

1886.
NEW ZEALAND.

WATER-SUPPLIES FOR MINING AND AGRICULTURAL PURPOSES, AND TOWNS

(PAPERS RELATIVE TO).

Laid on the Table by the Hon. W. J. M. Larnach, with leave of the House

Mr. H. A. GORDON, F.G.S., Inspecting Engineer, Mines Department, to the Hon. W. J. M. LARNACH, C.M.G., Minister of Mines.

SIR,—

Mines Department, Wellington, 1st June, 1886.

With reference to the information requested by Mr. W. Hammond Hall, the Engineer for the State of California, regarding the nature and character of the water-supplies in this colony, and as to whether they are used for irrigation purposes, I have the honour to report on the same as follows:—

The water-supplies may be classed under three heads—viz., (1) Water-supplies for goldfields, (2) water-supplies connected with agricultural and pastoral pursuits, (3) water-supplies for towns.

Water-supplies for Goldfields.

A large number of water-races have been constructed by private enterprise for bringing a supply of water on to the different goldfields districts for the purpose of working the auriferous deposits by hydraulic sluicing, and also as a motive-power for working machinery connected with mining; but, as the goldfields extended and the richest of the gold-deposits began to get worked out, the miners directed their attention to the deep wash-drift terraces that contained a little gold, but not sufficient to pay unless they were sluiced away in a wholesale manner. The quantity of water that had hitherto been brought on to some of the fields was insufficient to accomplish this object; and, as the works required were of so costly a character, the Government deemed it advisable, when taking into consideration the general policy of constructing public works, for the purpose of opening up the lands of the colony with a view of speedy settlement, to also make provision for the construction of works for the development of the mineral resources. Water-supplies for goldfields were therefore provided by the Immigration and Public Works Act of 1870, and £300,000 set apart for that purpose, with the view of enabling mining to be carried on in a more systematic manner, so as to make the large deposits of superincumbent auriferous-drifts wash on the terraces pay for working.

It may be mentioned here that there are large areas of land within the colony that are almost valueless for agricultural and pastoral pursuits, but have proved rich in mineral deposits; therefore, mining is an industry that requires to be fostered to a great extent, for in the rapid development of the minerals lies in a measure the future prosperity of New Zealand, as it will be the means of increasing to a large extent the population, tending eventually to settlement on the lands. The Government, having this end in view, deemed it desirable to construct waterworks in districts where the outlay was beyond private enterprise, and where the area of auriferous ground likely to be worked by means of these works was sufficient to warrant the expenditure. This was a difficult matter for the Government to determine, for after it became known that the Government would undertake works of this nature every district wished to secure as much of the money as possible; and the information that was received with regard to the extent of auriferous ground that could be profitably worked if a good supply of water was brought on to the field must have been given in some instances without due consideration, as few of these works will ever pay interest on the capital expended; but, if not taken as a commercial venture, they are the means of maintaining a population in the districts where they are constructed, and thereby increasing the revenue indirectly.

The waterworks constructed by the Government are in the Waimea-Kumara, Nelson Creek, and Charleston districts, of the West Coast, and the Mount Ida District, on the East Coast, of the Middle Island, and in the Thames District of the North Island. There are also works in course of construction in the Totara District, on the west coast of the Middle Island. A description of these works may be of interest, showing their cost and magnitude.

Waimea-Kumara Water-supply.—This consists of two water-races, one to the Waimea District, the other to the Kumara District. In conjunction with the latter there is a sludge-channel, or tail-race, to enable the tailings to be conveyed from the several mining-claims that are being worked by water from this supply, and deposited on a tailings-site common to the field. The water-supply for Waimea is taken from Kawahaka Creek (which is a tributary of the

