking the mean monthly value of H for the two years 1914 and 1919 at Christchurch, we have the horizontal forces—

0·22 C.G.S. + γ

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1914 ..	431	424	420	415	421	416	414	410	409	401	400	401	413
1919 ..	295	287	271	280	273	293	291	274	271	268	282	279	280

Apparent inequalities in γ

1914 ..	+18	+11	+7	+2	+8	+3	+1	−3	−4	−12	−13	−12
1919 ..	+15	+7	−9	+0	−7	+13	+11	−6	−9	−12	+2	−1
Means ..	+16·5	+9	−1	+1	+0·5	+8	+6	−4·5	−6·5	−12	−5·5	−6·5

Now, correcting these mean apparent inequalities for a uniform rate of secular change of about −19 γ per annum, or −1·6 per month, the corrections are approximately—

Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
−8·8	−7·2	−5·6	−4·0	−2·4	−0·8	+0·8	+2·4	+4·0	+5·6	+7·2	+8·8

Giving corrected inequalities—

+7·7	+1·8	−6·6	−3·0	−1·9	+7·2	+6·8	−2·1	−2·5	−6·4	+1·7	+2·3

and plotting these, we arrive at a curve the symmetry of which over ten months of the year is within the limits of observational error. This curve is shown at A in the diagram given, with its apparent constituent curves—B, a variation of half-yearly period with a complete amplitude of about 12 γ, and C, a variation in about a two-months period with a complete amplitude of about 3·6 γ, the latter curve undergoing a complete reversal, or a hesitation followed by complete reversal, at the time of solstices. Curve B has maxima at the solstices, minima at the equinoxes; and curve C has maxima in February, April, June and July, September, November; minima in January, March, May, August, October, December. A reversal at the time of solstice would be expected, as the direction of the sun's change of declination is then reversed.

It is hardly necessary to remark that such a degree of symmetry has not hitherto been noted here for any individual year. Indeed, it was the evident individual irregularity that led to the idea of combination in pairs at about half a sun-spot-period distance.

H.F. curves for the years 1905 and 1910 were first combined, and then those for the years 1914 and 1919 were combined with them also. It was then found that the curve 1905–10 differed very little, and systematically, from the curve 1905–10–14–19. On plotting 1914–19 the symmetry of the curve about the midwinter point was very noticeable.

The degree of seemingly accidental irregularity during the years taken singly is shown by the plotted diagram attached to this report. The average rate of secular change from 1913 to 1915 was about −30 γ, and from 1918 to 1919 it has been −24 γ, both considerably larger rates than that used in forming the diagram.

In comparing these H annual variations with E_m daily variations it must be remembered that the long-period H annual variation is presumably not affected by a time-lag behind the assumed producing cause, the sun; whereas in the short-period daily change of E_m some amount of lag probably exists. (E_m = the component at right angles to mean magnetic north.)

It is not until about 2.30 p.m. local time that the E_m curve becomes symmetrical at all in the local equinoctial vector diagram, and this amount of lag is rather unthinkable; but, anyway, the exact shape of the vector diagram is not well determined about that time. A half-hourly measurement of the daily curves about that part of the curve might reveal a sinuosity there corresponding to the annual H curve, but the sinuosity must be very small to be not immediately apparent in the quiet-day curves.

It has been noticed that the variations in mean monthly values of H.F. occurring at Christchurch agree over some months with those at Mauritius; and, as a possible peg to hang future investigation on, it is worth while calling attention to the great similarity existing between the variations in H.F. at Christchurch over the mean years 1905–10 and 1914–19. This, at any rate, proves that a mathematical analysis of the annual variation over a period of eleven years may yield valuable results. It would be rather surprising if it did not reveal solar changes of shorter period than the well-recognized 11·1 year average sun-spot period. A period of about twenty-seven days is already more than suspected, the exact length of which may prove to change with the varying presentment of solar latitudes to our earth. The time of rotation of the solar surface varies with the distance, from the sun's equator to the sun's pole, and the earth's orbit is inclined to the plane of the sun's equator, so that if the effect is due to radial projection of very minute electrified corpuscles impinging upon the atmosphere of the earth, the energy of projection varying with longitude on the sun's surface, such a variable period must be exhibited by the terrestrial magnetic field, and the variation of the period will be seasonal.

In order to rapidly complete the measurement of hourly values from curves it is intended to have constructed special scales of celluloid giving direct readings to 10 γ, and by estimation to 1 γ. This is rendered possible only when the scale values of ordinates are constant over a long interval, as has lately been the case.

Seismological Observations.

Milne Seismograph No. 16 has been kept in continuous operation. Details of the earthquakes recorded are now published in the *New Zealand Journal of Science*.

The recent advances in seismological science really necessitate more up-to-date seismographs in this country, and it is desirable that a Milne-Shaw boom should be supplied for our seismograph. Local microseisms continue on most nights to keep the boom of our seismograph in motion. These are evidently a feature of our locality. Their existence tends sometimes to prevent a reading of the time of arrival of preliminary tremors from the seismogram of distant earthquakes.

It is intended to publish New Zealand records every three months, but it is hardly possible to commence this for Christchurch records until the arrival of the new assistant.

Meteorological Observations.

As in previous years, these have been made at 9.30 a.m., noon, and 5 p.m. daily, with the omission of noon readings on Sundays. Monthly tables of results have been forwarded for the information of the Dominion Meteorological Office.

An increasing number of inquiries are made yearly for meteorological information for evidence in the Courts of law, and for use by other Government Departments.

Daily results have been published in the local newspapers for the information of the general public.

Amberley Substation.

During the year valuable records have been obtained at this station, which have enabled the tables of D and H to be published without any loss of hourly record.

MAGNETIC STORM OF 11TH TO 12TH AUGUST, 1919.

The magnetogram of this storm, which presented the usual "sudden commencement" of large storms, is published herewith. The range of the storm was about 600 γ (0·006 C.G.S. unit) in horizontal force, and about 43′ in magnetic declination. The "sudden commencement" was an increase in H.F. of 200 γ, and commenced at very nearly 6 h. 57 m. G.M.C.T. 11th August; but a preliminary slight disturbance in H and D occurs just after 3 h. G, and in H a larger preliminary disturbance occurred between 5 h. 30 m. G and the "sudden commencement." The mean H was evidently much less than normal after 8 h. G, and the type of disturbance changed just after 16 h. G, the irregular short-period oscillations after that time being more of the polar auroral type, which is most noticeable between 24 h. on 11th and 4½ h. on 12th G.

Similar oscillations occurred between 16 h. 15 m. on 11th G and 17 h. 15 m. G, with a marked break at 16 h. 40 m. It is noteworthy that the time interval between the extreme maximum value of H and the extreme minimum is only about one hour and a half, the whole storm lasting over twenty-four hours.

Below is given a table of exact times of the principal turning-points and commencements of some sudden changes:—

Table of Greenwich Times of Remarkable Features.

	H.	M.	
August 11	6	57·5	Sudden commencement.
	7	2	End of sudden commencement.
	7	36	Marked minimum in H.
	7	54	Marked minimum in H.
	7	57	Principal maximum of H.
	9	21	Marked turning-point (major H).
	9	27	Principal minimum in H.
	9	59	Marked turning-point (major H).
	12	8	Marked turning-point.
	12	17	Second minimum of H.
	12	32	Marked turning-point (minor H).
	14	8	Marked turning-point (minor H).
	15	52	Second maximum of H.
August 12	8	32	End of a sudden diminution of H.

MEAN ANNUAL VALUES, 1905.

