Instructions
for the Guidance of
The Staff of Surveyors
under the
Provincial
Government of Wellington.

Survey Office, Wellington, N.Z.
November 25, 1868.

FACSIMILE COMPILATION

Instructions here below, were downloaded from
old newspapers:
THE WELLINGTON INDEPENDANT
dated 6th & 20th March 1876

CIRCULATION
Best guess for the 1876 publication, is that having been written
and published by the Survey Department Wellington under the heading of
"The Provincial Government of Wellington 1868",
it was re-issued as the national guideline by the new Central Government 1876.
No local rules pre-1876 from other provinces have been found to date.
Provinces were abolished; ... to counties, and then territorial authorities.

AMENDMENTS ?
Given the 8 year discrepancy between the published date of 1868
and the action to reprint in newspapers dated 1876,
there are likely to be a few text differences if compared to an original issue.

THE MISSING APPENDICES
The oft referenced appendices herein
were not included in the newspaper publication.
They remain to be found for attachment herein.

CONTENTS

Note well: "Appendices" have not been found to date for this facsimile copy.

Instructions for the Guidance of the Staff of Surveyors under the Provincial Government of Wellington.

Survey Office, Wellington, N.Z.
November 25, 1868.

A uniform system of Surveying
essentially requisite for the prosecution of General Surveys.

1

For the economical and efficient prosecution of a general survey it is essentially requisite that a uniform system of operations should be determined and acted upon. Though various systems may be adopted to suit different localities, each having for its object to meet the requirements of population and to combat with the natural difficulties encountered with in the physical features of the country to be operated upon, yet the cost of surveys will be found to be proportionately more expensive the less efficient the system that is adopted. In order, therefore, to perfect the present system of surveying as practised in this Province the strict attention of the officers of the staff is directed to carry out the following instructions which also contain a general outline of the principles employed.

Primary object of the Surveys.
Chain Surveys liable to great accumulation of error.

2

The division of land into small sections being the chief object of the surveys in this Province, and as the districts may be said to consist generally of hilly and in most cases wooded country it is obvious that to find how many times a certain measure, such as a chain, is contained in a given piece of ground becomes a matter of some difficulty, and that by trusting entirely to chain measures under such circumstances, the accumulation of error must necessarily be great, thus rendering these surveys incapable of union "*inter se*" or of harmonious combination with other surveys.

Triangulation the best method for Surveys of an extended character.

3

Recourse must therefore be had to an accurate system of triangulation over such parts of the country as afford facilities for such a process, thus the wooded districts eventually became incorporated by an external network of triangles, precluding the errors before mentioned being transmitted beyond the precincts of their origin.

Top-down methodology required.

4

But even in the prosecution of a trigonometrical survey, which beyond dispute is the only safe basis for operations of an extended character, due regard should be given to the principle of working from "whole to part" and not from "part to "whole"; by the former method any errors become subdivided, but by the latter an undue accumulation becomes promulgated in the extension of the work.

The object of Major and Minor Triangulation.

5

Hence arises the necessity of applying two distinct series of trigonometrical operations, viz., the Major Series, embracing a large tract of country in as few triangles as the power of the

instrument at command and the natural features of the country will permit, thereby attaining the shortest lines of connection; and the Minor Series, the triangles of which derive their bases from the Major sides, and are made to be entirely dependent upon them. In turn these Minor sides afford checks to the chain measurements of the Sectional Surveys, and thus a system is initiated by means of which any undue errors become certainly detected, and limits to the intrusion of small unavoidable errors can be assigned.

The Major Triangulation, although assimilating in principle, not to be compared with the Great Trigonometrical operations of other countries.

6

It must be clearly understood that the Major Triangulation here spoken of is not of such a character as to be in any ways compared with the "Grand Trigonometrical Surveys of Great Britain or of India". The refinement and care bestowed upon these scientific operations were for the express object of measuring "Arcs of the Meridian" in order to determine the figure and magnitude of the "Earth", a purpose which can only be undertaken by wealthy nations and which would practically be of no service in meeting the wants of a new country, where the primary object is to execute expeditious and economical surveys so as to facilitate the sales of land and the settlement of the country.

Cost of Triangulation and statement of errors exhibited in the work.

7

In all National Surveys it is the custom to assign certain limits to the errors committed in the prosecution of the works, and this limit is apportioned according to the amount of accuracy known to be attainable in practice. By assimilating the principles of the Great Trigonometrical works to what is here called the Major Series, but without attempting to attain the same refinement and results, a considerable amount of accuracy is arrived at, and attended only with a moderate expenditure. It has been proved in this Province that the Major Series of triangles, the sides of which averaged from 8 to 10 miles, and executed with an 8-inch Transit Theodolite, exhibited errors less than six inches per mile at a cost of 14 shillings the square mile; and that the errors of the Minor Series of triangles, averaging from 2½ to 5 mile sides, and performed with ordinary 5 or 6 inch theodolites were less than 2 feet per mile when costing £2 14s. the square mile. As it would be impossible even in a champaign and well favoured country to attain such constant accuracy solely by chain measurements, these results may be satisfactorily considered to be far within a limit of error that could safely be assigned.

Order of procedure for Surveys.

8

To ensure an harmonious conformation of the various surveys, after a previous reconnaissance, the order of procedure should be :—

First, Major Triangulation;
Secondly, Minor Triangulation;
Thirdly, The traverses of the boundaries of blocks, their rivers, streams, road lines, and sectional subdivisions.