Arahura River) on to the terraces above Fox's, Goldsborough, and Stafford, in the County of Westland. On representations being made that there was a large area of auriferous-drift terraces, that would support a large population for a number of years if a sufficient water-supply were obtained by which they could be worked by hydraulic sluicing, the Government undertook the construction of a water-race having a carrying capacity of forty sluice-heads of water. It may be well to mention that by a sluice-head of water in this colony is meant an orifice or stream capable of discharging 60 cubic feet of water per minute. The system adopted here for measuring water is by a box 12ft. long, set level, and 20in. wide, having a bar of 2in. in depth and lin. in thickness nailed on the bottom at the discharge end; then an opening left for the number of sluice-heads required to be discharged, having always a pressure-board fixed above the opening to give a head of at least 6in. from the centre of orifice. But in supplying a large number of sluice-heads it is found in practice that the height of the pressure-board should not be less than the depth of the opening, to counteract the wavy motion there is on the surface of all running streams. A box 20in. wide, with an orifice of 20in. by 2in., with a pressure-board 5in. deep, is accurate enough to supply one sluice-head; but, in measuring a number of sluice-heads from one orifice, the size of the opening has to be regulated in accordance with the $\sqrt{2gh}$, the cubic contents, and area of the opening, which gives a varying coefficient of discharge. From a number of experiments that I have made with the discharge of water in orifices, I have formulated the following formula: The quantity of water discharged from a rectangular orifice per second $= 0.62 + (.0008a)A\sqrt{2gh}$, where g =gravity, h =the height of water in feet above the centre of the orifice, a = the area of orifice in inches, A = the area of orifice in feet. This is not absolutely correct, but so near that it is sufficiently accurate for all practical purposes. The works in connection with the Waimea water-supply consist of a weir constructed across the Kawahaka Creek—which acts as a dam or supply-reservoir, constituting the head-works—conduits, aqueducts, tunnels, and cast-iron siphon. The creek from which this supply is taken has not more than about fifteen sluice-heads of water flowing in very dry weather; but in wet weather there is always a good supply. It is simply a mountain-stream with a great fall, confined within a comparatively narrow gorge, which has in times of floods as much as five thousand sluice-heads of water. The head-works consist of a weir built of concrete across the bed of the creek and let into the banks on each side, having a foundation and abutments of solid rock. This weir stands about 12ft. above the bed of the creek, and forms a small reservoir, from which the water is taken into the race by a tunnel constructed through solid rock on one end of the weir, having at the intake end a sluice-gate for regulating the supply. These head-works are 772ft. above sea-level. A water-race is constructed from the head-works along the sides of the terraces, crossing the saddle between the watersheds of the Arahura and Teremakau Rivers, in principally open conduits, and fluming. The conduit is 5ft. 3in. wide in the bottom, and 3ft. 3in. deep, having a batter on the sides of $\frac{1}{4}$ to 1, and the flumes are of the same carrying capacity. For the first 3 miles 5 chains the water-race is constructed on a grade of 1 in 1,320, where it comes to a low saddle; thence there is a cast-iron siphon for 200 chains in length. The pipes are 3ft. in diameter, and the fall between the intake and the discharge end is 83ft., while the maximum depth of the valley through which the siphon is constructed is about 180ft. below the level of the intake end. From the end of the siphon the water is carried in open conduits, tunnels, and flumes, constructed on a grade of 1 in 660. The total length of this water-race is 17 miles 24 chains, and it has cost up to the present time £118,576. It was commenced in 1872, and completed in 1878. The price charged for water is as follows: From 8 a.m. to 4 p.m., £2 per head per week; from 4 p.m. to midnight, £1 10s. per head per week; from midnight to 8 a.m., £1 per head per week; a considerable reduction being made to parties who use water continuously. But as a rule very few use water at night: they simply work during daylight.

Kumara Water-supply.—During the construction of the waterworks for the Waimea District the Kumara goldfield was opened, and strong representations were made to the Government to bring in a large water-supply on this field. At this time a private company had undertaken the construction of a water-race; but the works were not of sufficient magnitude to bring in a supply to meet the demand. This company having obtained the principal water-rights in the immediate neighbourhood, the Government deemed it desirable to purchase these water-rights and enlarge the works, and also connect with the Waimea supply. A supply-race was constructed from the Kawahaka Creek, a little below the head-works of the Waimea Water-race, and the water in both these races was regulated from the supply-reservoir to meet the requirements of each district. The first scheme was to take the water from Kapitea Creek, where a weir of timber was constructed across its bed so as to form an embankment for a dam; but the quantity available in this creek was totally inadequate to meet the requirements of the field; this led to the construction of the supply-race and a second reservoir. The length of the supply-race is 4 miles 60 chains, and the main race is about 2 miles 40 chains, the latter portion having a carrying capacity of a hundred sluice-heads of water. In conjunction with this supply a large sludge-channel or tail-race was constructed to enable the miners to deposit the tailings on a common tailings-site near the Teremakau River. A tunnel was constructed for about 80 chains in length, having a sluice-box in the centre 3ft. 6in. wide and about 3ft. 6in. deep, with tramways at each side for the first 40 chains, and on one side only for the upper 40 chains, for working small trucks to bring in material to keep the channel in repair. This channel is paved in the bottom with stone pitchers 14in. in depth, and is constructed on a uniform grade of 1 in 26. It is found in practice that this channel carries away tailings and water to the extent of what fifty sluice-heads of water is capable of sending into it by the ordinary process of hydraulic sluicing. This enables twenty-one claims to be worked, each party tailing into it four hours per day. The miners on this field find that they cannot use the water in their claims for more than four hours per day advantageously, as the ground is so full of large stones which require to be broken up by blasting; they therefore employ the remaining four hours each day in breaking the stones and getting ready again for the water. The charge made for the use of this channel is 10s. per man per week of four hours per day; while the price of

water from the Kumara Water-race is £2 per sluice-head per week. The cost of the Kumara Water-race and channel has been £54,601. These works were commenced in 1876 and completed in 1879. Taking the whole of the works connected with the Waimea-Kumara Water-supply, they have cost about £173,077, and the value of water sold amounts to £60,338. The approximate amount of gold obtained by the miners whose claims were worked by means of these works was 140,861oz., representing a value of £538,359.