Magnetic declination	16° 25·4′ E. of N.
Magnetic horizontal force	0·22628 C.G.S. unit.
Magnetic inclination	67° 45·8′ S.
Northerly component	0·21705 C.G.S. unit.
Easterly component	0·06398 ,,
Vertical component	0·55348 ,,
Total magnetic force	0·59794 ,,

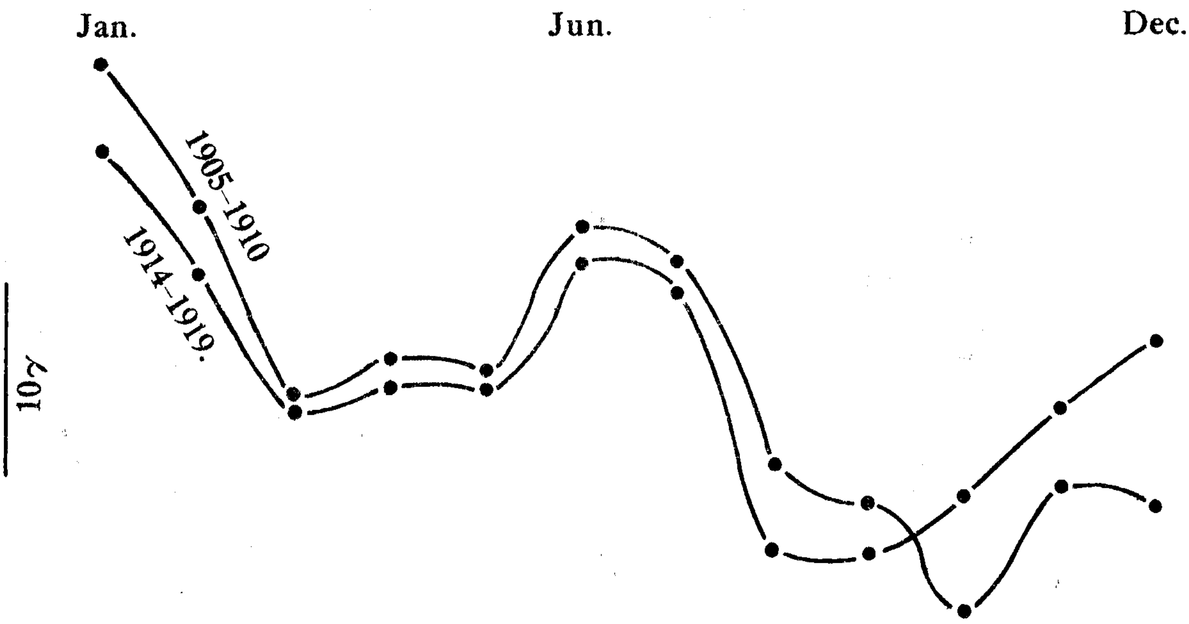
HENRY F. SKEY, Director.

Approximate Cost of Paper.—Preparation, not given; printing (700 copies, including diagrams, &c.), £80.

By Authority: MARCUS F. MARKS, Government Printer, Wellington.—1920.

Price 2s.]

Plate I.



Mean monthly H.F. at Christchurch for combined years 1905–1910 and 1914–1919.