Method to be pursued when the order of procedure cannot be adhered to.

9

But owing to circumstances over which there is no control, the above order cannot always be adhered to, and must therefore be modified in such a manner as to render the surveys easily susceptible of incorporation with the process immediately preceding.

Thus a block of un-surveyed land of moderate extent may be commenced by erecting one or more principal stations at distances averaging 8 to 10 miles apart so as to embrace the whole block and to become eventually points for the Major Series. The Minor Triangulation may then be proceeded with. Or small isolated blocks and sections may be at once submitted to the ordinary process of a chain survey after erecting minor trigonometrical stations to be hereafter fixed at intervals of from 2½ to 5 miles apart, to which the traverses can be referred. New Surveys adjacent to Trigonometrical points to take initial elements from them.

Link surveys to existing start points.

10

But in new surveys it will now be generally found that the localities lie adjacent to and within moderate distances from some fixed trigonometrical points affording the initial elements for commencing the new survey, viz. : — a point of departure, the direction of the meridian, and a base of ascertained length for the extension of the triangulation. In such cases advantage is to be taken of all or any of the above data to prevent further surveys partaking of the character of detached operations.

MAJOR TRIANGULATION.

Description of instrument to be used for Major Triangulation.

11

For Major Triangulation the instrument used should be an eight inch Transit Theodolite somewhat similar in construction to the altitude and azimuth instrument.

Base Line.

12

The base line from which the sides of the triangles in extension derive their measures ought to be selected on an even plain convenient for chaining and of not less than 2 to 2½ miles in length. As the accuracy of the succeeding work depends upon this initial measure, especial care and attention is directed to the line being quite straight and clear of impediments in the lay of the chain, to the expansion or contraction of the chain due to temperature, and to its stretch during measurements.

Standard length of chain, and its adjustment to 62 ° Fahrenheit

13

Previous to commencing the measurements a standard length of a chain should be laid down by marks between two blocks firmly let into the ground at a distance equal to the length of the standard chain when adjusted to a temperature of 62° Fahrenheit (the standard of British imperial linear measures), making an allowance for expansion or contraction of 0.0000065 being that to be adopted of iron on unity for every degree of Fahrenheit above or below 62°.

Method to be observed for the measurement of the Base Line.

14

The measurement may be made with the ordinary steel chain, which, when once adjusted, or nearly so, to the standard length laid down as above directed, should not be re-adjusted until the whole of the measurements are completed. The chain is to be tested with this standard length before and after each measurement (noting temperature) and its stretch carefully recorded. During measurements it should have a tension equal to 20lbs, as indicated by a spring balance, and its extremes are to be marked upon boards fitted for the purpose with

pieces of lead let into the upper sides, and with spikes underneath to fasten them firmly in the ground. Variations of temperature during measurements should be observed.

Amount of error to be admissible in the measurement of the Base Lines.

15

The base line should be measured at least three times and if well executed the amount of error need not exceed three inches for every hundred chains of its length.

Appendix A furnishes examples illustrating the measurements of the base lines on the Wharekaka and Opaki plains.

Note — If the base line lies elevated above mean sea level a reduction is necessary.

Log. reduction in feet = Log. length of base in feet + Log. height above sea level + Const. Log. 2.68009.

Selection of Stations.

16

The stations are to be selected upon the highest and most commanding hills whenever practicable, but if by reason of bush or other impediments this is not so, then care must be taken that their positions secure an unobstructed view of the stations in advance.

The network of triangles ought to be so arranged as to form a succession of polygonal figures, hexagonal being the most convenient, and as nearly equilateral as circumstances will permit. This however being difficult in practice, the rule to be observed is that no triangle for extension should contain angles less than 30° or more than 90°. Efforts should be made to obtain the bearings of both diagonals when the triangles arrange themselves in quadrilaterals, as is sometimes the case where the breadth of open country is limited.

Stations to be marked with boxes or blocks of totara, and with an iron peg, and to have piles or mounds raised round them.

17

An excellent and also an economical method of marking the centre of the stations is with boxes made of the heart of totara or other durable wood, into which the pole of the signal flag is inserted. These should be let into the ground previous to commencing the observations for bearings. In distant parts of the country it will be sufficient to place a sawn totara block 2 feet long and 6 inches square. An iron peg of the usual Government pattern is also to be placed at the station in case of accident from fire. To render the stations more easily distinguishable a pile of stones or a mound of turf about five feet in diameter at the base, and five or six feet in height is raised round the station.

Elimination of errors caused by false graduation on the limb of the Theodolite.

18

In order to diminish the effect caused by errors of graduation on the limb of the theodolite it is important that the bearings be read on the whole limb by successively shifting vernier A a certain number of degrees after every round of observations according to the number of repetitions required. Let a be the number of repetitions proposed, b the number of verniers, and x the shift of vernier A in degrees, then $x=360°/ab$. Four repetitions will generally be found sufficient, and as there are two verniers to the 8 inch theodolite by formula $x = 360°/42 = 45°$, or the number of degrees vernier A has to be shifted after every complete round of observations. If an Everest Theodolite having three verniers be used, and the same number of repetitions be required, then the shift on the limb would be 30°.

Errors arising from dislevelment and want of collimation.