Nelson Creek Water-supply.—This water-supply is brought from Lake Hochstetter, which is about 830ft. above sea-level, on to the terraces on the east side of Nelson Creek, in the County of Grey. The total length of the works connected with this supply is about eighteen miles. The head-works consist of a large reservoir capable of holding six months' supply without any water coming into it. This reservoir is made by placing an embankment across Nelson Creek, near Lake Hochstetter, thereby raising the original surface of the lake—which covers an area of about four square miles—12ft.; this extra depth of water also increases the area of the lake to a considerable extent. The embankment is made of earthwork, having a puddle-wall in the centre; the maximum height of the embankment being 24ft., and the length on the top about seven chains. It is 12ft. wide on the top, and has a slope on the breast of 3 to 1, which is pitched to a depth of 18in. with stones, while the outside slope is $1\frac{1}{2}$ to 1, and sown with grass. There is an outlet-tunnel constructed in the solid ground at one end of the embankment, which is lined with bricks set in cement; and at the intake end of the tunnel there is a sluice-gate for regulating the supply of water to the race. The water is conveyed in tunnels, aqueducts, and open conduits, which are constructed on a grade of 1 in 660, having a carrying capacity of sixty sluice-heads of water. There are about seven miles of tunnels, one mile of aqueducts, and the rest in open conduits. The country through which this supply is taken is very rough and broken, having a succession of deep gorges with almost perpendicular sides. These had to be spanned with bridges from 60ft. to 150ft. span. The longest of these bridges are constructed on the arch-braced principle, with boxing on the top. The size of the open conduits is 5ft. 3in. in the bottom and 3ft. 3in. deep, having a slope on the sides of $\frac{1}{4}$ to 1. The principal tunnels are constructed 3ft. 9in. wide and 6ft. in height in the clear. These have a drop of 2ft. at the intake end, which gives them the same carrying capacity as the open conduits. These works were first commenced in 1873, and were completed in 1878, their total cost being £90,152. The approximate amount of gold obtained by the miners by means of this supply up to the 31st March, 1886, was 26,341oz., representing a value of £100,754; while the value of water sold was £13,720. The price paid by the miners for water from this supply is as follows: From 8 a.m. to 4 p.m., £2 per head per week; from 4 p.m. to midnight, £1 10s. per head per week; from midnight to 8 a.m., £1 per head per week; continuous water, £3 per head per week for the first two heads, and £2 10s. for each additional head per week.

Charleston Water-supply.—This supply is taken from a reservoir which is constructed in a basin, and is entirely dependent on rain-water to keep it full. The water is brought on to the flats and terraces on the water-shed of the Nile River, in the County of Buller. This reservoir, and a water-race leading from it, were constructed by a private company; but, the supply being inadequate to the requirements of the district, the Government was induced to purchase this company's rights and enlarge the works, which has since been done. The purchase was completed in 1879; but, as the field did not prove so extensive as was at first anticipated, the enlargement has only been completed during the last year, and an extension is now in course of construction. The carrying capacity of the tunnels, flumes, and open conduits, which are, in the aggregate four miles in length, and form the works in connection with this supply, is twelve sluice-heads, and the cost of these works up to date has been about £14,183. The approximate amount of gold that this supply has been the means of obtaining is 5,478oz., representing a value of £20,953; while the value of water sold has been £3,529. It may be considered a supply of small magnitude; but it is sufficient for the class of mining there is in this locality, which is working black sand. The whole country here has been covered by the ocean at one time, and the gold obtained is of the same character as that found on the ocean-beaches, very fine and scaly. The price charged for water from this supply has hitherto been £2 15s. per sluice-head per week.

Mount Ida Water-supply.—This supply is taken from one of the branches of the Manuherikia River, in the County of Maniototo, and works have been constructed about seventy miles in length, which consist principally of open conduits, having a carrying capacity of about forty sluice-heads of water. This is brought on to the terraces in the vicinity of Naseby formerly known as the Hogburn Diggings. Near the termination point there is a reservoir constructed for storing water when not used for sluicing, which acts as a reservoir to supply flushing-water to a sludge-channel, which was constructed in connection with this supply for ten miles in length, in order to get clear of the tailings from the mining-claims, and deposit them on a large flat near the Taieri River. This sludge-channel, or, properly termed, tail-race, is constructed 6ft. wide in the bottom, which is pitched with stones, and the sides are lined with stones and scrub. This channel is constructed with three different grades—viz., 1 in 100, the lower portion; 1 in 60, the middle portion; and 1 in 40, the upper portion; which has proved a very objectionable feature in the construction of tail-races, inasmuch as they are always liable to silt up and block at the change of grade. The total cost of these works up to date has been £65,766. The approximate amount of gold that this water-supply has been the means of obtaining up to the 31st March, 1886, is 17,711oz., representing a value of £67,493; and the value of water sold and channel-fees amounts to £11,715. These works were completed in the early part of 1877; but the amount of gold and value of water sold is only calculated from 1878. The measurement of water from this supply is different from any of the other water-races. A sluice-head is known here as 16 inches, or a little over one-third of a sluice-head of water defined by statute. However, it is by the measurement known best in the district that the water is sold; and the price paid is £1 per sluice-head per week.