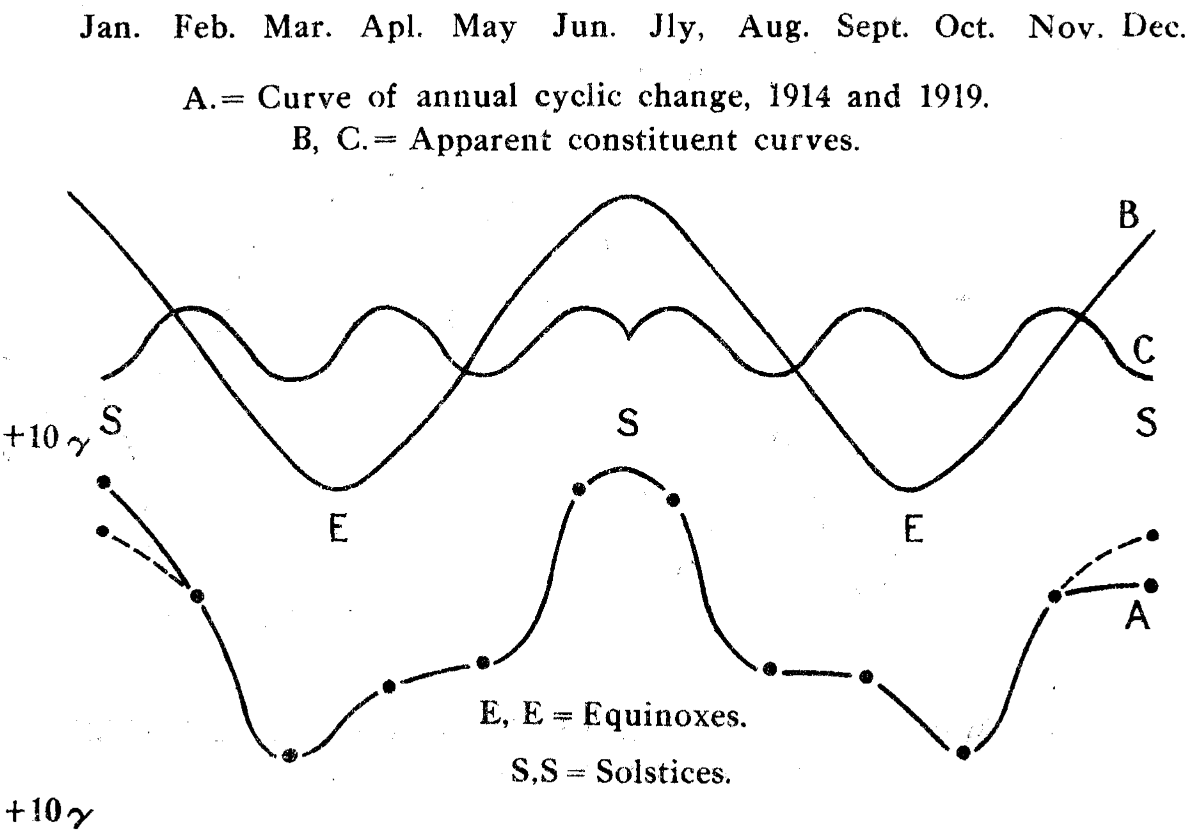
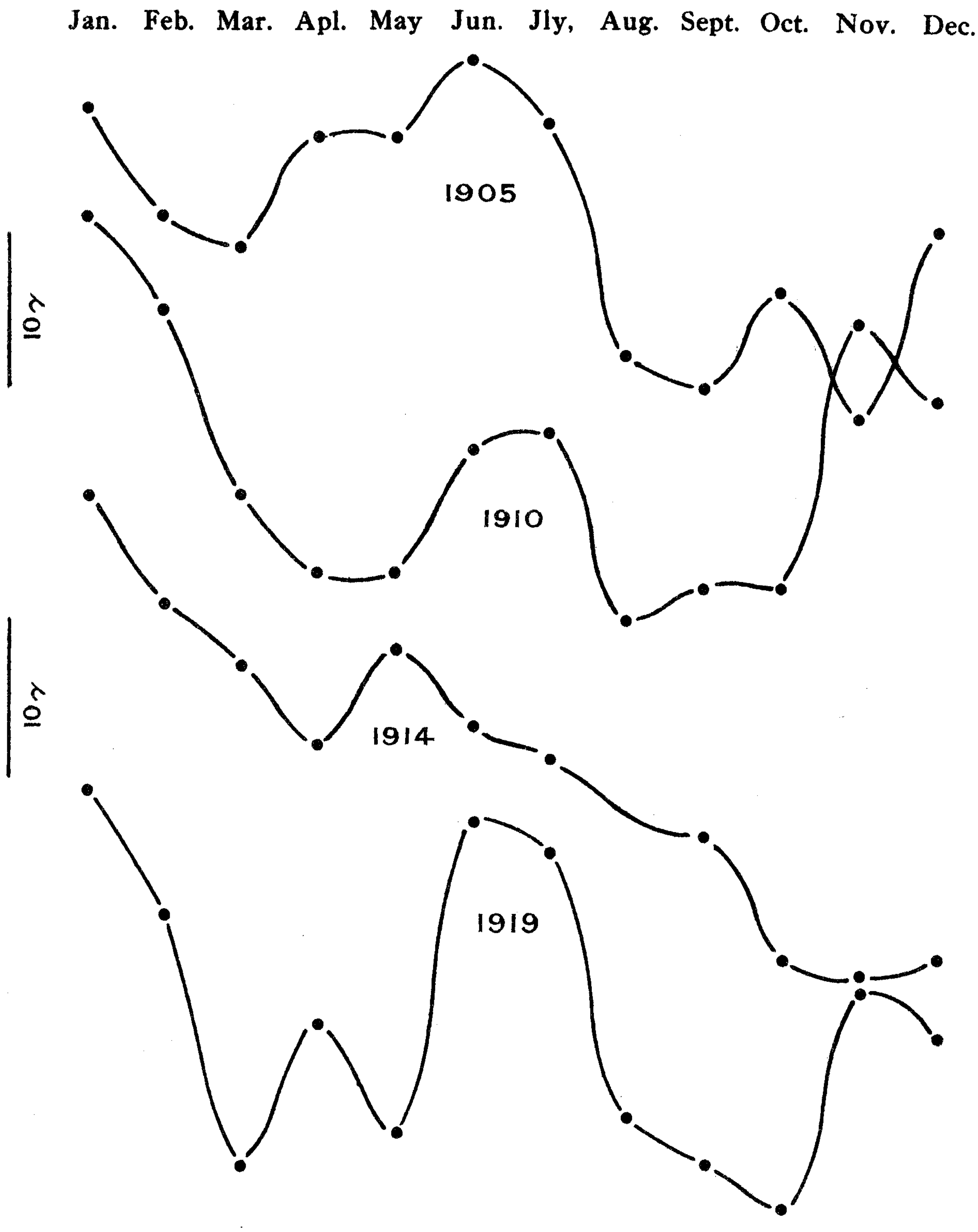
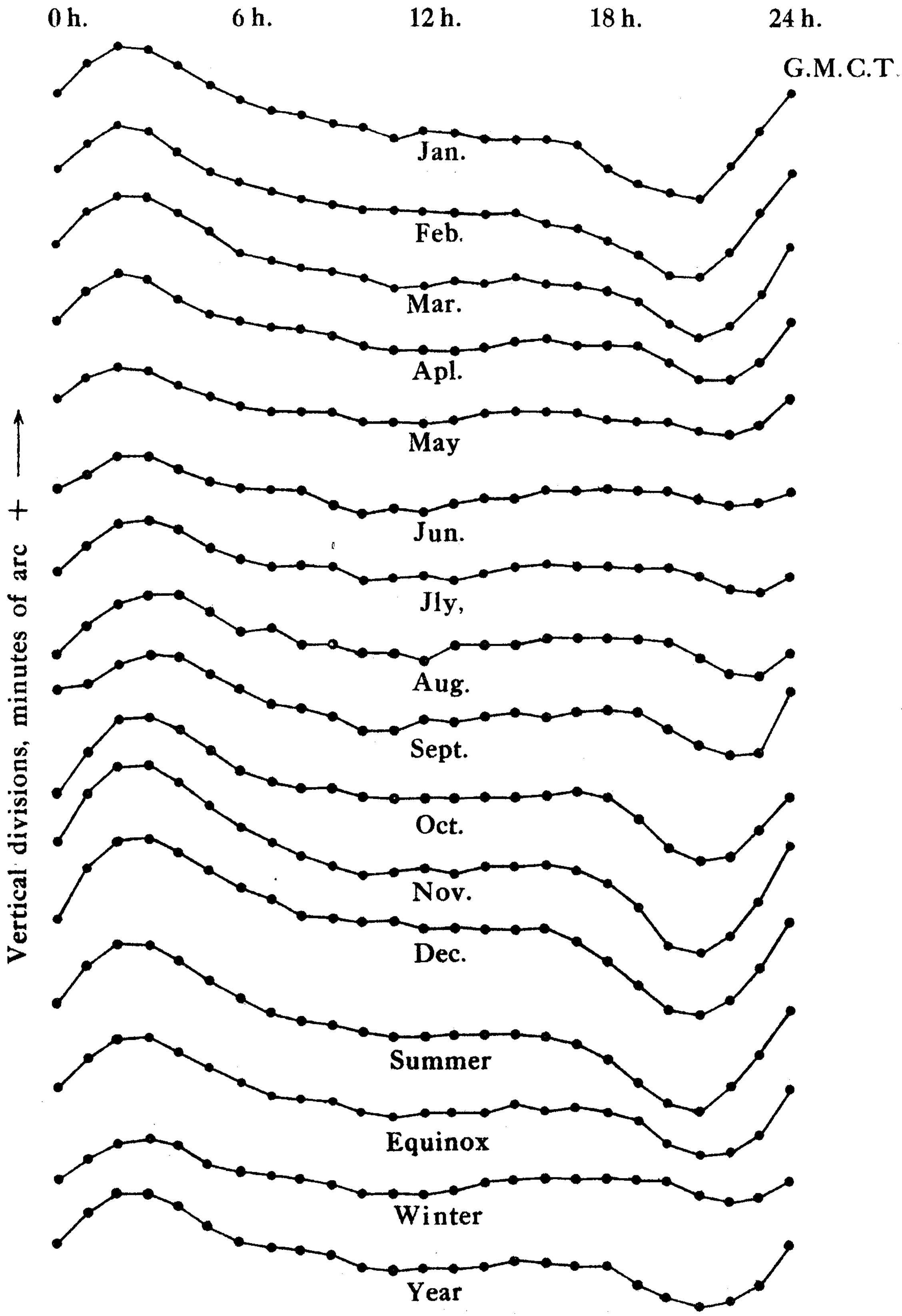


Plate II.



Mean Monthly values of MAGNETIC HORIZONTAL FORCE at Christchurch, 1914 and 1919.

