No. 1,237A.—“Memoir on the Public Works of the Province of Canterbury, New Zealand.” By EDWARD DOBSON, Assoc. Inst. C.E.

THE portion of the middle island of New Zealand, now known as the Province of Canterbury, was colonized by a society entitled the “Canterbury Association,” whose first settlers arrived in New Zealand at Christmas 1850-51. The Charter of the Association having reverted to the Crown, the territory to which it referred was included in the Province of Canterbury, as constituted by the New Zealand Constitution Act in 1853.

In November, 1854, the Provincial Government of Canterbury established a Department of Public Works, which was placed under the professional superintendence of the Author, who remained in charge of the department up to the end of the year 1868.

The present Memoir is intended to furnish a history of the Public Works of Canterbury, from the establishment of the Public Works Department in 1854 to the completion of the Railways in 1868, so far as their history presents points of professional interest.

During the above-named period the survey of the province, commenced under the Canterbury Association, has been completed by the officers of the Survey Department: the eastern portion of the province has been thrown open to settlement by the construction of many hundred miles of metalled roads; the western goldfields have been connected with the capital by a coach-road through the passes of the New Zealand Alps—a road remarkable, both for the boldness of its design and the circumstances under which it was executed; and a complete system of railroad has been surveyed, the key to which (a tunnel 129 chains in length through the crater wall of Lyttelton Harbour) has been successfully completed. Extensive harbour works have been constructed, public buildings erected in the principal towns, and telegraph and postal services carried to a fair state of organization.

The total expenditure on public works and surveys during the period referred to has been, in round numbers, one million eight hundred thousand pounds sterling (£1,800,000), the whole of which expenditure has been defrayed out of current revenue, with the exception of about five hundred thousand pounds (£500,000) raised on debentures, secured upon the railways and upon the Land Fund. The population in 1854 was about 6,000; in 1868 it amounted to a little under 54,000, including the mining population of the county of Westland.

Up to 1864 the whole of the Public Works were in the hands of the Public Works Department, and their cost was defrayed entirely out of current revenue. After that date, however, the

management of the towns and public roads passed entirely into the hands of municipalities and road boards, and the works undertaken by the Department were confined to railways, harbours, and those required for the settlement of the western goldfields.

With some special exceptions, the great bulk of the public works of Canterbury possess but little professional interest; the country being level, and the bridges chiefly of timber of ordinary construction. But, on the other hand, the fact that a mere handful of settlers, spread over a country nearly equal in area to the whole of Ireland (the province of Canterbury having a coast line 200 miles in length, with a breadth of 120 miles), have been able, out of provincial resources alone, to execute works to the extent of nearly two millions sterling, deserves attentive consideration as exhibiting a degree of success not often recorded in the history of colonization.

Amongst other elements, three leading features of the plans adopted for the colonization of the province may be mentioned as prominently contributing to the successful result above alluded to.

First. The price set by the Provincial Council upon the waste land, viz., £2 per acre, was sufficient, without being too high to prevent purchase by *bonâ fide* settlers, to leave a considerable revenue for public works, after including the cost of the survey and the ordinary expenses of Government, which had to be defrayed chiefly out of the Land Fund, the other sources of revenue being for several years comparatively trifling.

Secondly. The topographical survey was carried on steadily, year by year, in advance of the land-sales, so that not only intending purchasers had the advantage of consulting the detailed surveys of the districts in which they proposed to settle, but the purchased sections could be marked out on the ground, and the Crown grants issued without the delay attendant on the ordinary system of "selection before survey."

Thirdly. The Government year by year extended the roads through the purchased districts, so that every land-purchaser felt a confidence that the local wants of his district would receive due consideration in their turn.

An examination of the published returns of land-sales, and of public works expenditure in each district, will show the close connection between the roading of the country and the sale of the waste lands; and it is worthy of remark, that when the management of the roads was handed over to the road boards, and the policy pursued was one of local rather than provincial benefit the land-sales ceased, and with them the revenue, which up to that time had always been forthcoming for local improvements. Other causes may have contributed to this result, but the coincidence is very significant.

It will be seen by the above remarks, that the difficulties presented to the engineer, in the settlement of the Canterbury province, were of a totally different nature to those occurring in ordinary practice in a settled country, being social and political rather than technical.

It was necessary at an early date to decide upon the main lines of communication, in order that isolated works executed without any apparent connection might ultimately (as the temporary circuitous tracks became closed up by fencing) form portions of a connected whole; and to accomplish this the Government had to incur an outlay which might appear unnecessary, but which in reality saved a heavier expenditure than would otherwise have been requisite.

It was essential every year to open up fresh land for settlement, as upon this chiefly depended the progress of the land-sales, and at the same time to satisfy the claims of those who had settled on their land, and who were clamouring for metalled roads on which to take their produce to market.

It was requisite to provide employment for emigrants when work was scarce, but at the same time not to abstract labour from the ordinary work of the country; to avoid raising wages by employing labour at shearing-time, ploughing-time, haying-time, or harvest-time, and yet not to lay the Government open to the charge of wasting labour, or of doing work badly, because it had to be done in the wet season, when the Public Works Department had few or no competitors as employers of labour. Again, if work was done by contract, the farmers neglected their proper business, to engage in metalling contracts. If, on the other hand, work was done by day-labour, complaints were constantly made of waste and inefficiency, and of the inability of the settlers to compete with the Government as employers of labour. Lastly—and this was the greatest difficulty of all—the works could only be put in hand by dribblets, often at long intervals, and to such an extent only as might be warranted by the progress of the land-sales, and as might be authorized by the Provincial Council, whose views, as might be expected, were generally swayed by local wants and local interests; the Council of one year often ignoring the work of the previous one, and allowing important works to remain practically useless, for the want of some connecting link, the value of which was not apparent to the authorities. These difficulties were further intensified by the physical character of the country. The agricultural land is situated principally in the swampy tract on the seaboard; the pastoral, on the higher portion of the plains and in the back ranges. The farmers, therefore, wanted the money to be spent in bridging creeks and metalling the swampy roads near the coast. The sheep-owners desired side cuttings to be made in the hills, and approaches to the ford in the gullies, in order to get their wool-drays to their stations. The

farmers took their grain to market after harvest, when the unmetalled roads were soft with rains and frost, and often impassable. The sheep-owners carted their wool down to the port, and took back their station-stores in the heat of summer, immediately after shearing, when every mudhole was baked to the hardness of brick, and did not therefore require metalled roads, which would only lame their bullock-teams. Moreover, as, under the pasturage regulations, the stock-owners' leases were subject to be determined at any time by the purchase of the freehold from the Crown, it was not the interest of the non-holders to give any facilities for settlement in their respective districts; and so long as the drays could get down the wool for shipment, and return with the regular supply of station stores, they were perfectly satisfied, as the worse the roads, the less chance of the choice portions of the runs being bought up for settlement.