Thames Water-supply.—This is the water-supply for the goldfields of the Thames. It was commenced in January, 1874, and completed in February, 1877. The supply is taken from the Kauaeranga River, the Hiki and Mangakerikeri Creeks. The length of the main water-race is 10 miles 32 chains, consisting of 5 miles 20 chains of open conduits, 1 mile 1 chain tunnels, and 4 miles 11 chains of fluming. There are also two branch races, 1 mile 2 chains in length in the aggregate, consisting of 11 chains tunnelling and 70 chains ditching; making the total length of the works connected with this water-supply 11 miles 33 chains. The open conduits are constructed 4ft. wide in the bottom, 2ft. 3in. deep, with a slope on the sides of 1 to 1 where the fall or grade is 1 in 1,000; but a portion of the conduits has only a fall of 1 in 2,000, and where this occurs the cutting is 4ft. 4in. in the bottom, 2ft. 7in. deep, having the same slope or batter on the sides as previously mentioned. All the fluming and tunnels are constructed with a grade of 1 in 1,000. The flume is constructed of malleable iron, $\frac{3}{4}$ in. thick, and bent to a half-circle, being 5ft. 6in. across the top. The tunnels are constructed 5ft. high and 4ft. wide in the clear inside the timber, and timbered throughout. The carrying capacity of the race is twenty-eight sluice-heads—1680 cubic feet of water per minute. There are three reservoirs for storing water constructed at different places along the line of race, the largest of which covers an area of 26,000 square feet. The whole of the reservoirs are constructed with earthwork embankments having a puddle-trench in the centre, and covered with a coating of broken metal on the breast. The available height of race above Grahamstown, where the principal crushing-batteries are situated, is 145ft., and the total height above sea-level is 154ft. The water is distributed from the race and reservoirs through 4,392 lineal feet of malleable-iron pipes, and 2,300ft. of cast-iron pipes 20in. in diameter. There are also 3,300ft. of subdistributing-mains, 10in. and 12in. respectively. All the principal batteries on this field are driven by water from this race, the wheels used being principally Pelton's hurdy-gurdies. The present charges for water are £3 per sluice-head per week for a constant supply, and for an intermittent supply £4 per sluice-head per week for day-water, and £3 per sluice-head for night-water per week. With these charges it is found that low-grade quartz can be profitably worked, which would not pay when steam-power was used for driving the crushing-batteries. The total cost of the works in connection with this water-supply has been £80,709.

Totara Water-supply.—This supply is to be taken from the Mikonui River, in the District of Totara, in the County of Westland, to enable the auriferous terraces and flats in the vicinity of Ross to be worked. It was one of the earliest Government water-supplies projected in the colony. Early in 1869 some private persons made a survey of the ground over which the works had to be constructed, with the view of forming a company to undertake the construction; but as they were not successful in floating a company the scheme lay in abeyance until 1872, when Mr. James Brogden, of the firm of Brogden and Sons, large railway contractors, contemplated undertaking the work. This firm applied to the Government for certain concessions of land, which at that time it was not considered advisable to grant. After preliminary investigations were made, Mr. Brogden did not pursue the matter further. It was then brought under the attention of the Government, and a vote of £2,000 was granted to make a resurvey, to see if a better route could not be got. After this survey was completed it was considered desirable to abandon the line formerly surveyed, and adopt what is known as the Totara route, which has a length of 15 miles 64 chains, and is estimated to cost when completed £83,000. On this route there is a tunnel of about two miles in length, which has to be constructed principally from one end, owing to the great height of the range and the quantity of water to contend with in constructing the tunnel from the upper end against the fall or gradient, which causes the work to progress slowly. About three miles of short tunnels and a portion of this long tunnel are constructed; but it will take several years before the whole of the works in connection with this supply are completed. This work is known as the Mikonui Water-race. It terminates on the terraces near Donoghue's, about 500ft. above the level of the flat. The conduits and tunnels are being constructed capable of carrying fifty sluice-heads of water, or 3,000 cubic feet per minute, which will be used to work the terraces by hydraulic sluicing, and to drive machinery for pumping and working the deep levels in the flat. The auriferous ground in the flat in this district has been proved to contain rich auriferous layers of wash-drift to a depth of 230ft. below sea-level, and no rock-bottom has yet been obtained; but in the depth that has been reached seven different auriferous layers have been gone through, the deepest one of which is the richest. The cost of the works in connection with this water-supply has, up to the 31st March last, been £25,624.

These constitute the whole of the water-supplies that have been constructed at the entire cost of Government; but subsidies to the extent of £45,235 have been paid to private companies to assist them in bringing in water-supplies to various mining districts throughout the colony, while in addition to the actual cost of these works the departmental expenses have amounted to £6,515; making the cost of works constructed by Government £449,611, subsidies £45,235, and departmental expenses in connection with their construction £6,515; or a total of £501,361. The direct revenue from these works has not been sufficient to make them a commercial success; but they have been the means of employing a large population, who have obtained a considerable amount of gold that would not have been got if they had not been constructed. Taking, therefore, the direct profits and revenue derived from the population they have been the means of sustaining, the Government has been benefited by their construction.

Water-supplies for Agricultural Pursuits.

The only place in the colony where water has been brought in for agricultural pursuits is the Provincial District of Canterbury, on the Middle Island, in the Counties of Selwyn and Ashburton. These supplies are not for irrigation purposes, but merely for domestic use—watering stock, and for working threshing and chaff-cutting or other machinery.

Selwyn County.—There are four water-races in this county—viz., the Malvern, the Greendale, the Waireka, and Hororata Water-races.