19

The theodolite is further liable to errors arising from dislevelment, and from want of correct collimation. However carefully the mechanical adjustments for these errors may be performed they can never be made perfect, and are constantly liable to disarrangement.
But by simply reversing the instrument in altitude and azimuth the whole of the above errors become destroyed. Therefore observations cannot be considered satisfactory unless this system of reversion is attended to, taking care that the number of observations are equal upon each reversion of the instrument.

Errors arising from false centring.

20

There is still another source of error arising from the centre of rotation of the instrument not being a fixed point. The reading off of all the verniers at every observation cancels this effect.

Method of observing Bearings.

21

The instrument being firmly fixed over the centre of the station and carefully levelled is to be set with vernier A nearly on the back reading of a station from which observations have already been made, and the cross wire of the telescope brought to bisect exactly the signal of that station. Then un-clamp and slowly move the instrument in azimuth from left to right until it points nearly to the next station in order for observation, clamp, bisect, and read off as before. In this manner observe and read successively each station round the circle, until the station first set upon is read again, and record its return readings. Should these not differ materially from the former readings it is a proof that the instrument has not shifted in position during the round of observations which may now be considered as one set.

Second set of bearings.

22

Next set the instrument with vernier A 45° in excess of the given bearing of the back station referred to before, un-clamp the *lower* plate, and turn the whole body of the instrument round from *right* to *left* until the cross wire bisects the said station. Then proceed to re-observe every station as before directed. This will give a second set of observations on the same face of the instrument.

Third set of bearings. Face reversed.

23

Now turn the instrument completely round in altitude, shift vernier A 45° further on the horizontal limb, then un-clamp the *lower plate*, and turn the body of the instrument round in azimuth until the cross wire again bisects the reference station; the instrument by so doing will become completely reversed; the face of the vertical circle if before on the right hand side will now be found on the left of the observer. Re-observe all the stations for a third set of bearings to be termed "face reversed".

Fourth set of bearings. Face reversed.

24

Lastly shift vernier A still further 45° on the horizontal limb, and observe a fourth set of bearings also "face reversed".

Arithmetical means of the hearings to be taken.

25

By attending to the above directions, four separate observations, taken equally upon both faces of the instrument, and comprising eight readings (since there are two verniers) are obtained for each station, and the arithmetical mean of the readings is to be taken as the mean bearing, with every chance of its being within a very few seconds of the truth, providing that the levelling of the instrument has been attended to, and the observations carefully taken.

(See appendix for form of field book.)

Vertical Angles.

26

Vertical angles are to be observed to all principal stations upon both faces of the instrument; the mean readings will furnish the true angles of elevation or depression. The height of the instrument above the ground at the time of observing, and also of that part of the object observed to, should be recorded in the field book.

Base of Verification.

27

Similar observations are to be taken at every station until the base of verification is arrived at. This second base line must be measured with the same amount of care as was bestowed upon the first. The triangles comprised between these two bases will then form a complete series, and the computation of the sides should be forthwith commenced.

Geodetical Angles.

28

The differences at any station between the *mean bearings* of any two other stations observed there-from will be the Spherical or more properly the Spheroidal angle, included by the planes of the great circles joining the station observed from and the stations observed to. Since all three angles of every triangle used for computation must necessarily be observed, it follows that if correctly measured the sum of the angles should be 180° + *e*, where *e* denotes the Spherical excess which may be easily computed from the formula $e=a^2 \sin B \sin C/2r^2 \sin A \sin 1$, *a* being the side comprehended between the angles B and C, and *r* the mean radius of the earth; constant log. $1/2r^2 \sin 1 = 0.3735695$ adopting Professor Airy's value of the mean radius of the earth.

Legendre's theorem for the computation of small geodetical triangles.

29

Legendre's Theorem proves that if one third of the Spherical excess be deducted from each angle of a triangle, and then computing with the angles so diminished with an arc base, the results give arc sides equally as accurate as when computed by the rigid and very laborious process of using chord sides and angles. This theorem holds good with triangles of 450 mile sides. The Spherical excess amounts only to 1" in 70 square miles; now as the largest triangle of the Major Series does not exceed this area, it may safely be omitted in our operations.

Errors of observation in angles to be expunged.

30

In practice with an eight inch theodolite the sum of the angles of a triangle generally vary on an average some 10" from 180° + E, or say from 180° omitting the Spherical excess. This difference exhibits the amount of error made in the angular measurements, and may arise from

a number of unavoidable causes. It is obvious that to obtain satisfactory results for the succeeding computations the geometrical conditions of the triangles must be satisfied by a system of correction dispersing these errors. The easiest method is to apportion one third of the triangular error to each angle, thus making their sum equal to 180°; but the best, and the one to be recommended is that explained in Par. 8, Page 322, Galbraith's Trigonometrical Surveying and Levelling.

System to be adopted in the order of computation.

31

Unless a system is also adopted for the computations the results will be found to vary, perhaps even so much as *prima facie* to destroy confidence in the correctness of the work. It must always be borne in mind that accumulation of error is less liable when the computations are as few and direct as can be performed, therefore operose, circuitous, and complex modes, intelligible only to the computer, should be studiously avoided.

Detection of error on closing sides.