It will be readily understood that, with all these complicated interests, the progress of the public works was fitful and intermittent; yet, after a few years, the result was very marked and satisfactory, and by the middle of 1864 the whole of the eastern portion of the province may be said to have been roaded, more or less perfectly.

The principal works executed by the Government are as follows:—

1st, The Sumner road, from Lyttelton to Christchurch, which is scarped out of the cliffs for a continuous length of several miles. 2nd, The West Coast road, from Christchurch to Hokitika, which was constructed in nine months, through 100 miles of rough and difficult country, totally uninhabited, and, for the most part, densely timbered. 3rd, The Moorhouse tunnel on the line of the Lyttelton and Christchurch Railway, 2,861 yards in length, driven through the crater wall of an extinct volcano, under a summit level 1,220 feet above the sea; and, 4th, The wharf and jetties at the Lyttelton station, built upon a soft mud-bank, which is, in places, 50 feet in depth.

Amongst the road bridges there are few that possess any special feature of interest, with, however, two exceptions. These are—first, a drawbridge over the Waimakariri river, built on the telescope principle, from a simple design, and which worked satisfactorily; and, secondly, a bridge over the Taipo river, on the West Coast road, presenting several peculiarities of construction, which will be understood by inspection of the drawings.

The works of the Moorhouse tunnel have been so often described that there is little to add to the published accounts given in Appendix d, to which, as well as to the volume of drawings, reference may be made.

The harbour works possess considerable interest, which is

enhanced by their partial failure, the causes of which, as well as the constructive details, are fully set forth in Appendix g.

Before proceeding to describe the maps and drawings appended to this Memoir, it may be worth while to say a few words as to the system pursued by the Provincial Engineer in the management of his department. As fast as the topographical surveys were plotted in the survey office, tracings of them were furnished to the Provincial Engineer, who then proceeded to make detailed plans, to the scale of 3 chains to the inch, of all the lines of road, the features of the ground being marked on the plans in great detail. A network of levels was also run up from the coast, and extended as occasion offered, over the whole of the province; the heights being referred to spring tides at Sumner bar as a common datum; and the bench marks were marked on the road maps, and on the copies of the topographical surveys. The system of bench marks enabled all local levellings to be referred at once to the common datum, and was found to be of great service in determining the lines of drainage through the swamps.

In laying out roads on hilly ground, the principle uniformly adopted was to follow the windings of the spurs, contouring the gradients with the spirit-level, so as to minimize both cutting and embankment, and to dispense with culverts as far as possible. In the case of side cuttings, the gradient was contoured with the spirit-level and lock-spitted. The back line of the floor of the cutting was thus ranged out, and the depth of the cutting measured at every half chain. The width of the slope was then calculated and set off, and the back line of the slope lock-spitted. The work could then be let by contract at any future time when the funds might be voted by the Council, no plans or sections being required, or any details, beyond the rate of slope, the total length of the cutting, and its cubic content. Nor was much supervision required during the execution of the contracts, as the front and back lines could at any time be referred to, to check the correctness of the work. These details may appear trivial, but it was found absolutely necessary, in engineering a large district, with a limited professional staff, so to set out the works, and to let the contracts, as to dispense, in every possible way, with the necessity for working drawings, or for skilled superintendence.

One serious difficulty in the conduct of the road works was the want of timber. Although the forests on Banks' peninsula afford an almost inexhaustible supply of suitable building timber, the want of regular communication with the bays of the Peninsula, the absence of appliances for shipment, and the delays attendant on the crossing of Sumner bar, and the navigation of the Heathcote river, all combined to make it practically impossible to depend upon an order for any special sizes being delivered within six months.

The expedient adopted, therefore, was to keep constantly in stock a quantity of planks 16 feet 8 inches long, and 8 inches by 3 inches in section, and the bridges and culverts were built on standard patterns designed with reference to this unit of material. This plan also effected a great saving of office labour, as no drawings were required in ordinary cases, and as three planks made up 100 feet (board measure), any labourer was competent to take an account of the timber used, all that was necessary being to count the number of planks.

Another trouble, but of a very different kind, arose from the introduction of the watercress plant into some of the creeks near Christchurch. This plant spread with such rapidity as to threaten the very existence of the rivers; many of the streams being filled up with a solid mass of vegetation on which cattle could walk and feed, and which could only be got rid of by cutting it with knives, as trusses of hay are cut from a rick. The nuisance was only abated after several years' continual struggle and a very considerable outlay of money, the sum of £3,000 having been spent on the River Avon alone in the neighbourhood of Christchurch. After the lapse of several years, the plant seems to have exhausted itself, and is now kept under control without difficulty.

For convenience of reference the drawings and papers appended to this Memoir have been arranged in seventeen volumes, lettered a to r, each volume being complete in itself.

A few remarks, by way of synopsis, on the contents of each volume will be sufficient to enable the nature and extent of this information to be understood.

Appendix a.—Reports from the Provincial Engineers on the progress of the Public Works.

These reports give a good idea of the nature of the work of the Provincial Engineer, and of the manner in which the business of the department was carried on.

No. 2 contains a summary of the public works executed to the end of 1868. This may be consulted with advantage by those interested in the history of the province. No. 5 contains a sketch of the progress of applied science in Canterbury, prepared with considerable care for the members of the Philosophical Institute.

Appendix b.—Returns showing the Cost of the Public Works, and the working of the Road Boards.

This volume contains a complete set of statistics with regard to population, immigration, land-sales, cultivation, live stock, public works, road boards, and the public accounts.

It will be seen, by reference to these returns, that the total

Government expenditure, from October 1st, 1853, to March 31st, 1868, amounted to £2,887,196. 14s. 5d., of which amount a sum of nearly two millions was devoted to surveys and public works as under, viz. :—

EASTLANDS.		£.	s.	d.
Surveys		149,328	17	10
Geological Surveys		10,138	15	9
Engineer's department		31,762	19	10
Telegraph		14,486	5	6
Public Buildings		85,772	14	6
Public Works (ordinary)		398,181	3	7
Grants to Municipalities and Road Boards		167,800	0	0
Railways and Harbour Works		691,817	0	6
WESTLAND (Goldfields).				
Engineers' department		5,937	10	5
Surveys		31,280	15	11
Telegraph		19,965	3	6
Public Buildings		36,488	13	11
Public Works		221,605	11	8
Total		£1,864,565	12	5

This result must be considered a remarkable one, when it is remembered that nearly the whole of the amount has been defrayed out of the current revenue of a province whose population has never yet reached sixty thousand souls.

Appendix c.—Papers relating to the Sumner Road, and to the Heathcote Navigation.

Port Cooper, now called Port Lyttelton, the principal harbour of the Canterbury settlement, is the crater of an extinct volcano, the sides of which rise precipitously from the beach, forming a formidable barrier to communication with the interior.