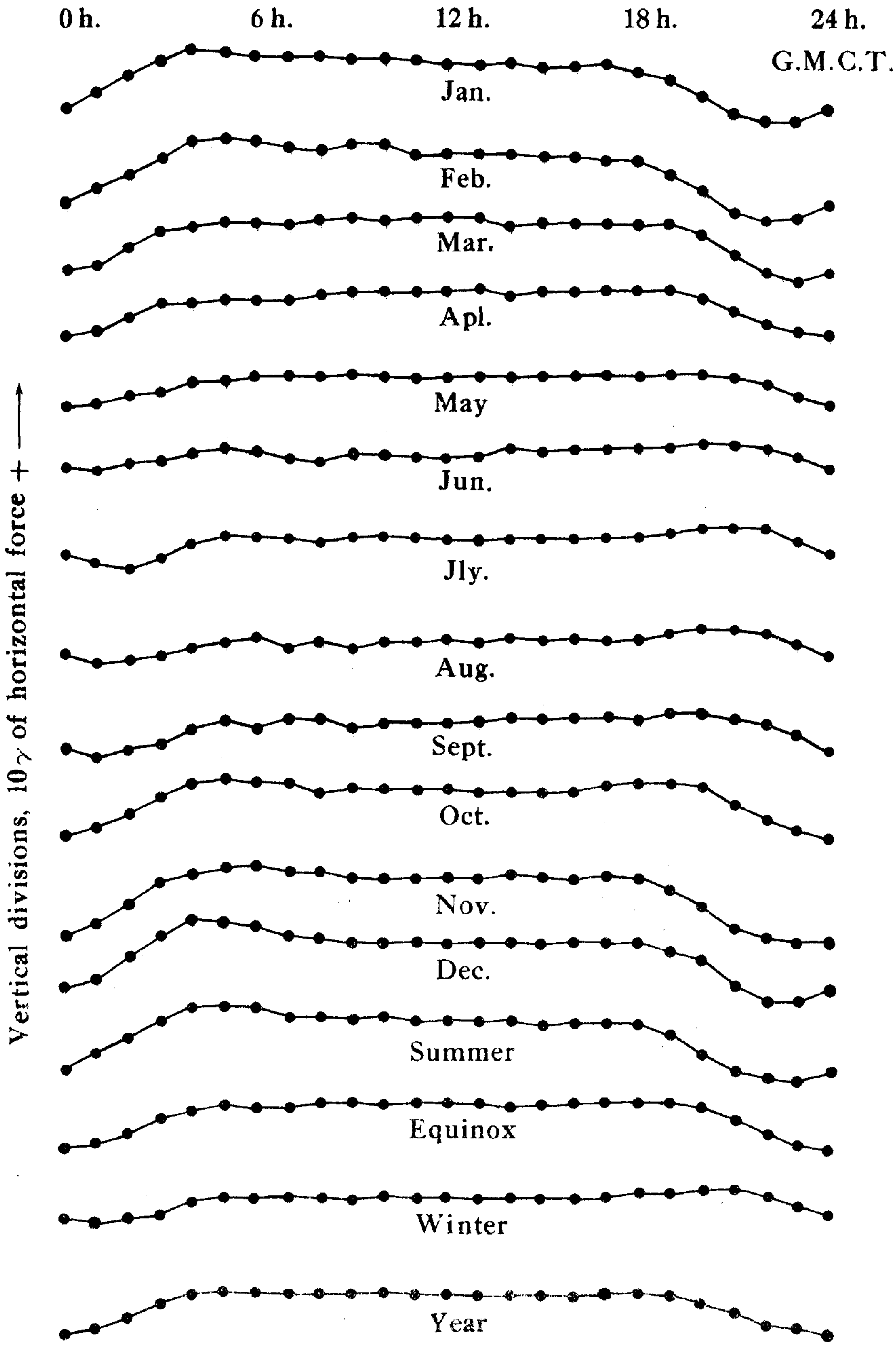
Plate III.



Mean monthly curves of MAGNETIC DECLINATION, 1905.

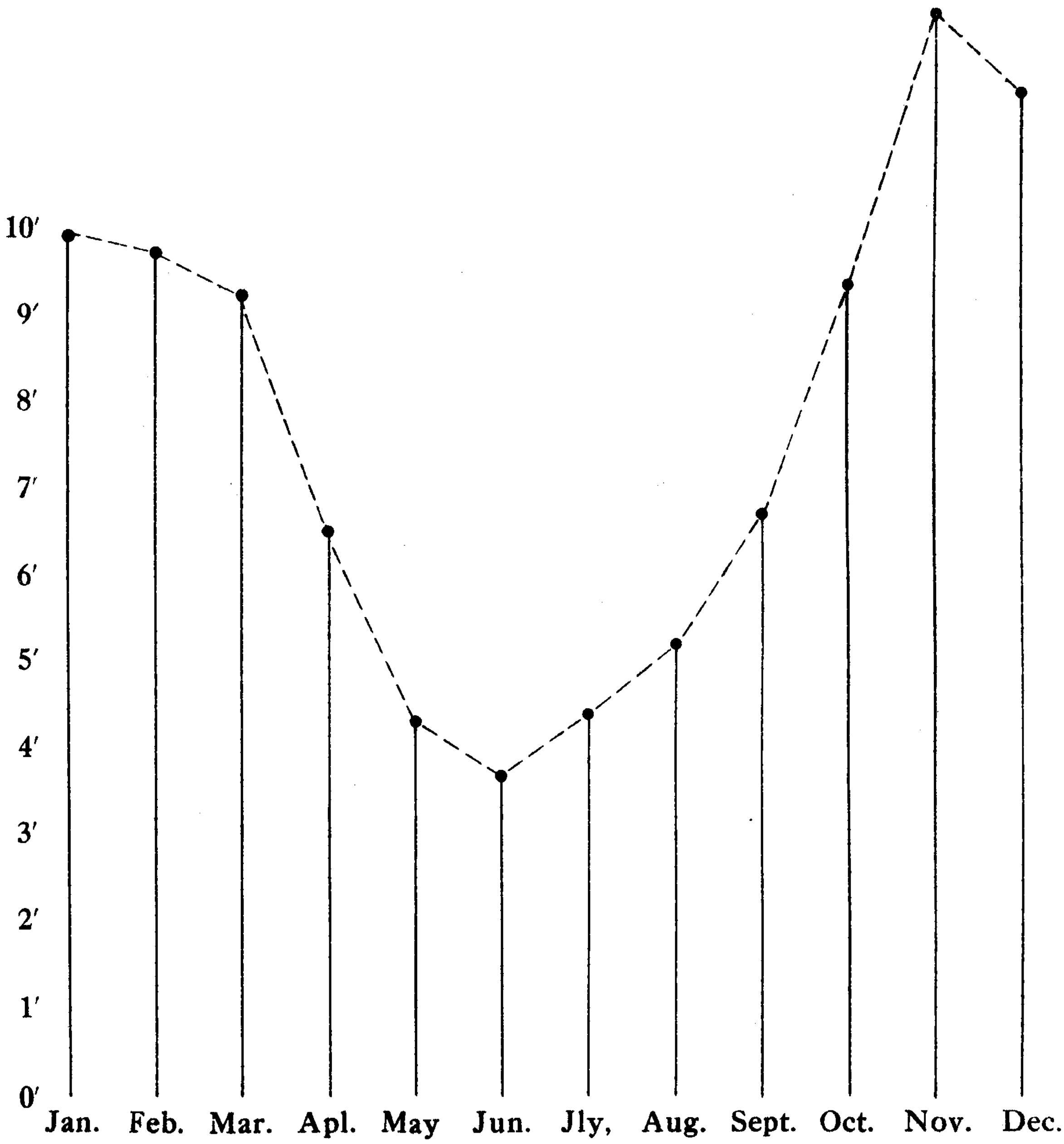
C—1A.

Plate IV.