Malvern Water-race.—This water-race receives its supply from the River Kowai, which is a tributary of the Waimakariri River. The head-works consist of a concrete weir or dam across the bed of the river, which raises the water about 10ft. above its normal height. The bed of the river is a mass of moving shingle, and in order to prevent this from getting into the water-race, a tunnel forty-six chains in length is constructed at right angles to the bed of the river, through a high terrace forming the right bank of the river, and is lined with concrete and brick. At the entrance of this tunnel two bywash-gates in the weir are placed close to the sluice-intake gate, which is set in concrete at the mouth of the tunnel. These bywash-gates carry away all the surplus water in the river in ordinary weather, and prevent the shingle accumulating at the entrance-gate of the tunnel, and also act as regulating-gates for keeping the water up to a certain level. The entrance-gates at the mouth of the tunnel are fitted with screw-lifts, so as to gauge the quantity of water to be admitted. During floods the surplus water that cannot pass through the bywash-gates goes over the top of the weir. At the lower end of the tunnel the water flows in an open conduit for ten miles, where it is divided into two main branches, the first branch being twelve miles in length, at the end of which the water is again divided into five branches. The second branch is twenty-two miles in length, and from it at intervals four branch races are taken, which are in the aggregate twenty-nine miles in length; the total length of the main and branch supplies being ninety-one miles. The water from these branch supplies is conveyed in distributing-channels, which form an aggregate length of about five hundred miles, and carry the water through almost every section of land in the district. The dimensions of the water-races are as follows: Main supply, 14ft. wide, capable of carrying water 1ft. deep; No. 1 Branch, 8ft. wide by 1ft. deep for twelve miles, afterwards 6ft. wide by 1ft. deep; No. 2 Branch, 8ft. wide by 1ft. deep for the first seven miles, and 6ft. wide by 1ft. deep for the remainder of the distance. The branch races are all 2ft. wide by 1ft. deep. The fall or inclination from the head-works in the main race is 30ft., No. 1 Branch 37½ft., and No. 2 Branch 40ft. per mile. The fall in the branch races is various, according to the direction in which they extend: those flowing in a southerly direction have about 25ft., and those flowing in an easterly direction about 15ft. per mile. Concrete falls, with aprons of grouted boulders, are placed at regular intervals in the main race, and similar falls made of wood are constructed across No. 1 and No. 2 Branches, to reduce the velocity of the current, which is limited to about 3ft. per second. The carrying capacity of the tunnel and main race, with the first two branches, is calculated at 18,000,000gal. of water in twenty-four hours, or 12,500gal. per minute. A flow through the head-works of 7,400gal. per minute has been found sufficient for all requirements in ordinary weather; but during the prevailing north-west winds, when the season is hot and dry, it requires about 8,600gal. per minute to provide for increased percolation and evaporation. The area of the district which is watered by this supply is 102,813 acres. The district is divided into blocks of land, containing about fifteen hundred acres each, and each block is entitled to receive and be supplied with a separate gauge, which is taken from the main or branch supplies according to the circumstances of the case; but a supply is not granted until the necessary application-form is signed by the proprietors of the land within the block proposed to be watered, in accordance with the water-race by-laws of the county. The total cost of these works was about £20,460.

Greendale Water-race.—The supply of water for this race is taken from the Hawkins River, which is a tributary of the Selwyn River. The head-works consist of a concrete chamber 6ft. square, into which a supply of water is led, by means of a sluice-box, from the river. From this tank or chamber earthenware pipes are laid for about two chains into an open ditch. The water is gauged by means of a sluice-gate in the chamber, which is worked with a screw-lift. The dimensions of the main channel are 2ft. wide, capable of carrying water 1ft. deep, and from the end of the main channel there are two branches. The water is simply allowed to flow in a sinuous course through the land to be benefited by means of the main race and the two branches, which nearly run through the whole district; the length of the channels being twenty-two miles, and the fall averaging about 30ft. per mile. The carrying capacity of the main and branch races is calculated to be 1,850gal. per minute, but the quantity of water ordinarily flowing is about 750gal. per minute. There are no gauges in use except in the head-works. The cost of the head-works and the first three miles of the race was £202, the remainder of it being constructed by the proprietors of the land. The area of land watered is 10,400 acres.

Waireka Water-race.—This is a race similar to the Greendale Water-race. The supply is taken from the Selwyn River by having a wooden culvert laid in the ground for about 84ft. in length, and connected with the river at the upper end and with an open channel at the lower end, a sluice-gate being fixed at the inlet end of the box to admit and regulate the water into the open channel. The main channel is 2ft. wide and 1ft. deep for the first mile and a half, and 1ft. 6in. wide by 1ft. deep for the next mile and a half. The distributing-channels are only in course of construction, but when completed will be about twenty miles in length. The cost of the head-works and first 2 miles 10 chains of water-race was £158; the remainder of the distance has to be constructed by the proprietors of the land that the supply will benefit. The area of the district that this supply will water is 6,178 acres.

Hororata Water-race.—There are two water-supplies in the Hororata District, which comprise about ninety-six miles of main channels. No. 1 supply is thirty miles long, in two branches, and has a carrying capacity of 700gal. of water per minute. No. 2 supply, including branches, is sixty-six miles long, and has a carrying capacity of 4,200gal. of water per minute. Fifteen miles of branch races are under contract for construction, and fifty miles additional are proposed to be constructed. The dimensions of the channels vary according to the quantity of water they are required to carry, the main channels having a fall of 5in. and 1in. per chain respectively. The branch races or channels follow the natural inclination or slope of the ground, having a minimum fall of 1in. and a maximum fall of 2in. per chain; and the general depth of the water in the races is one-half the breadth of the bottom, the slopes on the sides being 1 in 1; and the grade, fall, or inclination allowed being sufficient to give a velocity to the current of from 1½ft. to 3ft. per second.