The difficulty was partially overcome by rendering the Heathcote navigable, and by the construction of the Sumner road; but its final solution was the construction of the Moorhouse tunnel, which was opened for traffic December 9th, 1867.

The history of the early struggles of the settlers to obtain access to the interior are clearly narrated in the account of the Moorhouse tunnel, Appendix d. The maps of the Sumner road and of the Heathcote navigation are given in Appendix 1. The volume under consideration (c) contains a number of official documents relating to the subject, but of little more than local interest. The points of professional interest in connection with the road will be found in Appendix a, No. 2, paragraph 38.¹ A view of the

¹ This paragraph is as follows :—"The first important work undertaken by the Provincial Government was the cutting a track through the bush on Banks' Peninsula, to connect the harbours of Lyttelton and Akaroa by a line which, rising at an easy gradient from Pūrau beach, follows the summits of the ranges, and crossing

Heathcote swing bridge, the principal work on the road, will be found in Appendix r, No. 1.

Appendix d.—Railway Reports.

This volume contains a very fair account of the Moorhouse tunnel from a local paper,¹ copies of all the important reports upon

Mount Sinclair at an elevation of 2,600 feet, descends by gentle inclines into Duvanchelle's Bay. This was followed by the resumption of the works on the Sumner road, but under an important change of plan. The original line laid out by Captain Thomas rose at a uniform gradient from Lyttelton to Evans' Pass, whence it descended into Sumner Valley in the same manner. Although the gradient of this road was unexceptionable, its cost would have been very great, as it intersected the rocky terraces formed by the lava streams of which the Port hills are composed, rendering it necessary to make a series of heavy rock cuttings and high retaining walls alternating with each other throughout the whole of the ascent and descent. Your Engineer took the step of remodelling the gradients so as to correspond with the inclinations of the lava streams, by which means the road has been cut for the most part in soft clay and through the soft crumbling rock found in the upper portion of the lava stream, whilst it rests on a floor of solid rock. By this means both rock cutting and walling are reduced to a minimum, and the road was opened at a comparatively small cost. It was intended to cross the ridge by a tunnel 350 yards long, at a depth of 260 feet below the summit of the original line, but political considerations have interfered with the completion of the plan. The traffic is to this day carried over the saddle by the zig-zag track made for opening a temporary communication, pending the boring of the tunnel."

¹ The following is the article in question, extracted from the "Lyttelton Times:"—"To write an intelligible account of the Moorhouse tunnel, it is necessary to go back to the earliest records in the history of Canterbury. For, out of the geographical difficulty of communication between the port and the plains which met the first settlers on their landing, and which has ever since seriously impeded the progress of the province, arose the conception of the great work which may now be said to be virtually completed. There are many still among us who can recall the feelings of dismay and disappointment with which the lofty hills surrounding Lyttelton were first regarded. Beyond lay an almost interminable plain, which, even to the unpractised eye of the new comer, gave promise of full return for the labour that might be expended upon it. But before this could be reached a barrier of formidable dimensions interposed in the shape of lofty abrupt hills, and no available means existed of overcoming the difficulty. It must have required all the courage and resolution, with which the early settlers were so amply endowed, to have faced this serious and unexpected difficulty. The records of that date prove that it was universally felt to be the one drawback to the progress of the settlement, and that it caused great anxiety and disappointment to all the settlers. Many of the earliest pilgrims had been led to believe that they would find a practicable road leading to the plains, and their chagrin was proportionately great on finding their anticipations incorrect. From the first then we find one of the chief subjects of public interest to have been the discussion of the best means of communication between the port and the plains.

"When the first ships arrived with settlers there were but two ways of reaching the plains. One by scrambling over the hill, either by the line of the present bridle path or by Cass' Bay to Riverlow, the other by taking boat and going round by Sumner and up the Avon to the Bricks wharf, nearly opposite the cemetery. At that time the Heathcote was considered not to be navigable. A line of road *viâ* Sumner had indeed been surveyed by Capt. Thomas, but it was found impossible to proceed with it for want of funds. The incomers, as a rule, footed the hill while their goods went round by Sumner, and not unfrequently came to grief, for at that time the bar was imperfectly known, and decked river craft were hardly to be obtained. In a short time a tolerable bridle path over the hill was finished, which has since been widened and improved from time to time, and is still the

the Canterbury railways, and of the Resident Engineer's official report, February 18th, 1868, with details of cost and traffic returns.

principal medium of communication for foot and horse passengers. The completion of a cart-road from the foot of the hill on the Heathcote side to the river, the establishment of a ferry there, and the construction of a road to Christchurch, followed within the first year, and greatly promoted the convenience of travellers. About the same time the Heathcote was found to be navigable, and the Christchurch quay on the new road was opened. But the grand desideratum of a cart road to the plains was not yet to be accomplished. In December 1851, a meeting of the society of land purchasers was held to consider the report of a select committee of their body upon the best means of communication. The report recommended that a sum of £30,000 should be borrowed to carry out the Sumner road. Public meetings were held both in Lyttelton and Christchurch, endorsing the views of the society. It is curious to observe that so far back as this the subject of a railway tunnel was discussed and only put aside as being considered premature. Apparently it was easier in those days to pass a resolution in favour of borrowing than to obtain money, for nothing appears to have been done towards pushing on the Sumner road till the first Provincial Government took up the subject, and appointed a Commission, consisting of Messrs. Bray, Cridland, Dobson, Harman, and Jollie, to report upon the several modes of communication between the port and the plains. These gentlemen issued a report in April 1854, in which they recommended the Government to make a railway *viâ* Sumner, with a tunnel below Evans' Pass to Gollan's Bay, or, if that scheme proved beyond the resources of the province, to construct a cart road *viâ* Sumner with a tunnel through the top of Evans' Pass. This work was to be accompanied with certain improvements to the bar at Sumner. The present line of tunnel and railway was considered in the report, and though the cost was estimated only at £155,000, the scheme was considered by the Commissioners to be beyond the resources of the province. Another line was pointed out as worthy of consideration, in which the road was made to wind up the spurs at the back of Lyttelton to a tunnel 600 yards in length at the head of the gully descending into Dampier's Bay, at an elevation of 520 feet above the sea.

"The Government decided upon the road, and about a year after the date of the report referred to, the work of making the Sumner road commenced. On the 24th August, 1859, the road was formally opened by the Superintendent, Mr. Fitzgerald, who drove a dog-cart over it and arrived in Lyttelton without damage, to the surprise of many of those who doubted its capabilities for traffic. It was some time after this before the road was opened for the heavy cart traffic, which, from the time it commenced, has gone on gradually increasing to the present date.