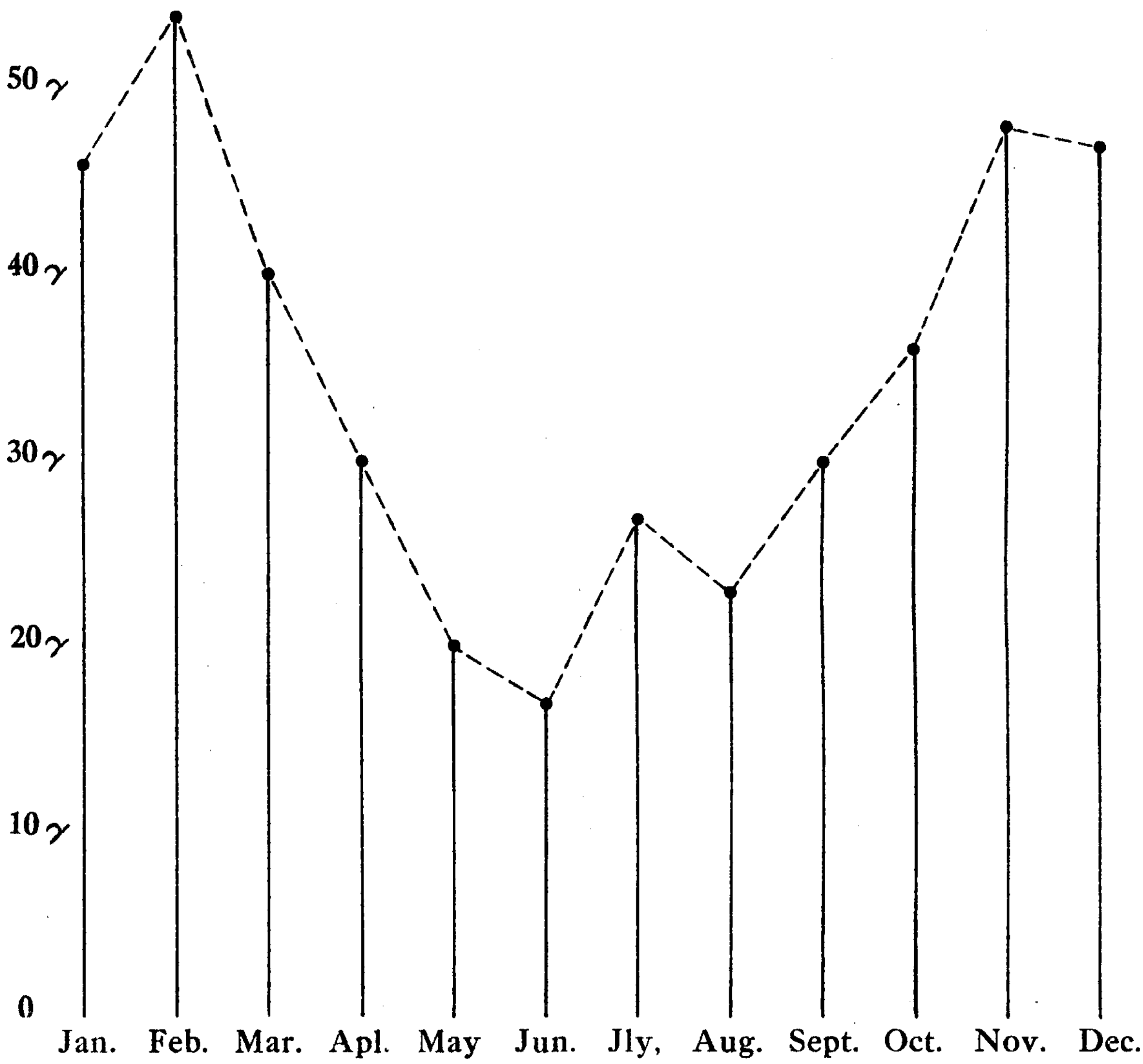
Mean monthly curves of MAGNETIC HORIZONTAL FORCE, 1905.

Plate V.



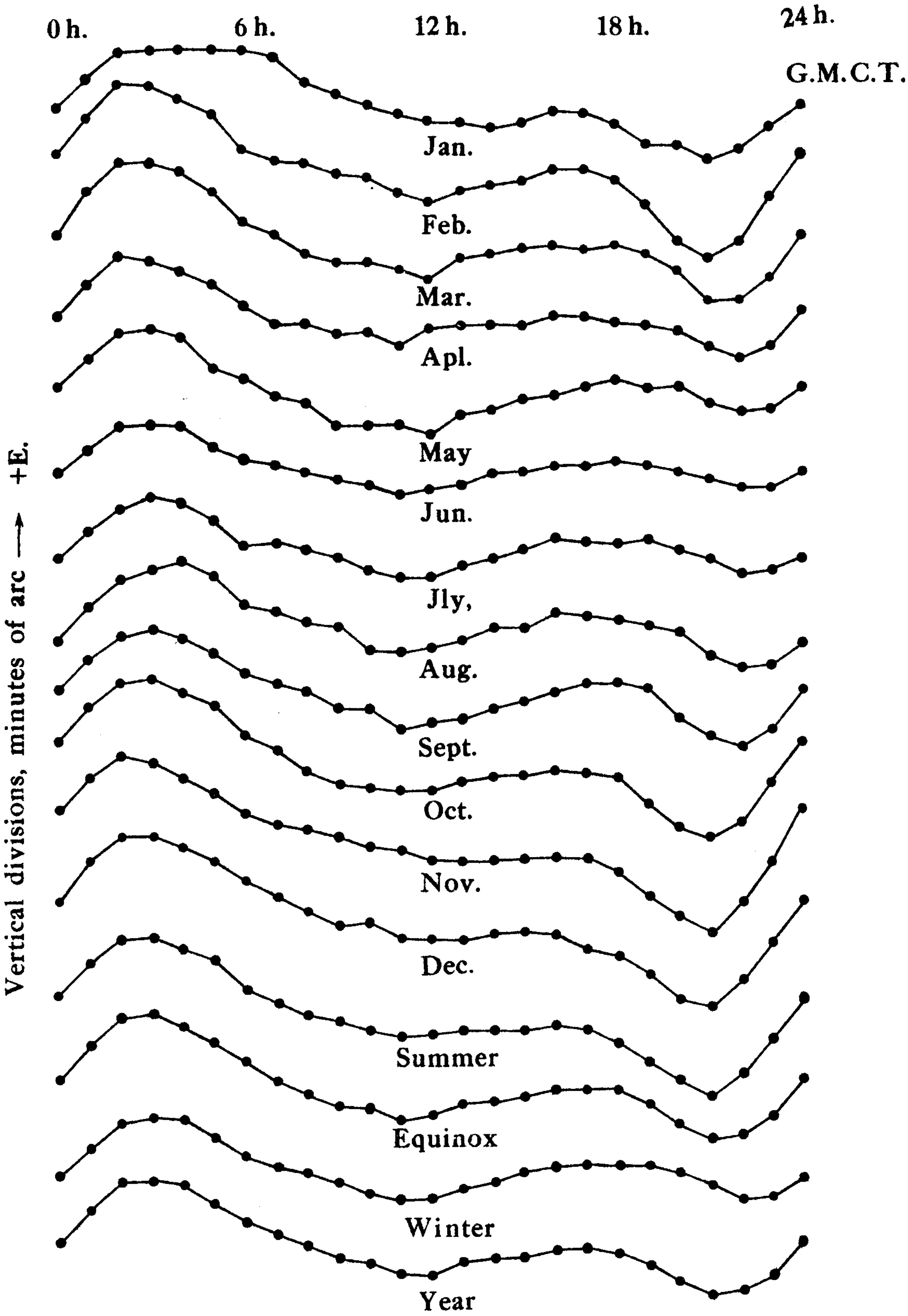
Mean diurnal range of MAGNETIC DECLINATION
at Christchurch, 1905.

Plate VI.



