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HENRY BUNNY,
PROVINCIAL SECRETARY.

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Report by Henry Jackson, Esq., Chief Surveyor, on completion of Trigonometrical Surveys over Crown Lands, &c.

Survey Office,
Wellington, 6th June, 1872.

SIR,—I beg to forward to your Honor herewith, a diagram map of the network of principal triangles which compose the Triangulation of the Province of Wellington, executed between the years 1866 and 1870.

The Trigonometrical Surveys, which were in existence prior to 1866, could scarcely be included under this nomenclature. They were unscientific in principle, and consequently erroneous in deduction. They merely included within their operations, in a disjointed manner, Port Nicholson Harbor, together with small portions of the Wairarapa and East Coast Districts. A strong prejudice existed at that time amongst the professional men in charge of the Survey Department, against this Trigonometrical mode of Surveying, which was condemned as impracticable in this Province, except at an enormous cost; whilst at the same time, it was regarded as a scientific theory from which no practical results could accrue. Thus it was not until so recently as 1866, that an organised system of Triangulation was commenced, when your Honor originated and intrusted to my charge the Trigonometrical Survey of the Province, on the completion of which, over Crown Lands, I have now the pleasure to report.

I will in the first place briefly sketch the method of procedure adopted in the operations, and then indicate the practical results which have accrued from their completion.

As a preventive to the accumulation of errors arising from a multiplicity of angular measurements, and at the same time to limit the character of the Triangulation in its prosecution, to the means at our disposal, it was intended at the commencement of the Survey to cover the Province with a network of triangles averaging 10 miles sides, to form what may be termed the major Triangulation, and that a secondary system of smaller triangles should succeed, taking for their basis these major sides. These principles were followed in the Wairarapa and over a large portion of the East Coast Districts; but owing to impediments presented by the natural features of the country in some localities, it was found necessary to modify this system either by reducing the size of the major triangles or by increasing them to such dimensions as would have defeated the main object of the Survey, viz:—the speedy determination of a sufficient number of triangulated points for the effective regulation of the chain surveys. The first mentioned course was adopted, and, confining the operations chiefly to the settled Districts and frequently checking the calculated deductions of the

triangulated sides by carefully measured bases, a symmetrical network of triangles —which will presently be proved to have harmonised *inter se* with remarkable precision—was thrown over those portions of the Province which were immediately under sectional Surveys.

The entire system of the Triangulation therefore rests upon eight measured bases. It will be needless here to detail the manner in which these bases were measured, beyond stating that the printed instructions for the guidance of the Survey Staff on this subject, were strictly adhered to; that every care was bestowed to ensure concordant results in the several measurements of each base line; and that the unit of measure employed was a new standard chain of 66 feet, by Troughton and Simms.

I will now proceed to exhibit in the following table the amount of precision attained in the execution of the work, premising that the severest test Triangulation can be submitted to, is that of comparing the computed length of a verification base line with its measurement.

Initial Base Line.		Verification Base Line.			Error of Triangulation per Statute Mile.
Place.	Measured length.	Place.	Measured length.	Computed length by Triangulation in terms of Initial Base.	
	links.		links.	links.	links.
Wharekaka ...	16025·66	Opaki ...	20196·05	20196·39	0·13
Whurekaka ...	16025·66	Barton's ...	10662·90	10665·30	+ 1·79
Opaki ...	20196·05	Whareama ...	10048·20	10049·60	+ 1·12
Petoni ...	14271·28	Omarapapaku ...	12708·29	12708·30	Nil, rejected
Omarapapaku ...	12708·29	Scott's ...	15178·88	15180·41	0·80
Scott's ...	15178·88	Wanganui ...	8623·37	8623·59	0·20
				Mean	+ 0·81

N.B.—The result between Petoni and Omarapapaku was rejected on account of the bad triangles between Kapiti and the Manawatu.

From such consistent agreements repeatedly occurring between the computed length of a side of the triangulation and its measurement, the ratio of error existing in the work may be inferred with a close approximation to truth; and, founding upon this assumption, I estimate that the mean error of the triangulation is 0·81 links or 6½ inches per mile, which is equal to a ratio of $\frac{1}{9748}$ This minute degree of error I attribute to the care which was bestowed on the angular observations; every angle of a triangle entering into the computations having been read off at least eight times on different parts of the limb of the theodolite, and to the system adopted of computing the triangles combined in a series of polygonal figures, so that discrepant results in the common sides of each series (if found to be within the probable errors of observations) became susceptible of elimination on differential principles, before operating on the succeeding ones.