"While the Sumner road was under discussion and in course of construction, various efforts were being made to improve the river navigation. It is a singular fact that in those days the idea of using the Heathcote river for the purposes of traffic was strongly opposed by some of the Lyttelton merchants. On the 18th December, 1854, Captain Drury, of H.M.S. 'Pandora,' reported upon the condition and capabilities of the Sumner bar. The general tenor of the report was adverse to making any attempt to improve the navigation by altering the natural form of the bar. The first attempt at introducing steam navigation on the river ended disastrously. The 'Alma,' a small paddle boat, after running a short time, took the ground on the bar on the 6th Jan., 1856. The attempts to raise her ended in breaking her back, and her spars rest in the quicksand at the present moment. Some time after this the course of the river was staked out by the Government, and leading marks put at the entrance. In the early part of 1858 the steamer 'Planet' commenced to run round to the river, and from that time the number of coasting steamers has steadily increased. The sailing craft employed on the river were in the first instance confined to vessels of fifteen or twenty tons, but in later years vessels of nearly 100 tons register have entered the river and discharged cargoes alongside some of the various wharves which have sprung up on the Heathcote.

"From the earliest period it seems to have been considered by the Government

Appendix e.—Reports on the Passes through the New Zealand Alps.

This volume, which is copiously illustrated with maps, views, and sections, contains a complete body of information upon the subject

of the province and the public that the combined traffic facilities afforded by the road and the river were insufficient, and that the construction of a more available and efficient means of communication between the port and the plains was merely a question of time and money. The public mind was impressed with the idea that the best means of overcoming the hill difficulty was by tunneling through it and connecting the capital city with the port by railway. Accordingly we find that a second Commission was appointed by Government in November 1858 to consider the subject, consisting of Messrs. Bray, Cass, Harman, Whitcombe, Wyld, Dobson, and Ollivier. A short time before this Mr. Dobson had reported to the Government that the tunnel would pass entirely through volcanic rock, and that the term of construction would be from five to seven years. The Commissioners in their report considered two leading schemes. One, that now executed, advocated by Mr. Bray; the other, *via* Sumner to Gollan's Bay, proposed by Mr. Dobson on account of the greater depth of water at that place as compared with Lyttelton. At the same time a Commission was appointed in London, consisting of Messrs. Cummins, Selfe, and Fitzgerald, with instructions to refer the question of route between Lyttelton and Christchurch to Mr. R. Stephenson. The latter referred it in turn to Mr. G. R. Stephenson, who decided on the 10th August, 1859, in favour of the present direct route. Previously to this decision, Mr. Fitzgerald, while in England, had urged very strongly upon the Government the propriety of carrying a line of railway with sharp curves and steep gradients along the Sumner road. This proposal was entirely negatived by the Commission as well as by Mr. G. R. Stephenson.

"Shortly after this, the English Commissioners entered into a contract with Messrs. Smith and Knight, of London, to execute the works for the sum of £235,000 (exclusive of stations), the work to be completed in five years. The contract was subject to determination either by the Government or the contractors at any time within four months after the arrival of the contractors in Canterbury, if either the Government should be unable to provide the money, or the contractors should find on examination that the work could not be done for the money. In either case the Government had to pay the cost of making trial shafts to the extent of £3,000, and to relieve the contractors for their engagements with the workmen sent out by them.

"Messrs. M'Candlish and Baynes, agents for Messrs. Smith and Knight, arrived in Canterbury, December 24th, 1859, and proceeded at once to sink the shafts. In consequence of the first Railway Bill passed by the Council having been disallowed by the Governor on the 26th January, 1860, the Provincial Government was not able to give an answer to the contractors on the 24th April following as to whether the money could be obtained for the line, and it was therefore agreed between the contracting parties that an extension of time should be allowed, the Government agreeing to pay the cost of carrying on the works. In November the Government having obtained the necessary powers for constructing the line and raising the requisite funds, signified to the contractors their readiness to proceed, but Messrs. Smith and Knight, through their agents, declined to ratify the contract, and Messrs. M'Candlish and Baynes shortly after left New Zealand.

"Mr. Dobson then proposed to open out the ends of the tunnel with the labour available in the Colony, and to advertise for tenders for the remainder of the work. But the Council declined to accept the proposal, and a long delay occurred, during which the trial headings were slowly carried on by the working party sent out by Messrs. Smith and Knight.

"In May 1861, the Government accepted a tender from Messrs. George Holmes and Co., of Melbourne, to complete the line from Lyttelton to Christchurch, a distance of six miles, with the exception of the stations, in five years, ending June 1st, 1866, for £240,500, the cost of the tunnel, 2,838 yards long, being fixed

of the central ranges. In connection with this volume, the views given in Appendix r may be studied with advantage, as also the account of the construction of the Otira road in Appendix a, No. 5.

at £195,000. The first sod was cut in the Heathcote valley on the 17th July, 1861, and this may be said to have been the date of the commencement of the tunnel works, as up to this time nothing had been accomplished beyond sinking the trial shafts, and driving 96 yards of heading, viz., 30 at the south, and 66 at the north end of the tunnel.

"The plan adopted by the contractors was to mine the whole work from a wide bottom heading. To expedite the work three additional shafts were sunk, one close to each front, and one in the clay cutting at the north end of the tunnel, whilst at the same time a gullet was driven up the cutting to meet the heading. Although the ground proved very wet in places, rendering it necessary to close pole a length of seven chains through clay and sand, this plan was perfectly successful, and the timbering remained in good order until the commencement of the brick-lining, at the end of the following year.

"On the 29th September, 1862, Mrs. Moorhouse laid the first stone at the north end of the tunnel, that of the south being laid by Mr. John Hall, in April, 1864.

"The works were at first carried on under great disadvantages. The Otago gold fever broke out soon after the commencement and a great number of the men employed left for the new gold field. The profitable nature of the trade between Melbourne and Dunedin made it for a time difficult to induce shipowners to take freight to Canterbury from Melbourne, whence all the plant and material for the work had to be procured, whilst the wreck of one of the mail steamers deranged the postal communications, and lastly, the amount of water met with at the Lyttelton end of the tunnel was so great, that the inner heading had to be abandoned until the completion of the drive from the beach gave a natural drainage for the work.

"The ventilation, which many people once thought would prove a great difficulty, has been most admirably arranged. In the first instance, air was driven in by fans worked by horse-power, but this soon proved quite insufficient, and when the works had extended some distance much time was lost owing to the difficulty of getting rid of the smoke. To obviate this on the Lyttelton side, the upper portion of the tunnel was partitioned off by a floor or brattice, about 9 feet above the rail-level, forming a smoke flue connected with one of the shafts, at the bottom of which was placed a furnace which, by rarefying the air, caused a steady current up the shaft and drew the smoke away from the face of the workings. A similar plan was adopted at the north end, the chimney of a forge being led into the shaft and answering the purpose of a furnace, but the brattice was only continued for a short distance beyond the upcast shaft.