32

Triangles arranging themselves in a polygonal figure, as BCDEFG, having a common apex at A, afford an easy and effective check upon the accuracy of the work. If AB be the given base it is obvious that by successive calculations of the triangles round the circle the side AB should return exactly to its measure, provided the triangular errors before mentioned have been so dispersed as to satisfy all equations of condition. But as this will rarely be the case the difference exhibited between the side AB, and its calculated measure on return, if within certain limits, may be eliminated on the principle of a gradual accumulation of error. It is quite practicable that this limit should be within the proportion of one link to every 100 chains of the length of side.

Elimination of Errors.

33

In order that the angles and sides should agree after eliminating the errors in each proceed in the following manner. The sum of the angles round the apex at A must be made equal to 360°, and the sum of the three angles of each triangle to 180°. Let AB be the base from which the computations emanate, then the sides AC, AD, AE, &c, in turn become new bases for continuation. Compute these round the circle and compare the difference between the Log. AB and that obtained by computation from the last base AG, call the difference *d*. Generally Log. AC=Log.AB+Log. sin B + Log. cosec C, but since Log.AC has to become Log.AC + *x*, *x* being the small logarithmic correction due to a gradual accumulation of error, then Log.AC + *x* = Log. AB + (Log. sin B + *x*/2) + (Log. cosec. C + *x*/2) . Take out the Logarithmic difference due to one second for these angles in every triangle of the series as indicated by a dot in the diagram and call the sum of these Log. differences *s* ; then *d/s* will be an arc of correction in seconds to be applied to each of the above mentioned angles. When the accumulated error causes the side AB to exceed its proper value, this correction is substractive from those angles to which the sine is applied and additive to those taking the cosecant, but the contrary is to take place when side AB is found to be short of its proper value. The sides may either be recomputed with these new angles or corrected in proportion to the angular corrections applied, and the discrepancy in the side AB will then totally disappear. These corrections are only to be applied when the errors are extremely minute and within the probability of errors in observation. (See Instructions for topographical surveying by Lt.-Col. Waugh, Bengal Engineers)

Polygons succeeding in order to be computed on the same principles.

34

Successive polygons CDEHIK, &c, should be operated upon in the same manner, observing in every case that two sides have always become unalterably fixed, the one affording a base for continuation whilst the other serves as a check. In this manner any number of triangles may be extended and the work verified during progress until the measured base of verification is reached. When the triangles form into Quadrilaterals as GLMF they present no check unless the bearings of both diagonals have been observed. Elimination of error in this latter case is analogous to the method just described, computing the triangles in the following order FLG, GML, GFM.

Test of Triangulation by base of Verification.

35

One of the severest tests that a Trigonometrical survey can be submitted to is a comparison of the computed length of the second measured base, brought up in the manner described with its actual measure. The maximum error allowable is one foot per mile, but in practice it has been found to be considerably within this limit. Should, however, the errors be large but not exceeding the above limit, their elimination on the principles before mentioned should be accomplished; this process entails the reworking of the computations.

Meridional and Perpendicular Co-ordinates.

36

The next process is to compute the meridional co-ordinates of every station from some one station generally chosen in a central part of the survey. If, however, one of the stations is also that of a previously executed trigonometrical survey, it would be proper to adopt it for this purpose, since it will furnish a point of departure and direction of the meridian in terms of the former survey and an ascertained height above sea level. The bearing of any one side in the triangulation having been determined upon those of all the rest are obtained by the application of the *corrected mean angles* of the computations. Suppose B to be the point of departure, first compute the meridian distance of A with the given bearing and length of side AB, then that of C from the two stations A and B, and in like manner those of D, E, F, &c , consecutively. It is to be remarked that the two resulting distances for any station should uniformly agree to a decimal of a link, since there exists no inconsistency between the angles and sides of the triangles. The differences between the meridian and perpendicular distances between any two stations afford data for computing the bearing and length of side, and by comparison with the observed bearing presents another check upon the accuracy of the work.

Plotting.

37

The scale to be adopted for the map is 80 chains to an inch. Previous to plotting the paper should be divided into squares representing meridian and perpendicular lines six miles apart. These lines besides facilitating the protraction of the work serve as measures of latitude and departure for the connexion of sheet to sheet and eventually become convenient basis for setting off the true meridional and longitudinal lines. Also, with the aid of a table of Natural Tangents bearings may easily and accurately be protracted from them, and they preserve a uniform scale for reference notwithstanding the expansion or contraction of the paper caused by changes of temperature. It is recommended to plot the stations from their computed Meridional co-ordinates and then to verify each by the protraction of its bearing and distance from other stations.

The bearings and lengths of the sides must be neatly written upon all the lines specifying whether derived from observation, computation, or measurement conformable with the rules furnished in Appendix. The Meridional Co-ordinates are to be written against every station.

Differences compared between plane and spherical measurements as affecting the Survey.

38

As the spherical excess has been omitted to be taken into account in the computations of the triangles, for the reasons advanced in Paragraph 29, the results may be affirmed to be based upon the false supposition of the earth being a plane instead of a sphere. Now, as the difference between an arc on the earth's surface and its chord amounts only to 24 feet in 69½ miles, and as the limit of error assigned for our work is considerably greater than this amount, it follows that for the purposes intended the omission is immaterial, and taking into consideration the means at command, it may also be advanced that the computations have been affected on the true assumption of the sphericity of the earth with as much propriety as if the very small necessary corrections had been strictly attended to.

Computations of Latitudes and Longitudes.