By reference to the map, your Honor will perceive that the connections between Wellington and the East and West Coasts respectively, are not as yet satisfactory, that between Wellington and the East Coast being merely the apex of two adjacent triangles, whilst the West Coast connection is formed with very inefficient and imperfect triangles between Kapiti and the Manawatu River. In order, therefore, to obtain a rigid connection, and simultaneously to explore and prepare for settlement a very large area of the Province, a series of triangles of sides, varying from twelve to twenty-five miles, has been planned, as indicated on the map by dot lines joining the selected stations over which the angular measurements are now being taken.

The perfect symmetry and large dimensions of these triangles, while forming the desired connections in a rigid manner, are proofs that the character of the work should rank in the first order of Trigonometrical operations. But the means at our disposal will not permit the attainment of the precision usually expected to result from such undertakings, where the greatest refinement is observed. If, therefore, a precision is attained to be equal to, and to confirm the estimate of error I have above stated as existing in the perfected triangulations, I unhesitatingly aver that this will be more exact than is required for the ordinary purposes of surveying, and will preclude the necessity of future similar operations, excepting for the furtherance of scientific researches.

In order to illustrate the practical results accruing from the Trigonometrical survey, I must now glance retrospectively at the conditions of the sectional surveys prior to the execution of this work. They consisted of numberless detached works, dependent solely on chain measurements. The errors arising from direct linear measurements over hilly and broken ground, were unavoidably great, and those, when added to the other errors emanating from a diversity of meridians, equally unavoidable in bush country, would have resulted in such a degree of inaccuracy as to render these surveys incapable of combination. Moreover, apart from these inevitable errors, there were others resulting from the incompetency and carelessness of some of the surveyors. The most important results

to be derived from the Triangulation may therefore be stated as follows:—The correct exhibition of the relative positions which detached surveys occupy, with a view to their combination; the indication of the accumulated amount of error existing in the same; the infallible detection of errors, and the precluding their promulgation outside their precincts in future surveys.

That these important results have been accomplished is fully exemplified by the compilations of the surveys which have been effected in this office during the past two years, and by the fact that our sectional surveys are now being prosecuted with such a degree of accuracy, that chained measurements are rejected as erroneous, when their results, on comparison with the triangulated measures, exhibit a ratio of error greater than one link in every ten chains traversed. It may further be stated that small as the assigned limit of error may appear to be, it is nevertheless a fact that the average rate of error now committed in the prosecution of chain surveys, does not amount to more than one-half of this limit.

Another very important result derived from the triangulation is the geodetical deductions of the latitudes and longitudes of its principal stations, with reference to an initial point. In co-operation with J. T. Thompson, Esq., Chief Surveyor of the Province of Otago, I was occupied during the years 1870 and 1871 in fixing astronomically the longitude of my private observatory at the Hutt. The observations were embodied in our joint report to the Hon. the Colonial Secretary, dated November, 1871, in which we stated the longitude of the Hutt Observatory to be 174° 57' 40·84" East. I also determined the latitude of the same place by observations on stars with the transit instrument in the prime vertical and with the following result:—

Date.	Star.	Position of Transit Instrument.	Latitude. South.	Mean.
			° ' "	° ' "
1870. July 22	ν Centauri	Circle, North ...	41 12 10·74	41 12 11·72
„ 26	Do. ...	Do. South ...	41 12 12·71	
„ 22	γ Lupi ...	Do. North ...	41 12 09·76	41 12 11·48
„ 26	Do. ...	Do. South ...	41 12 13·20	
			Mean ...	41 12 11·59

From these data the geographical position of the Wellington Observatory, considered as the initial point of surveys, has been computed to be in latitude 41° 16' 46·84" South, and longitude 174° 48' 49·65" East, and on this basis the geodetical latitudes and longitudes of the triangulation have been computed.