"On the Lyttelton side this system answered perfectly well, and the ventilation has continued good ever since, but on the Heathcote side, where the work for the last quarter of a mile has been driven by a top heading (the temporary floor being left above the permanent rail-level for drainage purposes), the ventilation at the close of the work became sluggish, and recourse was had to driving air on to the face by means of four fans driven by an eight-horse steam-engine. This proved perfectly successful.

"From a comparatively early period, more or less difficulty has been experienced from the quantity of water, which has poured down from the roof and sides of the tunnel. But the difficulties have invariably been promptly met and overcome by the ingenuity of the engineer and contractors. At the Heathcote end inconvenience was caused solely by the difficulty of getting rid of the accumulation of water. On this side there were no springs rising from the floor, as at the Lyttelton end, and what fell from the roof was in the first instance easily pumped out. Afterwards, as the level of the workings was raised, it was found necessary to adopt other means for keeping them from being flooded. A syphon was employed for this purpose, which discharged the water into the railway ditches in the

Appendix f.—Reports on the encroachments of the Waimakariri River.

This volume contains a number of reports upon the Canterbury rivers, as well as upon the encroachments of the Waimakariri, and

Heathcote valley at a distance of more than six hundred yards. This simple contrivance drew the water from a sumph or well, to which the drainage from the inner workings was carried by a deep gutter. From the time the syphon was first introduced it has worked successfully, and discharged without cost or labour many millions of gallons of water.

"On the Port side no difficulty was experienced in getting rid of the water after the drives had once been opened out, as the drainage simply ran along the floor into the sea. The real difficulty here lay in protecting the men from the constant down-pour, which at times extinguished the lights and rendered it almost impossible to continue the work. So wet was the ground for a long period, that it became necessary to use water-proof cartridges, and even then misfires were continually occurring. For a long time the work was carried on under an iron shield, which was supported on runners on each end of the drive, and in some measure protected the men from the water which fell continually from the roof. After a short time the water ceased to fall, and both roof and sides are now perfectly dry, whilst the springs rising on the floor continue to run freely. This would seem to prove satisfactorily that the springs must be artesian, because soon after they were tapped and diverted, the water which had accumulated above the workings ceased to fall. This view of the matter is further confirmed by the fact that no water has been met with in the shafts at more than forty feet above high water level. It is worthy of remark that the principal spring tapped on the Port side was of the temperature of 70 deg. Fah.

"Ever since Messrs. Holmes and Co. undertook the contract the work has proceeded without interruption and without pause. . . . When the resources and population of Canterbury are considered, and it is remembered that for a period of six years the work of the tunnel has gone on day and night without ceasing, we think that, apart from scientific and engineering considerations, it must be considered a very remarkable work, and command the admiration of the outer world.

"In a scientific point of view, and as an example of engineering difficulties successfully overcome, the work may fairly claim the attention of the profession. The present tunnel affords, we believe, the first instance where a complete section of an extinct volcano has been opened out. . . . The rock in the tunnel may be described as a series of lava streams and beds of tufa, intersected by vertical dykes of phonolite. The lava streams generally consist of scoria, overlying a coarse pink trachyte, which passes gradually through shades of grey, purple, and blue, into a black finely-grained dolorite intensely hard and tough; the lightest and softest rock being at the top, and the densest and blackest at the bottom. Regarded from an engineering point of view, the work must be considered eminently successful. Wherever difficulties have been met they have been quickly and successfully overcome. The syphon employed for the drainage of the upper half of the tunnel is probably the longest on record. The system of ventilation has proved perfectly adapted to the requirements of the case, and has been not only effective but simple and comparatively inexpensive. It is worthy of remark that the engineers of the Mont Cenis tunnel have since found it necessary to adopt similar means of ventilation in that famous work.

"The system employed to secure the correctness of the alignment of the two ends of the tunnel was very simple. A permanent mark was fixed in the centre line of the tunnel, on a tower built on the dividing range, nearly midway between the two ends. A transit instrument being placed on the meridian of the tunnel as well as of the tower on the hill, it could be seen at once whether the flame of a candle placed in the centre line of the work inside the tunnel was in a vertical plane with the mark on the tower. But it was also desirable, in case of error, to have the means not only of correcting but of calculating the amount of such error,

an account of the disastrous floods of February, 1868, with reports from the Engineers' department on the best means of protecting Christchurch from future floodings.

Appendix g.—Papers relating to the Lyttelton Harbour Works.
(*Vide* Plate 2.)

This volume contains a series of reports upon the proposed harbour works, amongst which No. 3 may be referred to as containing a review of all the plans which had then been proposed for the improvement of the harbour; also the contracts for the sea-wall and for the screw-pile jetty, with copies of the contract drawings.

The contractor for the screw-pile jetty proved unequal to the

and this could be readily done. The permanent mark on the central tower consisted of a batten six inches wide, with a black stripe one inch wide down the centre. The eye-piece of the transit instrument being furnished with five vertical wires placed at equal distances apart, the value of the space between any two wires at a distance equal to that of the mark on the tower can be ascertained by reference to the width of the batten, which thus gives a scale by which the error in the position of a light placed in the tunnel under the tower can be rated with great exactness. It has been by this means that the alignment has been tested from time to time, and the proof of the correctness of the system has been established by the present results.

"In spite of the peculiar character of the work the health of the men has been generally very good. Accidents have been of rare occurrence, and of comparative unimportance. . . .

"Throughout the whole period there have been no strikes or disturbances among the men. They have been well treated by their employers, and have behaved well in return. . . .

"Messrs. Holmes and Co. have had to contend with difficulties quite serious enough to have frightened men less determined and persevering than they have proved themselves to be. Scarcely had they commenced work before the sudden discovery of gold in Otago upset all previous calculations as to the cost of labour, and seriously interfered with the shipping arrangements, by which they hoped to receive the bulk of their plant from Melbourne. Hardly had this excitement quieted down before the Canterbury gold fields were discovered, and the West Coast road created a demand for the special kind of labour required in the tunnel, thus depriving the contractors of many of their most practised hands. But these and numberless other minor difficulties have never interfered with the work, which has been continued night and day, more as if it had been carried on by mechanism than by the labour of sentient human beings. To the contractors' steadiness and perseverance the province mainly owes the fact that this weary work has been brought to a successful issue.

"And not to the contractors only, but to the engineer, Mr. Edward Dobson, is a debt equally due. Of him it may be fairly said that, latterly, his whole energies—his very being—have merged themselves into the tunnel. Whatever the most unwearied care and the closest supervision could effect for the benefit of the great work has been done by him. His name deserves to be, and doubtless will be, brought prominently before his professional brethren in the old world as soon as the successful result of this great experiment becomes known.

"The total length of the tunnel, as nearly as can be ascertained at the present moment, is in round numbers 2,870 yards, or about thirty yards more than the contract measurement, and the cost, according to the contract, is £195,000.