39

Hitherto the plot of the work has been entirely based on the principles of Plane Trigonometry. Sir John Herschel remarks - "The true way of conceiving the subject of a Trigonometrical Survey when the spherical form of the Earth is taken into consideration is to regard the network of triangles with which the country is covered as the bases of an assemblage of pyramids converging to the centre of the Earth". With reference to these observations instructions for the computations of the latitudes and longitudes of the stations and the convergency of the meridians from the computed sides and bearings of the triangulation, and for the graticule of the map will be hereafter issued.

MINOR TRIANGULATION.

Instructions for the Major Series generally applicable for the Minor Series.

40

As ample instructions have been given for conducting the Major Series of triangles upon principles the best suited for the attainment of a degree of accuracy to be within an assigned limit of error, and as the same principles modified are generally adaptable to all trigonometrical operations, it is only necessary to show, without repeating that which has already been described, their application to the Minor Series of triangles succeeding the first process.

Average size of the Triangles, and the class of Instrument to be used.

41

The sides of the triangles should average from 2½ to 5 miles, and the class of instruments the best adapted for the work is the 5 or 6 inch Transit and Everest Theodolites.

Triangles to be based upon the sides furnished from Major Series.

42

The base should be derived when ever practicable from the sides of the major triangles by what is technically termed "breaking down" from the latter sides. Thus the sides AC, BC of a major series furnish suitable bases for the determination of the minor points D, E and F, and the sides deduced from such data become in turn new bases for extension of the minor series.

When it is impracticable to emanate a base from the major series of triangles, recourse must be had to actual measurement, as detailed in Paragraphs 12 to 15. The measured length ought not to be less than one mile, and the limit of error allowable is one link for every hundred chains.

Form of the figures for extension of the Triangles and manner of marking the Stations.

43

Extension of the triangles by net work or in longitudinal series throwing out additional triangles from the flank where required according to circumstances that present themselves should be adopted taking care that every major point that lies within or adjacent to the scope of operations become also points of the series, thus incorporating the whole of the work so as to form an harmonious combination. The stations are to be marked with the totara block and iron peg described in Paragraph 17.

Angular Observations and limit of error.

44

All three angles of every triangle for extension must be measured with the same care for guarding against errors as explained in Paragraphs 21 to 26. The triangular errors from experience have been proved to average less than 20", and in any case should not exceed the limit of one minute.

Tertiary points fixed by intersection.

45

Tertiary points lying within the minor series of triangles should be determined by intersection from at least three stations in order to ensure identity of the point observed. One observation on each face of the instrument will be sufficient for such points. Angles ranging from 15° to 150° give satisfactory results.

Computation of the Triangles.

46

The sides being small the triangles are treated exclusively as plane, and errors of observation are dispersed by equal distribution on the three angles. The system for computation of the triangles in extension, the elimination of errors in their sides and the subsequent process of protraction of the stations on the map are analogous to the methods detailed for major triangulation. The limit for errors in the sides as exhibited on closing with previously ascertained lengths is 4 links in 100 chains. The scale of the map should be 40 chains to an inch, unless otherwise specially desired.

Topographical features to be truthfully depicted.

47

The delineation of topographical features furnishes a wide scope for the exercise of artistic talent.

The master lines are — 1st : The water courses.
2nd: The leading mountain ranges.

The junctions of principal streams, and the most remarkable peaks ought to be accurately fixed by intersection from the stations, and the characteristic configurations of the ground whether in rounded and undulating or peaked and rugged hills, the general direction of the water courses, ridges, and spurs, the watersheds, bush and other natural features, after a careful study with the aid of a pocket compass, may become faithfully depicted on the map.

It should be borne in mind that rude sketches from memory consisting of caterpillar like daubs for mountain ranges and spurs and vermicular lines for streams unlike nature and untruthful in existence only disfigure the map and render it incorrect, whereas drawings from nature with the relative distances of the features accurately delineated enhance to a high degree both the beauty and usefulness of the plan.

SURVEYING BY TRAVERSE.

The system of surveying by traverse explained.

48

After a sufficient number of Trigonometrical points have been fixed over a block of land undergoing survey, the delineation of its boundaries, streams, proposed road lines, and sectional subdivisions is to be operated upon by traversing, which is a system of measuring by a series of successive straight lines of various lengths and on dissimilar bearings, a circuitous route from any one point to another, however distant or placed with reference to each other. The sums of the meridian and perpendicular distances between the stations composing the traverse furnish data for the computation of the bearing and distance between the two points, and if these points are also trigonometrical stations of the survey it is obvious, if the work has been accurately performed, that the deduced bearing and distance from traverse should coincide with the trigonometrical values thereof. Again if when the traverse starts from a certain point, and after proceeding in a circuit it returns to this same point, then the sum of the distances gone north should be equal to that gone south, and the sums of the distances gone east and west should also be equal. Hence the traverse system furnishes an easy check for ascertaining the accuracy of the work, and thus practical limits to the errors committed may become assigned.

Degree of accuracy attainable by the traverse system of surveying.

49

Upon open and tolerably level country, where it is possible to obtain fair length of lines between the traverse stations, and where no great impediment to the horizontal lay of the chain is met with this system is susceptible of remarkable accuracy. The small unavoidable errors exhibited on computing the meridian and perpendicular distances ought not to exceed the limit of one link for every ten chains so traversed, and in the actual prosecution of such surveys they have proved not to exceed the one half of this amount. But over hilly and rough localities where the lines are necessarily short, and the horizontal measurement of a chain's length over the ground may be said at best to be equivocal, this process entirely fails, and should therefore only be employed for obtaining the points of intersection of section corners, and the lengths of those important lines when there is evidence of the practicability of applying the system, or in the absence of all other available methods.