Head-works are constructed by having a concrete weir across the stream to be used for supply, having a box laid in the bed of the stream above the weir with an iron grating on the top, the bars being from $\frac{1}{4}$ in. to $\frac{3}{4}$ in., apart. This keeps the coarse shingle from getting into the box, which leads the water into a concrete tank or chamber, made on the bank of the stream, where a sluice-gate is fixed to admit and regulate the quantity of water into the pipes or concrete sewer which leads from the tank to a point where an open channel can be made. Wherever these pipes or sewers are used they are placed at such an inclination or fall as to secure a velocity of at least 3ft. per second. The system of distributing is by constructing branch races through the properties of those requiring water; and, the water being kept continually flowing, these branches very soon present the appearance of natural streams. The rate charged for water from these water-supplies varies in the different districts: From the Malvern Water-race—water for a head-race, £25 per annum; for supplying any hundred acres, £1 5s. per annum; license to take water in vessels from the water-race, £1 per annum; for water supplied into tank through a race, 6d. per 1,000gal. The rates from the Greendale Water-race are the same as those for Malvern District; but from the Waireka Water-race no charges have yet been decided on. The rates from the Hororata Water-race are £1 per annum for taking water in vessels for domestic or other use, and £1 per annum for each hundred acres of land that is supplied with water. Since the construction of these water-supplies the value of the land has been increased to the extent of £1 10s., and in some instances £2 per acre.

Ashburton County.—The length of artificial water-races in this county is 800 miles, of which there is a length of thirty miles for main channels and 770 miles of distributing-channels; the main channels having various carrying capacities, from 10,000gal. to 15,000gal. of water per minute, having a width at the bottom from 6ft. to 15ft., and a depth of from 12in. to 18in. They are constructed with a fall or inclination, varying according to the natural slope of the ground, of from 12ft. to 40ft. per mile; but in all cases in the main channels the velocity of the current is reduced by a fall, at intervals, to such an extent as to prevent a scour taking place. There are seven sources from which water is taken. These supply, in the aggregate, about 55,000gal. per minute. Head-works, where the supplies are lifted, generally consist of concrete weirs, constructed across the beds of the streams in the gorges near the base of the mountains; but in some instances the supply is taken direct from the rivers, and where this is done protection-works of a simple kind are constructed. The distributing-races are at distances apart varying from three-quarters of a mile to a mile and a half, and so placed as to pass through almost every property on the plains. These distributing-races are generally about 9in. deep, and from 15in. to 18in. wide at the bottom, with side-slope of 2 to 1. They run on gradients approximating to the natural declivity of the ground (about 50ft. per mile near the mountains, and 20ft. per mile near the sea). The total cost of construction is £22,500, and the land benefited by this supply comprises an area of about half a million acres. The rate charged the owners and occupiers of the land is merely a mileage-rate, to cover the cost of maintenance. Where sites are suitable the occupiers are allowed, under the Council's direction, to utilize the races for water-power, on a small scale, for chaff-cutting purposes, &c., without charge.

Water-supplies for Cities and Towns.

These comprise supplies for cities of Auckland, Wellington, and Dunedin, and the towns of New Plymouth, Nelson, Timaru, Oamaru, and Rotorua.

Auckland Water-supply.—The supply for the City of Auckland is obtained from a series of springs, situated about three miles from the city. These springs are from a district composed of beds of scoria (lava), which at some period has been discharged from the adjacent extinct volcanoes, Mounts Eden, Albert, and the Three Kings, comprising an area of about 2,370 acres, having a watershed of 5,760 acres. The water percolates through the beds of scoria, which form an excellent filter, and is collected at the springs, which are situated 25ft. above the sea-level. The supply is pumped direct from these springs into a high-level reservoir at Kyber Pass, and a low-level reservoir at Ponsonby, within the city. The former reservoir has a capacity of 1,750,000gal., and the latter 3,000,000gal.; the heights that the water is lifted being 284ft. and 209ft. respectively. The reservoirs are constructed of earthwork, the dams being composed of clay, consolidated, with a wall of puddled clay in the centre, extending all round the reservoir. The slopes of the water face are coated over with concrete 9in. in thickness; and the whole of the reservoirs are covered over with a corrugated-iron roof, in spans of 35ft. The Kyber Pass reservoir has a maximum height above the city of 306ft., and the one at Ponsonby 231ft.; the former being only used as an auxiliary, and for giving extra pressure in case of fire. The pumping-mains are turned off at Ponsonby, and only connected to the reservoir at Kyber Pass in the case when fires occur. The pumping-engines are of the compound beam type (rotative), working up to 180 horse-power, and are capable of pumping 2,250,000gal. of water in twelve hours into the reservoirs. The pumping-mains are 21in. in diameter and about three miles in length. The mains for supplying the city from the reservoir are about fifty-one miles in length, and varying in their dimensions from 4in. to 12in. in diameter. These works were designed and constructed by W. Ewington, M.I.C.E., at a cost of £125,000. The rate charged for water for domestic purposes is $2\frac{1}{2}$ per cent. on the rateable value of property, and 10d. per 1,000gal. for working machinery.

Dunedin Water-supply.—This city has two supplies, known respectively as the northern and the Southern supplies. The northern supply is obtained from a stream known as Ross's Creek, which has a watershed of about 1,000 acres. The head-works are situated one and a quarter miles from the city boundary, and comprise a main reservoir capable of holding 51,000,000gal., and a reservoir with a capacity of 6,000,000gal. of water. The main dam or reservoir is constructed with an earthwork embankment, having a puddle-trench in the centre, across the bed of the stream, the length of the embankment being 363ft., and 12ft. in width on the top. The slope on the breast is 3 to 1,

and is pitched with stone, the outside slope being 2 to 1, and covered with grass-turf. The maximum depth of this reservoir is 48ft. At one side of the embankment a by-wash is constructed with stone, 20ft. wide and 4ft. 6in. deep. This by-wash, in conjunction with a storm-water channel which is constructed for nineteen chains in length, is capable of carrying all the surplus water in the highest flood. At the reservoir there is a stone-valve tower with inlet and outlet pipes, the latter being laid under the embankment on stone-pillars. From the reservoir the water is conveyed to Dunedin in cast-iron pipes 12in. in diameter, which are calculated to deliver at the town boundary 2,777gal. of water per minute, or 166,620gal. per hour. The maximum height of this reservoir above the city is 372ft. The cost of the main supply was £142,650, and the extensions within the city £16,971, making a total of £159,621.