"According to the design drawn in London, the tunnel would have entered Lyttelton at a slight curve. This part of the plan was altered, so as to give a straight run throughout."

work, and accordingly the contract was cancelled, and the jetty finished by daywork, under a competent foreman. It was found that the mud-bank was too soft to support the screws, and accordingly additional lengths of piles were cast, and a solid core of hard wood placed in the bottom of each pile, and driven down to the solid rock, on which the weight of the structure was made to rest; the flanges of the screws simply acting as supports to check lateral vibration. The diagonal bracing was put in by divers without difficulty, the exact length of each brace being taken from a template applied by the diver to the work after the piles were screwed down to their proper depth. The whole work has been completed in a satisfactory manner.

The sea-wall slipped forward in two places during the progress of the work, the total amount of forward movement in each case being between 5 feet and 6 feet.

The Author does not consider that any advantage would have been gained by carrying the piles down to the solid rock, as, in all probability, the outward movement of the embankment would in that case have overturned the work and destroyed it. He considers that the partial failure of the work may be attributed to two causes: first, that the stone embankment was deficient, both in bulk and weight, for the duty it had to perform; secondly, that the tipping of the clay embankment was commenced before the stone embankment had had time to take a solid bearing, so as to form an abutment to resist the pressure of the backing.

The work has since been completed by driving an outer row of piles and putting in fresh capsills, jointing, and planking; and locomotives have been running for twelve months over the embankment without any further slipping, or more than the ordinary amount of settlement.

It is worthy of notice, that no effect whatever was produced upon the seawall, or the jetties, by the great earthquake wave of August 16th, 1868, although the sea receded so as to lay dry a great portion of the harbour, and it might have been reasonably expected that the removal of the pressure upon the ground in front of the seawall would have been accompanied by the subsidence of the station ground.

The drawings attached to the volume show the nature of the alterations made from the contract design in completing the seawall. The breakwater is still in progress by prison labour. The section annexed to the Engineer's report shows the construction of the work. It has been ascertained, by boring, that the rubble has sunk through the mud down to the solid rock, a depth in some places of 50 feet.

Appendix h.—Reports on the Telegraph Department of New Zealand.

This volume contains the official reports published by the general government upon the construction and working of telegraph lines throughout New Zealand, and will be found to contain much valuable information.

It is greatly to be regretted that similar reports have not been published with regard to the line, made by the Provincial Government of Canterbury, between Christchurch and Hokitika, some account of which is given in Appendix a, No. 5.

Appendix i.—Statistical Maps. (*Vide* Plate 1.)

This is an atlas, containing in a series of eight maps, statistics respecting the distribution of forest land, the lines of coach road, the drainage outfalls, the river navigations, the railways surveyed, the railways completed, the wooden tramways, and the telegraph lines.

PRINCIPAL COACH ROADS.

Hokitika to Greymouth. Distance 24 miles.—Four-horse coach daily. This road is simply a track along the sandy beach; but there are bridges, built by private speculation and with heavy tolls, across the Arahura and Parva rivers, and a ferry at the Tere-makau.

Hokitika to Ross. Distance 16 miles.—Four-horse coach on alternate days. This is nothing for the greater part of the way than a track along the beach. Cargo boats go from Hokitika to the head of the Mahinapua lake.

Christchurch and Hokitika. (West Coast Road.) Distance 149 miles.—Four-horse coach twice weekly. For the first 8 miles out of Christchurch this road is formed and metalled. Thence to the Kowai river it is a mere track across the plains. From the Kowai river to the sea-beach at the mouth of the Arahura it is for the most part thoroughly formed, drained, and metalled. The road was opened for coach traffic throughout, March 20th, 1866. The cost of the road was, in round numbers, £150,000, or at the rate of £1,500 per mile.

South Road. (Christchurch to the Waitaki.) Distance, Christchurch to Timaru 100 miles; Timaru to the Waitaki river 38 miles, exclusive of the loop line to Waimate.—Four-horse coach on alternate days from the Selwyn Station on the Southern Railway to Timaru, communicating with coaches to Oamaru and Dunedin. The first few miles of the south coast are formed and metalled; but from Weedon to the Orari river it is simply a track across the open plain, which has been opened for traffic by making cuttings

[1869-70. N.S.]

at the river banks and putting culverts at a few swampy creeks. From the Orari river to the Waitaki the road is, for the most part, through freehold property, and is in many places formed and metalled, with bridges over the numerous creeks. At the Rakaia there is a well-appointed ferry service; the other large rivers are forded, except during freshes, when the traffic is often stopped for days together. The cost of this road up to June 30th, 1864, including the loop line to Waimate, was, in round numbers, £32,000.

North Road. (Christchurch to Hurunui.) Distance 56 miles.—Four-horse coach daily to the Hurunui; three times daily to Kaiapoi. With the exception of a few miles beyond the Weka Pass this road is formed and metalled throughout; and with the exception only of the Kowai, the Wapara, and the Waitohi, all the creeks and rivers are substantially bridged, the above-named rivers being forded. The road presents no features of interest in an engineering point of view except at the Weka Pass, where it is carried through the limestone range by a series of rock cuttings. The amount expended on this road up to June 30th, 1864, was, in round numbers, £45,000. This does not include the cost of the bridge over the Ashley or the Waimakariri. A considerable sum has been spent by Road Boards in the improvement of the road since the above-named date. There is no coach traffic north of the Hurunui river; but the country is practicable for dray traffic northward as far as the plains extend, viz., for about 28 miles beyond the Hurunui.

Kaiapoi and Oxford. Distance, Kaiapoi to Rangiora 8 miles.—Omnibus twice daily. Rangiora to Oxford 21 miles; mail-cart on alternate days. This road is formed and metalled as far as Rangiora, but is in a state of nature for the remainder of the distance, except at a few points where culverts have been built over creeks and swampy places have been drained and metalled.

Christchurch to Lyttelton. Ferry and Sumner roads. Distance, Christchurch to Heathcote Ferry, 4 miles; Heathcote Ferry to Lyttelton, 8 miles.—Coaches four times daily, until the opening of the railway into Lyttelton. This road is metalled throughout. It presents a series of engineering difficulties, which have only been overcome at considerable cost. The principal work is the drawbridge over the Heathcote river. The cost of the road up to June 30th, 1864, was, in round numbers, £38,000. A considerable sum has since been spent upon the improvement of the metalling by the respective Road Boards.

Christchurch and Governor's Bay. Distance 6 miles.—Coach on alternate days. This road is, for the greater part of its length, a mere shelf cut in the steep hill side, many portions having required blasting.

Christchurch and Leeston. Distance from Christchurch to South-

bridge 30 miles.—Four-horse coach daily. This is a level road, fenced, drained, and metalled through an agricultural district. There is a good timber bridge over the principal channel of the Selwyn river.