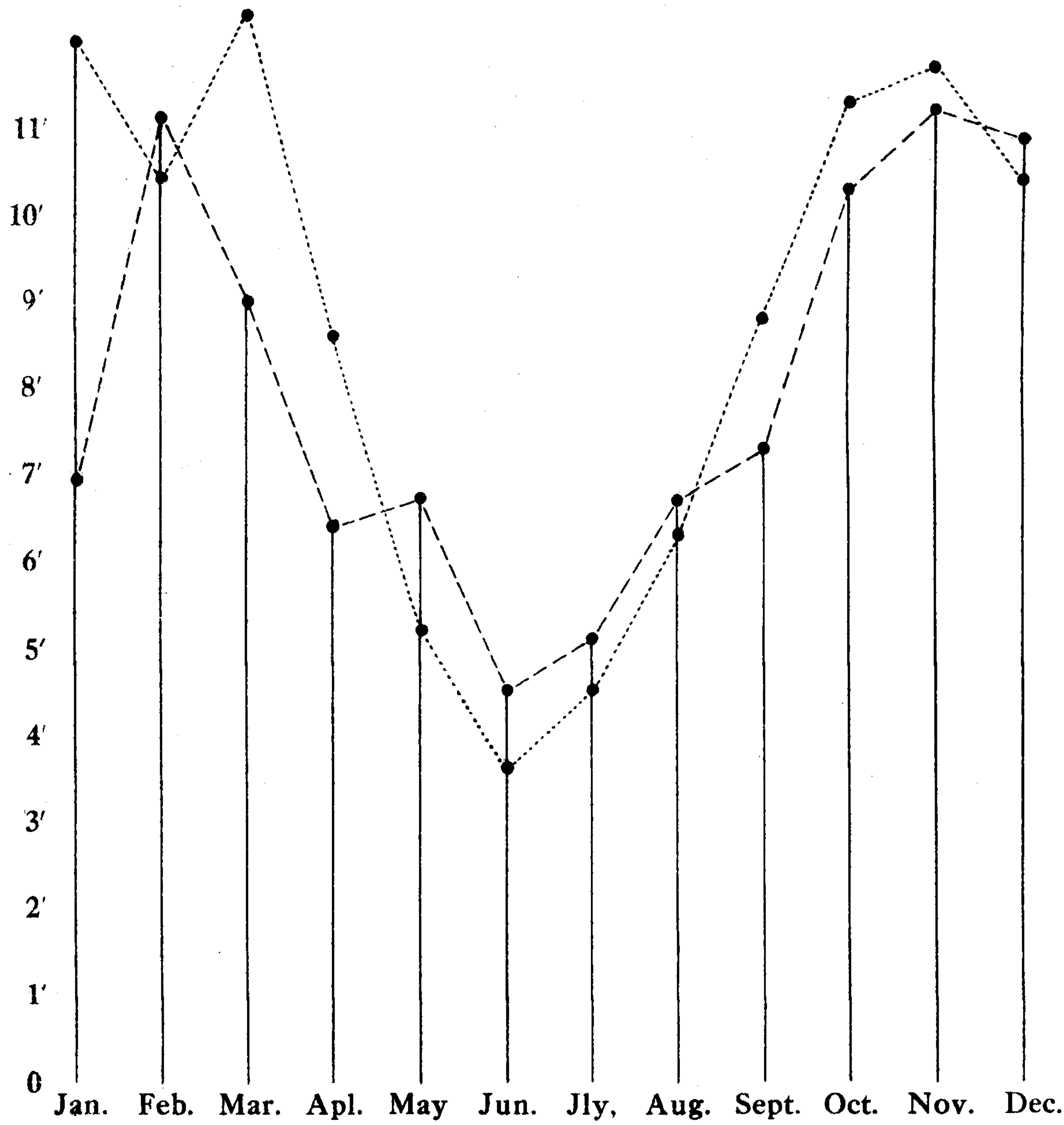
Mean diurnal range of MAGNETIC HORIZONTAL FORCE at Christchurch, 1905.

Plate VII.



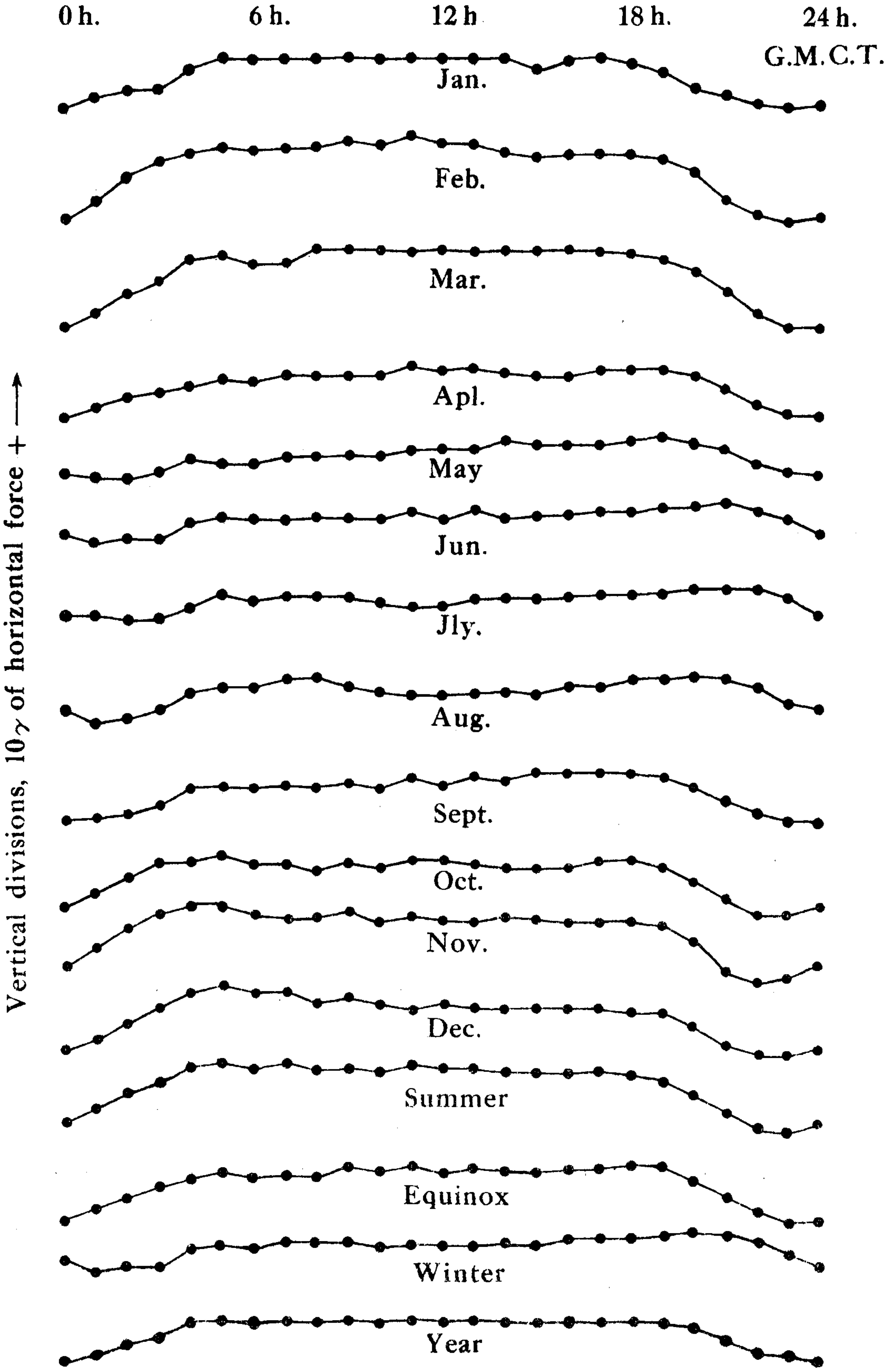
Mean monthly curves of MAGNETIC DECLINATION, 1919.

Plate VIII.