The southern supply is obtained from a creek known as the Silver Stream, the watershed of which is about twelve thousand acres. At the present time only one branch of this creek has been utilized. The head-works are situated about three miles from the city boundary, and comprise a main reservoir capable of holding 23,000,000gal. of water, cast-iron standpipes for valves within inlet and outlet pipes, and storm-water channel. The dam is constructed with an earthwork embankment, having a puddle-wall in the centre, 402ft. in length and 12ft. in width on the top. The slope on the breast is 3 to 1, covered with stone pitching, and the outside slope is 2 to 1, covered with grass-turf. The maximum depth of water in the reservoir is 43ft. On one side of the embankment is a by-wash, 8ft. wide and 3ft. deep, to carry off the surplus water. When this reservoir is full its maximum height above the city is 422ft. This reservoir is supplied with water from an open conduit—with short tunnels lined with brick going through the spurs—which is about twenty miles in length, and follows the contour round the hills. This conduit is 3ft. wide at the bottom and 2ft. 6in. deep, having a fall or gradient of 4ft. per mile. The several creeks on the line of conduit are crossed with stone culverts or wooden fluming set on stone piers. The whole of these creeks are intercepted above the line of conduit by a dam and inlet-gate to a short subsidiary race leading into the main conduit. At the head of the main conduit there is a concrete weir constructed across the bed of the Silver Stream, which acts as a dam; and from this the water is admitted into the main conduit by an inlet-gate.

The water from the reservoir is carried under the embankment of the dam in cast-iron pipes 18in. in diameter, and from this for a distance of one mile in pipes 14in. in diameter. From this point into the city there are two branches, one of pipes 14in. and the other of pipes 12in. in diameter respectively. These pipes are calculated to be capable of delivering 3,999gal. of water per minute, or 479,166gal. per hour. The cost of the works in connection with this supply was £80,636, making the total cost of both supplies £240,257. The rates charged for water are as follows: For domestic purposes, upon all lands and buildings whose annual rateable valuation does not exceed £12 10s., the charge for water is 10s. per annum; from £12 10s. to £100 annual valuation, 7 per cent.; from £100 to £200, 6 per cent.; from £200 to £300, 5 per cent.; exceeding £300, 4 per cent. Water-closets—for hotels, per annum, for the first, £4; for every other, £1: in private houses, the first free; the second, £2; every other, £1. Baths—in hotels, the first, free; the second, £2; every other, £1: private houses, free. Hydraulic lifts, 1s. 6d. per 1,000gal. Steam boilers and other purposes not otherwise specified, 1s. per 1,000gal. Water supplied to shipping, 2s. per 252gal. Meter-rent—up to 1½in. in diameter, £1 per annum; exceeding 1½in. but not exceeding 2in. in diameter, £1 10s. per annum; exceeding 2in. but not exceeding 3in., £2 10s. per annum. Water supplied to suburban boroughs, 6d. per 1,000gal. Water for motive-power or any other purpose or use not specified above, as per special agreement.

New Plymouth Water-supply.—The water-supply for the Town of New Plymouth is taken from the Waiwakaiho River at a point about three miles above the town. A weir is constructed across the bed of the river which raises the surface of the water 5ft. 9in. This weir is constructed of concrete blocks laid across the bed of the river, having a slope or batter on the breast and outside of 1 to 1, forming, as it were, an equilateral triangle set up across the river, with the top edge cut off, so as to fix a wood coping, which is held down by bolts to the concrete-blocks, on the downstream side. There are two rows of piles driven, one row close to the concrete wall, and the other row about 12ft. distant, the space between these rows of piles being filled in with boulders. The object of having these two rows of piles is to carry a timber apron, which is 14ft. in length, having an inclination of 1 in 5. The width of the river at the point where the weir is constructed is 200ft. There is an open conduit constructed from the weir for twenty-seven chains in length, where a fall of 12ft. 6in. is obtained. At this point there are two low-pressure turbine-wheels erected, which are used to pump the water from the river to a height of 150ft., into a service-reservoir. This reservoir is constructed in the shape of a frustrum of a cone, the base being uppermost; the width across the top being 192ft. in one direction and 126ft. in another, and it has a depth of 12ft. This reservoir is excavated for 6ft. under the level of the surface, and banked up for 6ft. above the surface, and lined with concrete 6in. in thickness. Its holding capacity is estimated at 1,250,000gal. of water. Before the water is lifted into this reservoir it is roughly filtered through gravel- and charcoal-beds. The maximum height of the reservoir above the town is 240ft., and the minimum height 160ft. The mains are laid from the reservoir to the town, consisting of cast-iron pipes 10in. in diameter and three miles in length. There are also six miles of service-mains, varying from 3in. to 8in. in diameter. These works were designed by Messrs. Barr and Oliver, engineers, and cost £22,000. The rates charged for water are—7 per cent. on the annual valuation of property when the water is taken in dwelling-houses; when not used in dwelling-houses, 3½ per cent. on annual valuation; when used in shops, 2½ per cent. on annual valuation; for working small machinery, from £8 to £16 per annum, according to the quantity of water required.