Akaroa and Duvanchelle's Bay. Distance 6 miles.—Coaches run, in connection with the steamer, between Lyttelton and Tiger Bay, the intervening distance being travelled with saddle-horses. This is a very hilly but well-made road, commanding beautiful views of Akaroa harbour.

DRAINAGE DISTRICTS.

Rangiora.—The morass known as the Rangiora swamp covers an area of about 7,000 acres. It is fed by the waters of the Cust river, which sink into the shingle plain a little to the westward of the swamp, and reappear in numerous springs and creeks which, however, have no outlet, being penned back by the comparatively high ground bordering the Waimakariri river. The system of drainage adopted was the cutting of a main outfall through the centre of the swamp, having a fall of about 25 feet per mile, connected with a system of branch drains to intercept the creeks and bring them down the centre drain. With some trifling exceptions the greater part of the district has not only been purchased, but is under cultivation.

Papanui.—A great part of the land in the neighbourhood of Papanui was originally little better than a quaking bog; but since the cutting of the drainage outfalls it has been reclaimed and brought into cultivation.

Halswell.—The River Halswell runs for several miles between swamps, from which it is separated by high banks, the water-line of the river being often higher than that of the adjoining swamps. Thence, the only means of getting an outlet for the drainage of these districts is by cutting drains nearly parallel with the course of the river, but at a less inclination, until a point is reached at which the river shall be sufficiently below the head of the outfall to give an effective discharge for the swamp waters.

There are many other districts besides those here named in which drains have been cut by the Provincial Government; but these are simply ditches, cut without any other view than that of lowering the water-level, and have, in some cases, been productive of seeming inconvenience, by flooding the low lands with the water brought down from a higher level.

RIVER NAVIGATIONS.

Grey River.—High water, full and change, 10h. 15m.; mean rise and fall of tide about 9 feet. Vessels of 200 tons come up to the

town, and barges of from 16 tons to 20 tons burden are towed up to the coal-mines 7 miles above the town.

Hokitika River.—High water, full and change, 9h. 39m.; mean rise and fall of tide about 9 feet. The entrance is constantly shifting its position, and should not be attempted by vessels under canvas alone, or drawing more than 8 feet. Vessels of 200 tons are towed in by steamers and lie alongside the wharf. Above the town the river is only navigable for boats.

Okarito River.—Steamers of light draught enter this river under favourable circumstances; but the entrance should not be attempted by sailing-vessels, on account of the circuitous and shifting nature of the channel.

Saltwater Creek.—This is one of the mouths of the Ashley river, and is simply a tidal creek nearly dry at low water. Steam lighters and small craft come up to the wharf with the flood tide and lie on the mud to discharge.

Waimakariri River.—This river is navigable for vessels drawing 6 feet up to the town of Kaiapoi: above the town it is only navigable for boats, and that for a short distance only.

Avon River.—This river falls into the estuary of the Heathcote, and is merely a boat navigation.

Heathcote River.—High water, full and change, 4h. 20m.; rise and fall of tide 7 feet. This river is navigable for vessels of 100 tons to Christchurch Quay, 2 miles from Christchurch. Before the opening of the Moorhouse tunnel, the traffic between Port Lyttelton and Christchurch was principally carried on by steam lighters plying between the harbour and the railway wharf at Ferrymead.

RAILWAYS SURVEYED.

Lyttelton and Christchurch. (Cookson's Valley Line.)—This line was opened throughout December 9th, 1867.

Christchurch and Gollan's Bay. (Sumner Valley Line.)—This line was surveyed with a view to making a terminus in Gollan's Bay, where the harbour is deeper than at the town of Lyttelton, but the project was abandoned in favour of the Cookson's Valley Line.

Great Southern Railway.—This line has been opened for traffic to the south bank of the Selwyn, 23 miles from Christchurch, and has been set out and the requisite land reserved, subject to prior purchases, to the north bank of the Waitaki river.

Great Northern Railway.—This line has been surveyed and the route decided upon; but with some trifling exceptions its site has not been reserved from sale, the greater part of the land through which it passes having become freehold property at an early date.

Malvern Hills.—This line has been laid out and the land reserved as far as the Kowai coal-field.

Little River.—This line was surveyed with a view to connecting Christchurch with the forest at the head of Lake Forsyth; but the land has not been reserved, and the project has been abandoned for the present.

West Coast.—This line has been surveyed from its junction with the Great Northern Railway, near Horsleydown, to the town of Hokitika on the west coast, and the necessary reserves made.

Hokitika and Greymouth.—This line has been surveyed and the necessary reserves made, except where the line passes through freehold or native reserves.

Grey Valley.—This is a line proposed to connect the port of Greymouth with the valuable coal-mines on the Grey river, and with the level country in the Grey Valley, which is at present only accessible by wretched bridle-tracks, and by a rapid and dangerous river navigation. The necessary reserves have been made, except where native reserves occur upon the river-banks.

RAILWAYS COMPLETED.

Lyttelton and Christchurch.—This is an important line, connecting the port-town with the capital of the province. It is 6 miles in length, and passes, by a tunnel 2,838 yards long, under the hills which surmount the harbour, the summit level being upwards of 1,200 feet above the sea. The Lyttelton terminus is in front of the town, and has been reclaimed from the harbour. Steamers and vessels of 300 tons load and discharge at the railway jetties; but vessels of large tonnage lie off the town and discharge by steam lighters. The line was commenced, January 1860, and opened throughout, December 9th, 1867. The gauge is 5 feet 3 inches. The rails are double-headed, weighing 70 lbs. to the yard, with fish-plated joints and chairs of 22 lbs. each, spiked to sleepers of native timber.

Great Southern Railway.—This is a portion of the trunk line to the south. It was opened to the Selwyn, 23 miles from Christchurch, October 7th, 1867. The only works of importance are those at the Selwyn river, which was crossed by an embankment, and a lattice girder bridge on stone piers, for which a timber piled viaduct is being substituted, both the embankment and the bridge having been destroyed by the flood of February, 1868. The gauge is 5 feet 3 inches. The rail is flat-footed, weighing 65 lbs. to the yard, fastened to cross sleepers with wooden screws.

Halswell Quarry.—This is a wooden tramway, 4-feet gauge, laid along the side of the Lincoln road, for the purpose of bringing stone into Christchurch from a quarry on the Port Hills, distant about 6 miles. It is a private speculation, assisted by the Pro-

vincial Government, who advanced the proprietors £5,000, to be repaid in stone for the construction of the Government buildings.

Little River Sawmills.—This is a wooden tramway, or rather a set of wooden tramways, similar to the preceding one, and forms a portion of a more extensive work which was intended to connect the Little River Sawmills with the town of Christchurch. At present the logs are brought down the tramway to the mills, whence the timber is taken by tramway to the Little River, and thence by water-carriage to the western end of Lake Forsyth, whence it is again taken by tramway to a point on the shore of Lake Ellesmere, across which it is taken in punts to supply the Ellesmere district. The sawmills and tramways are private property.