Rules for detecting errors in the bearings of the traverse lines, and for their elimination.

50

Euclid, Book I, Prop, XXXII, demonstrates, that any rectilineal figure can be divided into as many triangles as the figure contains sides, and consequently that the sum of the interior angles, plus 300° is equal to twice as many right angles as the figure has sides. The application of this theorem furnishes a complete check upon the angular measurements of the traverse. Thus if the theodolite is set up at a Trigonometrical station, with the axis of the telescope pointing to another one, whilst the vernier reads the known bearing between these two points, the bearing of the first or any station visible of the traverse is obtained in terms of the

Trigonometrical Meridian. Then when the instrument is removed to the station so observed and set back on the Trigonometrical Station with the vernier still on the same reading the bearings of the adjacent stations are obtained, and thus successively the bearings between all the stations. The difference of bearing between any two adjacent stations is an angle of the rectilineal figure formed by the traverse. If then the so deduced bearing from the last station of the traverse to a second Trigonometrical Station arrived at differs somewhat from the correct bearing as obtained by resetting the instrument when on this second Trigonometrical Station to the former one left or to any in view, this difference will exhibit the amount of error committed in the measurements of the interior angles of the rectilineal figure before alluded to. The best method of expunging these errors is by equal dispersion throughout the traversed stations, and their limit should be confined to one minute for every two bearings.

Manner of preserving an uniform meridian.

51

Care must therefore be taken to observe as many of the traverse stations as can be seen from the trigonometrical points so that by constantly referring back to such data for correction the dispersion of errors may be limited to their proper precincts; and also in depressed localities such as ravines and beds of rivers and streams, where stations are liable to become numerous, long bearings should be thrown from point to point near to the traverse for constant and convenient reference, to preserve the uniform direction of the meridian.

Detection of errors in the Chain Measurements of a Traverse.

52

If the above rules for preserving an uniform meridian throughout the traverse have been strictly attended to and provided distances have been fairly chained, the sum of northing and southing, or of easting and westing by traverse will be found to coincide nearly with the trigonometrical values in the case of a traverse performed between two points fixed by triangulation or to closely balance in instances when the traverses check by closing circuits. If the errors exhibited lie within the limits stated in Paragraph 49 they may be apportioned amongst the several distances according to the following rule: as the sum of all the *chained* distances of the traverse is to the whole error in northing and southing or easting and westing respectively, so is each *chained* distance to *its correction*, additive or substractive from the particular northing or southing, easting or westing between the two stations, and then the sum of the meridian distances so corrected will agree with the check data.

Cases in which this system of Traverse may be modified.

53

When all the coordinates on the meridian have been referred to some one point on the survey, they afford an easy method for the deduction of the bearing and distance between any two of the points, and thus great facilities are acquired for setting off and running intersecting lines at certain intervals apart, to represent the divisional lines of the several purchases or applications for land. But when the object of the traverses is simply to delineate the course of streams and other features forming what may be termed indefinite boundaries in in order to compute the areas of blocks, but without requiring to base thereon the dimensions of definite boundary lines or of sectional sub-divisions, then the same amount of accuracy is not sought for, and it will only be necessary to plot the traversed stations by the ordinary method of protraction.

Standard length of chain to be obtained from the Survey Office, and its uniform length preserved during survey operations.

54

The instrument used for traversing is generally a 4-inch theodolite. The length of the chain used is a subject of primary consideration; the correct standard length as obtained from the Survey Office, must be carefully preserved by laying down blocks to mark this length on the occasion of every shift of camp, and the chain should be tested with this measure after every day's work. The neglect of this precaution causes a vast amount of inconvenience besides making use of a wrong measure, which in itself is a very reprehensible proceeding; and should this measure be constantly varying all efforts to test the accuracy of the work become unavailable notwithstanding the care that may have been bestowed in its execution, and thus the survey is rendered incapable of being harmoniously combined with other surveys.

Reduction of lines measured over uneven surfaces to the horizontal measure.

55

The dimensions of all lines are to be given as if measured on the horizontal plane, and the area of land is to be computed on the same basis. The measurements of lines, therefore, over the surface of hills and slopes of various inclinations require to be reduced to the horizontal measure, either by calculation or by the more practical method of holding the chain or part of it at a time as nearly horizontal as may be judged and letting a plum line fall from the elevated end to the surface of the ground.

Field Book.