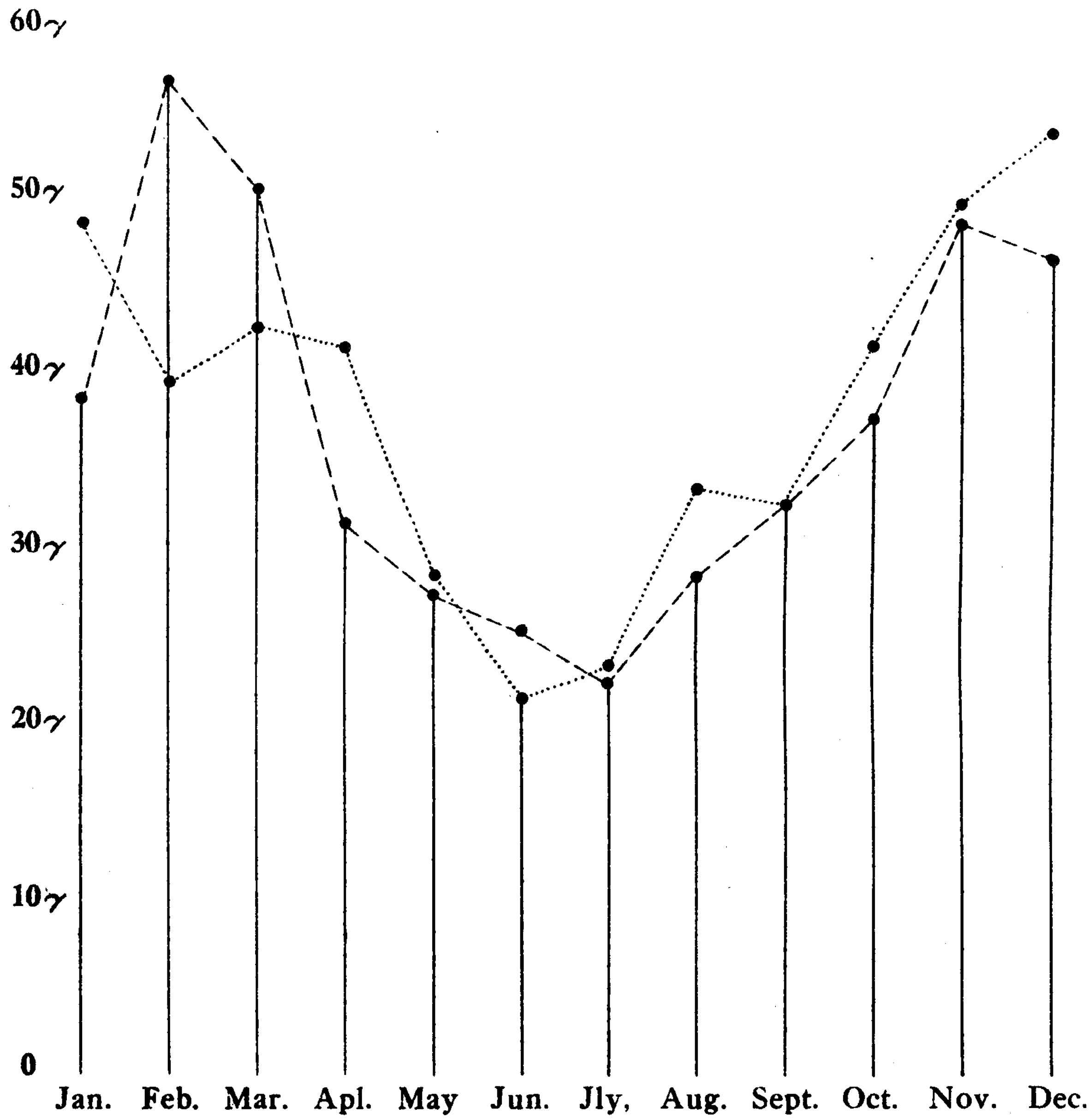
Mean diurnal range of MAGNETIC DECLINATION
at Christchurch.
For 1918, thus:············ For 1919, thus:– – – – – –

Plate IX.



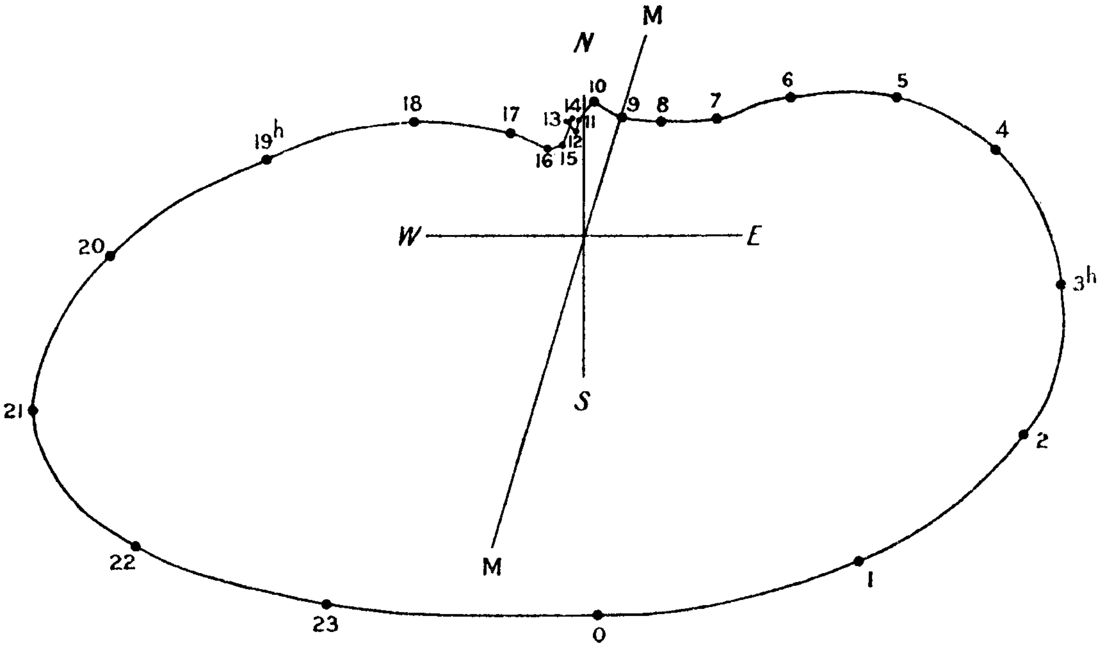
Mean monthly curves of MAGNETIC HORIZONTAL FORCE, 1919.

Plate X.

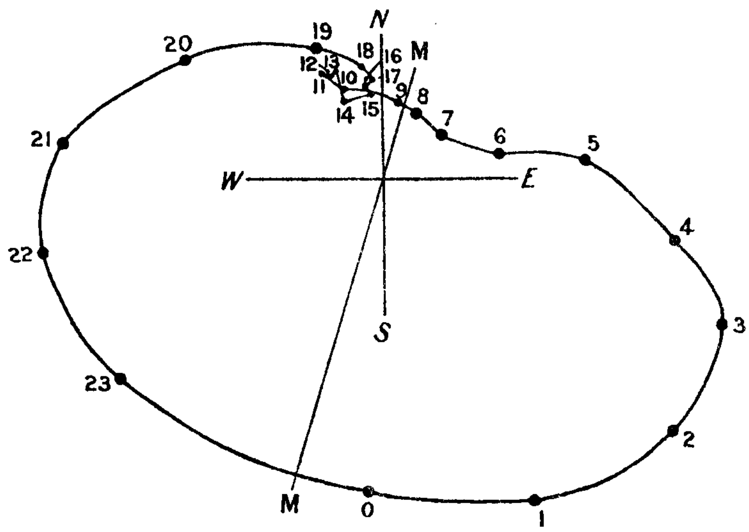


Diurnal range of MAGNETIC HORIZONTAL FORCE at Christchurch.