The true meridian was determined by astronomical observations at the Hutt Observatory, and at the base line in the Opaki Plain. From those data the true bearings of the sides of the triangulation were arrived at by computation, the Hutt meridian being used for the Wellington and West Coasts Trigs., while the Opaki meridian was adopted for those of the Wairarapa and East Coast. The two determinations of the true meridian were found to differ by thirty seconds, on comparing the true bearing from Mount Matthews Trig. station to Pencarrow light, as furnished by each determination. This difference may be said to represent the accumulated instrumental errors in the angular measurements of the triangulation between the Hutt and the Opaki, and assuming that these have been gradually accumulating errors, the mean error in the bearings of the sides of the triangulation would be fifteen seconds, or equivalent to six inches per mile, which ratio of error remarkably coincides with that which I have before stated.

With reference to the cost of this work, it is necessary, in the first place, to offer a few explanatory remarks. The area of Crown land covered by triangulation is two and a quarter millions of acres. The main triangles shown on the map are composed of 150 stations; while the minor triangles, which the small scale of the map does not permit of entry thereon, furnish about 750 more stations, fixed with almost the same care and accuracy as the principal ones. As both works have progressed *pari passu*, and were executed by the same officers, I must summarise the total cost thereof, and thence infer the probable cost of each work.

The total cost was £7000, which is in the ratio of three farthings per acre or £8 per station. But as some of the major stations were built in a most substantial manner, (see drawing on map) thereby entailing considerable extra expense in construction and in furnishing the means of transport to reach them; while as the delays occasioned by the state of the weather, in obtaining observations from them to distant objects, would also increase the outlay per station for the main triangulation—I estimate the increased expenditure to amount to £18 per station, which would give a ratio of one farthing per acre for the main triangles and a half-penny for the minor.

In connection with this report, I desire to diverge somewhat from its legitimate purpose in order to allude to and rebut, those expressions of doubt and scepticism with reference to the value and practical usefulness of this system of surveying, which emanated from certain professional quarters, when on my arrival in New

Zealand in 1862, I strongly urged its adoption in this Province. At that time I was not in a position to prove to demonstration the ultimate advantages of the system: but now that it has been subjected to the test of a fair trial, the results show that it is neither fettered with impracticable theories, costly in execution, nor unproductive of important practical benefits. Although many of the highest professional authorities have commended this work, alike with respect to its principle and execution, yet there are still to be found certain others holding antagonistic views, who stigmatise the precision claimed to have been attained, as either the result of chance coincidences or of a wilful and dishonest manipulation of figures, in order to produce an apparent coincidence in results.

Both those charges are absolutely baseless, and can be readily overthrown. To rebut the first charge, it is only necessary to point out that "chance coincidences" are not liable to repeat themselves, again and again, with startling frequency, under totally separate and different conditions, as they do in the results of the work to which I have been referring; while with respect to the second, I simply challenge those making it to offer one jot or tittle of proof in its support. In order that the means may not be wanting for this, I am perfectly willing to submit to competent inspection the whole of the original field books and calculations of the work.

The successful completion of this work will ensure a high degree of accuracy in the execution of the sectional surveys—a condition on which the secure tenure of land in a great measure depends; and when that, amongst many other important results has been achieved, I may be pardoned for expressing my deep satisfaction that the views I advanced ten years ago in favor of a trigonometrical system of survey, have been so completely justified by the logic of facts and experience. And this satisfaction is largely enhanced by the reflection that the results of the work referred to, justify that confidence so generously reposed in me by your Honor, when entrusting its execution to my care; while it must also be said that had it not been for your Honor's powerful and consistent advocacy of the adoption of the trigonometrical system of surveying in this Province—against strong opposition from professional quarters—and the hearty support which you afforded towards the work during its progress, I should never have been in a position, as now, to report on its successful completion, and to indicate the many important and beneficial results attendant thereon.

I cannot here refrain from strongly recommending the adoption of the same system in those Provinces where it has as yet been neglected; because sooner or later, this will require to be done, and the longer it is delayed the more difficult the solution of the problem of "adjustment of surveys" will be found.

In conclusion, I beg to bring under your Honor's special notice the ability and zeal which have been displayed by Messrs. A. Dundas, and J. Mitchell, District Surveyors, in the preformance of the Field work in connection with this survey; and I also desire to express my acknowledgement of the cordial support which I have received from J. G. Holdsworth, Esq., Commissioner of Crown Lands, in furtherance of this undertaking.

I have the Honor to be,
Sir,
Your most Obedient Servant,

HENRY JACKSON;
Chief Surveyor.

To His Honor
William Fitzherbert, Esquire, C.M.G.,
Superintendent.

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