56

The field book is to be paged and indexed, and should be kept in a neat and explanatory manner the reverse case being a sure indication of carelessness and neglect. Memoranda are to be entered in pencil at the time and place of observation, and are not to be entrusted to memory nor noted on slips of paper, as such are liable to become lost, and thereby entailing the necessity of going over the work again. The pencil remarks are to be inked in as soon as practicable, and no erasures are permitted, nor are leaves allowed to be torn from the book. The field book is ruled with a double line down the centre of the pages, between which the chain distances are entered, and commencing at the bottom of the page. The offsets are noted to the right or left of this central column, according as to whether they lay on the right or the left hand of the chain line, and opposite to the distance that they have been measured or estimated from. A circle round a distance thus (1500) denotes the total length of line between two stations, and the commencement of a new line should further be marked by a line drawn across the page. Each traverse station should be numbered, and the bearings observed from them entered on the left hand side of the page. Always write down the backset from which the meridian is derived at each station thus B.B. station 1=221° 40' and whenever the backset of the last station observed from is rejected for that derived from a more reliable source, or otherwise when the bearing as brought up by traverse is to undergo correction by a reset of the instrument upon a bearing known to be a more correct one, the back reading of the last station, as well as the fore reading to the station in advance, should be recorded in order to obtain the requisite data for the correction of the errors committed in observing the bearings up to this point as explained in Paragraph 50. If this remark is neglected there will be no evidence forthcoming to prove the constant direction of the meridian throughout the survey. The field book is to be deposited in the Survey Office on the completion of the map.

Traverse stations to be permanently marked at certain intervals.

57

Every traverse station should be temporarily pegged during the prosecution of the work, and eventually at intervals averaging 40 chains along the traverse, three of the stations lying in consecutive order should become permanently marked with blocks 4 inches square, and eighteen inches long, but if there is an absence of Trigonometrical points throughout the survey the size of these blocks ought to be increased to six inches square and two feet in length. One of the stations is to be chosen whenever practicable within the view of a Trigonometrical station. These precautions will furnish to a future Surveyor a point of departure, and a correct bearing of the meridian in terms of the survey for commencing additional work without entailing the necessity of re-executing much of the traverse work in order to arrive at such data.

Uniformity of lines to be preserved in laying out sections.

58

The preliminary traverses having been executed, the next process is to subdivide the block into small sections. As it is the custom to sell land in this Province prior to survey the selections usually vary greatly in size and shapes, and consequently it requires some discrimination on the part of the Surveyor to scheme these purchases into sections complying with the terms of the application, and at the same time to preserve uniformity of lines. The following are the chief points to which attention is directed : —

The sections should be generally in rectangular figures, and if possible, lying in the direction of the Meridian and Perpendicular.

As the frontages upon road lines, rivers, streams, &c, vary in proportion to the number of acres applied for, these measures are to be calculated upon the back line, which is invariably to be placed at an average distance of forty two chains from the frontages in cases where the percentage for road allowance is included, or of forty chains when this allowance is withheld.

When a number of applications lie together, no unpurchased land should be permitted to remain intervening excepting in such quantities as to form other sections.

Allowance for Roads.

59

The allowance for roads is to be made as follows :—

On purchases under 500 acres an allowance of 5 per cent.

On purchases above 500 acres and under 1000 acres 4 per cent.

On purchases above 1000 acres 3 per cent.

For example, an application for 400 acres will require that 420 acres be laid off on the ground, and the total average is written thus on the map : 400 + 20 ; and similarly that for 900 acres should be marked out equal to 900 + 30 acres.

Method of laying out 5s. Land.

60

The regulations affecting 5s. (5%) land, demand that the sections should range from 80 + 4 acres to 320 + 16 acres. In large applications as great a number as possible of these section lines are so schemed as to intersect at or pass through the Trigonometrical stations, and their dimensions are based accordingly upon these points.

Former surveys to be verified.

61

In cases where sections have been previously laid out the pegs should be sought for, verified, and connected with some point in the new survey. When the pegs of former survey cannot be found, and the owners on application refuse or are unable to point them out, then they should be replaced in accordance with information supplied from office maps and Crown Grants.

Relation between section and survey line's.

62

If the section lines are based upon Trigonometrical stations a bearing and distance deduced by computation should be recorded from every Trigonometrical station to the nearest intersecting lines, but when they are based upon traverses or conjunctly upon Trigonometrical and traverse stations the points of impingement of the section lines upon the traversed lines should also be calculated and recorded from the nearest traverse station.

Method to be pursued for fixing sectional corners.

63

In open country it will generally be found that the corners of sections can be conveniently and very accurately determined by running lines, either on the bearings of the section lines or on those as computed from the Trigonometrical or other well fixed points in the survey, until they intersect each other at the point desired. (See Paragraph 53.) It is recommended in the latter case that the points of intersection should be determined by at least three such bearings, as their near coincidence will be an indication of the accuracy of the work. It is very necessary that proper precautions are taken to preserve the true direction of these lines by referring as opportunities offer to points which will furnish check bearings. In bush or partly bushed country a system combined of chained and of intersecting lines should be adopted.

Manner of marking Section Corners.

64

The corners of sections are to be marked with a block of totara 6 inches square and 2 feet in length, leaving only 4 inches above the surface of the ground, also with the usual Government iron peg and with lockspits dug three feet long and one foot in width and depth in the exact direction of the section lines, and further to indicate the true direction of these lines for fencing and other purposes pegs are to be driven at any convenient distance from the corner peg. Too much care cannot be bestowed to ensure the durability of these marks.

The angular points only of the boundaries of land comprised in one Crown Grant to be marked on the ground.

65

When a number of sections are comprised in one Crown Grant, only as many of the corners as are also the angular points of the external boundaries of the Crown Grant are required to be marked on the ground, and it is not necessary to cut or to indicate throughout the direction of the lines between any two such corners provided the pegs can be determined by other more direct means. Bearings should be given from the corner peg or from some point near to two or more survey marks in view.

Scale for Maps.