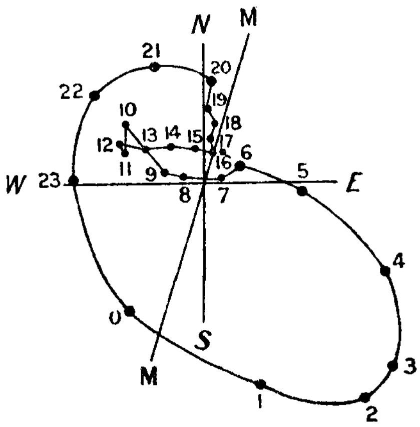
For 1918, thus:·············· **For 1919, thus:**— — — — —



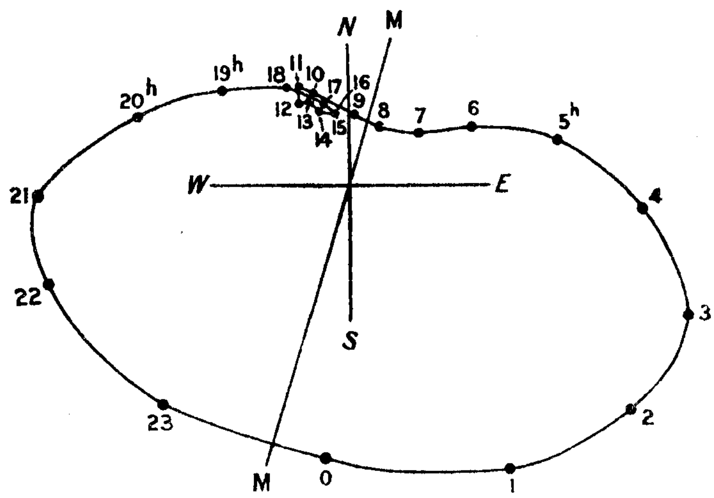
Vector Diagram for Summer Months, 1905, all Days.



Vector Diagram for Equinoctial Months, 1905, all Days.



Vector Diagram for Winter Months, 1905, all Days.

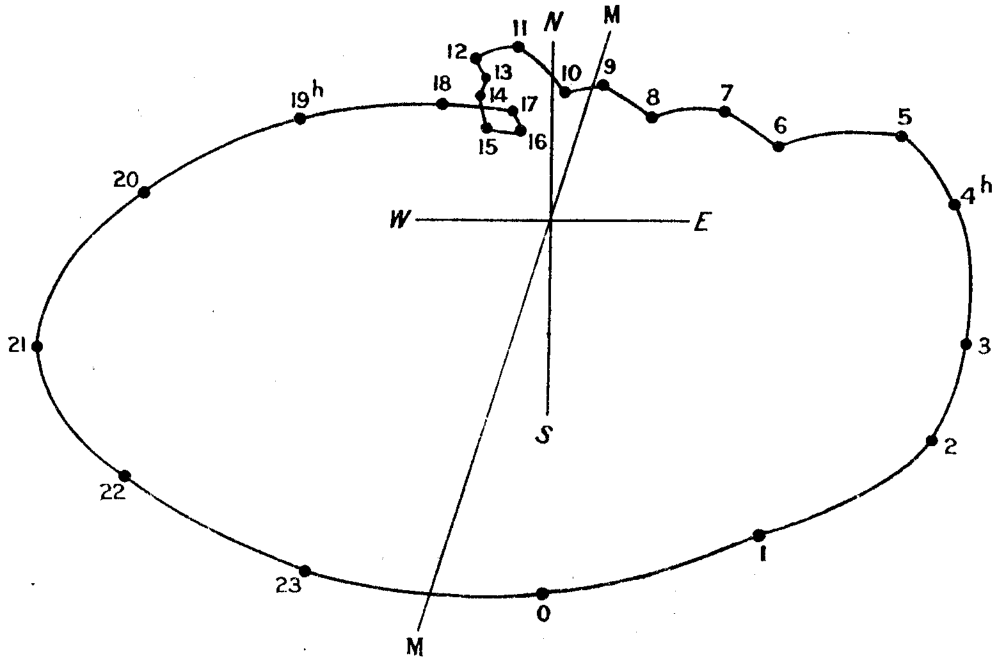


Vector Diagram for Year 1905, all Days.

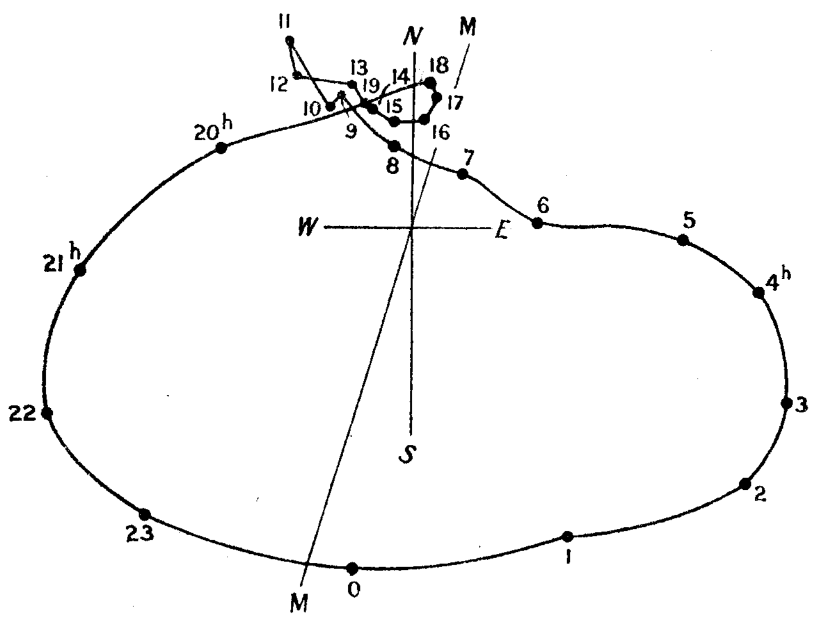
Mean Diurnal Horizontal Disturbing Forces for Year 1919 at Christchurch.

(Greenwich Hours indicated.) **N S. Geographical Meridian.**
M M Magnetic Meridian.

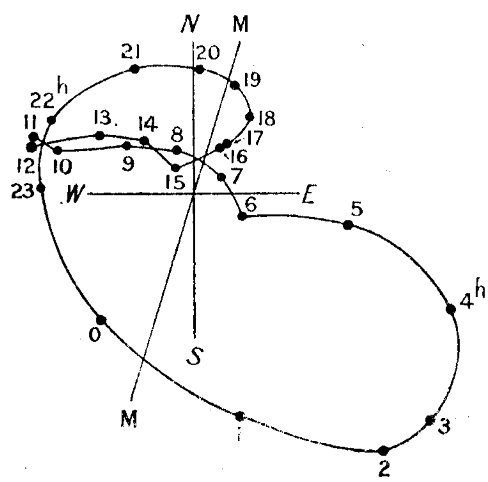
Plate XII.



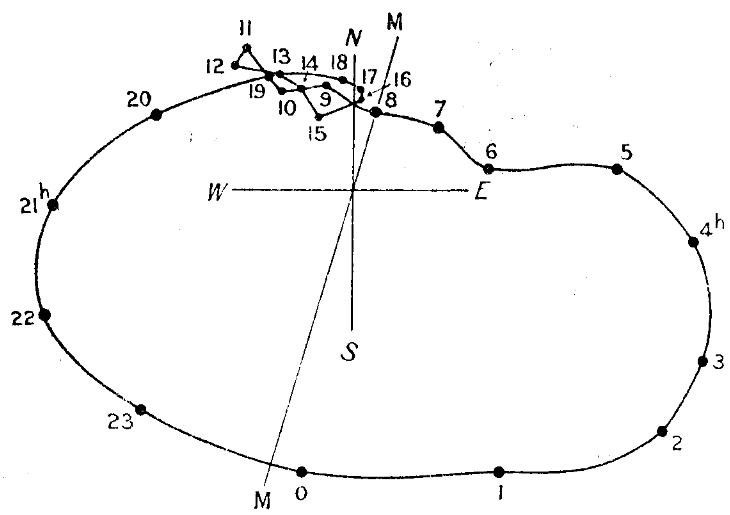
Vector Diagram for Summer Months, 1919, all Days.



Vector Diagram for Equinoctial Months, 1919, all Days.



Vector Diagram for Winter Months, 1919, all Days.



Vector Diagram for Year 1919, all Days.

Mean Diurnal Horizontal Disturbing Forces for Year 1919 at Christchurch.

(Greenwich Hours indicated.) N S. Geographical Meridian.
M M Magnetic Meridian.