WOODEN TRAMWAYS.

No. 1. This is a narrow-gauge line of the cheapest possible construction, laid for the most part on the beach just above high-water mark, to connect the town of Greymouth with an extensive mining district upon the Paroa or Saltwater creek. The total distance is nearly 7 miles.

No. 2. This is a well-constructed tramway of 4-feet gauge, connecting Hokitika with the coach-road to Christchurch, which terminates at the beach close to the mouth of the Arahura. The line is laid on the sandy beach, immediately above high-water mark. Cost, £980 per mile, exclusive of carriages and station buildings. It pays a handsome dividend to the shareholders. Length, $4\frac{1}{4}$ miles.

No. 3. Hokitika and Kaineri.—This line is also 4-feet gauge; but it is laid through the forest, and required a considerable amount of earthwork and clearing, as well as several bridges. Cost, £1,038 per mile. Length, 130 chains.

No. 3a. Hokitika and Ho Ho.—This tramway is similar to the foregoing. Length, $2\frac{3}{4}$ miles. Cost, £946 per mile.

No. 4. Ross.—This tramway is on a gauge of 5 feet 3 inches, and is to connect the Ross diggings with the beach track to Hokitika. The original line has been abandoned, and a more direct line is now in course of construction.

The whole of the Westland tramways have been executed by private companies, without any assistance from the Government. They are constructed, for the most part, on the loose sandy beach where it would be impossible to construct a permanent metalled road; or through swampy forest, where the formation of an ordinary cart-road would be attended with great cost. These tramways are worked by horses, and have proved a great convenience to the public, as well as being remunerative to the shareholders.

TELEGRAPH LINES.

The line from Lyttelton to Christchurch, that from Christchurch to Hokitika, and the extension of the latter line to Greymouth, were constructed by the Provincial Government. The northern and southern lines were constructed by the General Government. The whole of the lines are now in the hands of the General Government, with the exception of a wire from Lyttelton to the Selwyn, which is devoted exclusively to railway business.

Appendix k.—Topographical Maps.

This atlas contains the last published survey of the province to the scale of 4 miles to the inch; the environs of Christchurch to the scale of 1 mile to the inch; the Westland gold-fields to the same scale; and a plan of the lower portions of the Grey River Valley, showing the position of the coal mines, with the line of railway now in course of construction between Greymouth and the mines.

Appendix l.—Maps and Sections illustrating the several plans proposed for connecting Port Lyttelton with the Canterbury Plains.

This atlas contains maps of the Heathcote navigation, the Sumner road, the proposed Sumner Valley railway, and of the Lyttelton and Christchurch Railway as executed. These maps will fully illustrate the history of the Moorhouse tunnel given in Appendix d.

Appendix m.—Sections of the Little River and the Great Southern Railways.

These sections are instructive, showing as they do not only the level character of the plains, but the fact that many of the rivers run on ridges above the general surface of the plain. This is very observable in the section of the Southern railway, as regards the Wannabrumi old river-bed, the Selwyn, and the Rakaia. At the crossing of the latter river it may be seen that the water-line is higher than the top of the eastern terrace. The level to which the flood rose in the River Selwyn in February, 1868, is marked upon the section, by which it will be seen how little chance there was of any embankment standing against such a torrent, and how essential it is in dealing with such rivers to leave abundant waterway.

Appendix n.—Northern and Western Railways.

This atlas contains a map and sections of the proposed Northern and West Coast railways. These sections exhibit what at first

sight may appear paradoxical, viz., that the portions of these lines which traverse the level plains require heavy earthworks, on account of their running at right angles to the watercourses, whilst the lines through the ranges, being contoured on the hill sides, are carried for miles on surface gradients, with light side cutting, through a mountainous and difficult country. It is proposed to cross the dividing range by inclines respectively of 1 in 19 and 1 in 22, worked by engines specially designed for this service.

Appendix c.—Timber Bridges.

This atlas contains working drawings of the bridges over the Waimakariri and Taipo rivers, referred to at the commencement of this Memoir. The Waimakariri bridge was built as a private speculation, the contractor receiving a lease of the tolls for seven years. It was opened and shut by means of a chain and capstan placed under the bridge, worked by a moveable handle inserted in the floor of the shifting portion. A view and description of the Taipo Bridge will be found in Appendix r.

Appendix p.—Lyttelton Tunnel. Engineering details. (*Vide* Plate 3.)

This atlas contains a complete set of illustrations of the progress of the tunnel works, compiled from sketches made during their progress.

Copies of No. VII., Sheets 1, 2, and 4, were exhibited at the New Zealand Industrial Exhibition held at Dunedin in 1865, when a silver medal was awarded to their Author.

No. VII., Sheet 5, is instructive, as showing the great variety in the forms of construction adopted, as well as the manner in which the unfinished portions were secured, to allow of locomotive traffic being carried on before the completion of the masonry.

There are several points connected with this tunnel worthy of record.

1. The almost total freedom from accident, only two lives having been lost during the progress of the works.

2. The absence of strikes amongst the workmen, notwithstanding the excitement consequent on the breaking out of the gold diggings in New Zealand, in Otago, and afterwards in Canterbury.

3. The perfect accuracy of the lines and levels.

Lastly, the uninterrupted manner in which the works were conducted by the contractors from the date of cutting the first sod to the final completion of the line.

The general history of the Lyttelton and Christchurch railway and of the Moorhouse tunnel are given very accurately in Appendix, No. 1.

Appendix q.—Lyttelton Tunnel. Geological Section.

The Author is indebted to Mr. Julius Haast, his son-in-law, Provincial Geologist, for permission to introduce this interesting section, which is believed to be the first complete section that has ever been made through the crater wall of a volcano.

Appendix r.—Views illustrating the Physical Geography of Canterbury.

This volume contains thirty-six views, selected for the purpose of giving, in connection with the Topographical Survey, as correct a view as possible of the various characters of the physical features of the province. The Notes appended to each view will be found to contain information both of a technical and of a general character.

In concluding this Memoir, the Author has simply to express a hope that, as a record of the engineering operations connected with the successful settlement of a previously uninhabited country, it may be found not only to possess present interest, but that it may become valuable as a record of precedents for future reference.

In illustration of this Paper, it has been decided to reproduce a map of the province (Plate 1), and to indicate thereon the information contained in Appendix i; also the details of the Lyttelton Harbour works, Appendix g (Plate 2), and of the Lyttelton Tunnel works, Appendix p (Plate 3).

[Mr. GREGORY,

MAP
of the
PROVINCE OF CANTERBURY
NEW ZEALAND.

REFERENCE.

- Coach Roads shewn thus ———
- Drainage Outfalls " ———
- River Navigation " ———
- Railways completed ———
- Railway Surveyed ———
- Wooden Tramways ———
- Telegraph Lines ———
- Coal Seams ———