66

The scales to be adopted for Maps unless special directions to the contrary should be given are:-

For Townships:

1 Chain to an inch for small portions.

2 Chains to an inch for general plans, containing ¼ acre allotments.

3 and 4 Chains to an inch for general plans, containing 1 acre allotments.

For Suburban and Rural Sections:

4 and 5 Chains to an inch for blocks under 500 acres.

6 and 8 Chains to an inch for blocks from 500 to 1000 acres

10 Chains to an inch for blocks from 1000 to 5000 acres.

20 Chains to an inch for blocks above 5000 acres.

For District Maps, 40 Chains to an inch.

For General Maps, 80 Chains to an inch.

Plotting.

67

The plans are to be drawn upon mounted paper which should not be cut less than two feet square. Having set off meridian and perpendicular lines 50 or 100 chains apart according to the scale adopted (see Paragraph 37) proceed to lay down the principal points from their computed meridional co-ordinates and then to plot in the intervening work with the ordinance card protractor. All lines drawn upon the plans are to have their bearings and distances legibly written upon them when possible to do so without crowding, otherwise a table shewing this data is to be inserted in the blank space of the paper (see Appendix).

Type of writing on the Plans.

68

The style of writing upon the plans should be plain, neat, and tending more towards general utility and saving of time and labour than to pictorial and elaborate effects. The size of the letters should be strictly proportionate to that of the plan; the most conspicuous characters are to be used for names of the first order whilst the lesser characters indicate those of smaller importance (see Appendix). The bulk of the writing should lie parallel with the top and bottom of the plan; curved lines are preferable for names of Districts, Blocks, Mountain Ranges, Rivers and Streams, but in no case should the writing appear upside down on the plan.

Opposite Corners of Roads.

69

A road line running by stages on different directions requires that the variations in length of its opposite sides for every succeeding stage should be computed in terms of the known angle that the new stage makes with the preceding one. A straight line drawn between any two opposite corners of a road bisects the angle included between the stages at those points, and consequently the bearing of this line is known. Again the distance between the opposite corners is readily obtained by inspection from a Table of Natural Tangents and Secants, being equal to the cosecant of half the included angle above alluded to; also the difference in length between the opposite sides of the road to these points is equal to the cotangent of the same angle. For example: suppose the stages of a road 100 links wide run in directions bearing 25° and 155° then the included angle is 130° and the bearing from corner to corner opposite is 90°.

Now, by reference to a Table, the Natural Cosecant and Cotangent of 65° or one half the included angle to Radius 100 is 110.3 links. and 46.0 links respectively, the first indicating the distance between the opposite corners and the second what one side of the road is longer than the other to these points. By successive computations for every angle that the road makes the total lengths of the opposite sides for every stage becomes known, which is very important where sections front upon tortuous road lines. The opposite corners of cross roads are determined in the same manner. Notwithstanding the very simple manner by which these dimensions for opposite sides of roads are obtained, they have frequently been stated in impossible quantities on the Maps, thus betokening on the part of the Surveyor either a wilful neglect or a gross ignorance of the first principles of Geometry.

Computing Book.

70

The computations of a survey are to be kept in a book for the purpose and to accompany the plan when forwarded to the office of the Chief Surveyor. The writing of the figures must be clear and the statements methodically arranged so as to exclude all doubt in the mind of a second person who may have to recompute the work; besides neatness and order materially conduce to the accurate and expeditious working of any elaborate calculations.

Difficulties met within a Survey and not provided for in these instructions to be dealt with by the Surveyor or by reference to Chief Surveyor.

71

As it is utterly impossible by written instructions alone to impart to the Surveyor a thorough knowledge of the various and often complex duties required to be performed or to provide for all contingencies that arise in the progress of actual operations, much must necessarily be left to his intelligence and discretion, and when difficulties are encountered which he is unable to overcome an immediate report detailing the circumstances should be made to the Chief Surveyor.

Concluding Remarks

72

Lastly the Surveyor should endeavour by a careful study of the Standard works on Surveying to make himself thoroughly acquainted with not only the minor but also the higher branches of the profession and this combined with industry and zeal in the performance of his public duties will acquire for him a high professional reputation and the respect of his employers.

---------- / - \ ----------

Returns and Vouchers.

The following Returns and Vouchers are to be forwarded to the Survey Office by each officer of the Staff.

MONTHLY: Abstract of labourers' wages; voucher for contingent expenses; journal of work; report on the general progress of the Survey.

QUARTERLY: Vouchers for field and instrument allowances.

ANNUAL: Return specifying the nature and quantity of work performed by the Surveyor in each District or Block, and the cost of the separate surveys.

Hours for Work.

The hours for work whilst in the field are from 8 a.m. to 5 p.m. during summer months, and from 8.30 a.m. to 4 p.m. during winter.

Trigonometrical stations to be repaired when requisite.

The trigonometrical stations and other important survey marks when visited by a Surveyor should be repaired if found to be out of order. *Surveyors to supply themselves with book and instruments.*
The Trigonometrical Surveyor is to provide himself with a five or six inch transit or Everest theodolite, Galbraith's Treatise on Trigonometrical Surveying and Levelling; Shortrede's Tables of Sines and Tangents, Hutton's Logarithms, and a complete set of plotting instruments; and the Sectional Surveyor with a four or five inch Theodolite, a modern treatise on surveying, Hutton's or Chambers' Logarithms and a complete set of plotting instruments.

HENRY JACKSON,
Chief Surveyor.