Nelson Water-supply.—The water-supply for the Town of Nelson is exclusively a gravitation scheme. The main supply is taken from a tributary of the Maitai River, at a point about four miles from the town. The head-works consist of a reservoir constructed with stone, capable of holding 500,000gal. of water; there is also a second reservoir, built of stone and cement, which is capable

of containing 700,000gal. The height of the first reservoir is 345ft., and the height of the second 300ft. above the level of the town. These reservoirs are connected by an open conduit. From the second reservoir the water is brought into town by cast-iron pipes varying in size from 7in. to 10in. in diameter; thence the water is carried in distributing-mains of various dimensions through the town, in proportion to the quantity of water requiring to be delivered. The total length of the mains, including branch supplies, is about fourteen miles; these are calculated to supply about 400,000gal. of water per day. The total cost of the works in connection with this water-supply was £24,860. The rates charged for water are as follows: Dwelling-houses, $3\frac{1}{2}$ per cent. on the annual rateable value; stores and warehouses, 2 per cent. on the annual rateable value; driving machinery, at a fixed sum per annum, according to the diameter of the supply-pipe—viz., 1in., £7; $1\frac{1}{2}$ in., £10; and 2in., £15 per annum.

Timaru Water-supply.—The water-supply for the Town of Timaru is taken from the Pareora River, and conveyed for the first two miles in open conduits, tunnels, and flumes, and for a short distance in an earthenware pipe 18in. in diameter, and thence to the town in cast-iron pipes, 14in. in diameter. The length of the main supply-pipe is sixteen miles, and the service-pipes in town about twelve miles, making a total of twenty-eight miles of pipes. The carrying capacity of the main pipes is 1,042gal. of water per minute, or 62,500gal. per hour. A concrete weir is constructed across the Pareora River, in a narrow gorge about eighteen miles distant from the town, which forms a dam in the river; and from this dam the water is taken into the open conduit at an elevation of 800ft. above the level of the town, and is discharged from the pipes into a reservoir covering an area of about one acre, excavated in clay, and lined on the sides with bluestone pitching. This reservoir is 250ft. above sea-level, and gives a maximum height above the town of 124ft. The total cost of the works in connection with this supply was £70,000. The charges for water are as follows: (1.) Upon all lands and buildings to which water is supplied whose rateable value on the valuation-roll does not exceed £12 10s., 10s.; exceeding £12 10s., but not exceeding £100, 7 per cent. on annual valuation; exceeding £100 and not exceeding £200, 6 per cent. on annual valuation; exceeding £200 and not exceeding £300, 5 per cent.; exceeding £300, 4 per cent. (2.) Upon land and buildings to which water can be but is not supplied, situate within a hundred yards of any part of the waterworks, one-half of rates above mentioned. (3.) Upon all buildings used as stores or warehouses or for any purpose other than a dwelling-house, £2 10s. per centum on rateable annual value. (4.) Any dwelling-house remaining actually unoccupied for not less than six months in any year, if the owners or occupiers give notice in writing to the Council of the dates on which the same became vacant and on which it was again occupied, shall be rated at only one-half the amount otherwise payable. Extraordinary supply—under the head of supply to single tenements consuming or using more than the ordinary supply—is charged by meter at the rate of 2s. per 1,000gal., at a minimum of 7,500gal. per quarter. Owners of blocks of buildings desiring one meter only, and using more than the ordinary supply, are charged manufacturers' rates and minimum. Hotels—first-class, having ten or more bed-rooms, per annum, £2 10s.; second-class, having less than ten bed-rooms, £1 10s. Lodging- and boarding-houses having five or more bed-rooms, £1 10s., and under five bed-rooms, 15s. per annum each. For public baths, per 1,000gal., 1s. 3d.; manufactories, 1s.; supplies for motive-power, water-engines, and hydraulic lifts, 4d. per horse-power per hour, but the minimum charge is 20,000gal. per quarter; boilers for steam-engines, £1 per annum per horse-power; condensing-engines, £2 per horse-power per annum; butchers' and bakers' shops, 25 per cent. additional on ordinary supply; livery stables, 10s. per horse-power per annum for the maximum number kept; cattle, mules, or asses, 5s. per head per annum; for marine boilers or ships of war, 1s. per tun; for ordinary shipping, 2s. per tun; breweries, chemical works, and public wash-houses, 1s. per 1,000gal.

Oamaru Water-supply.—The water-supply for the Town of Oamaru is brought from the Waitaki River at a point about twenty-five miles distant from the town. The water is conveyed in open conduits, tunnels, and flumes for about twenty-four miles, at the end of which there is a reservoir, situated about one and a half miles from the town, constructed partially by excavation, having at one end an earthwork embankment, with a puddle wall in the centre. This embankment has a slope of 3 to 1 on the breast and $1\frac{1}{2}$ to 1 on the outside, the inside slope being faced with a layer of puddle 12in. in thickness, and afterwards pitched with stone, having a coating of broken metal. In bringing the water from the Waitaki River to the reservoir, six tunnels, two of which are forty-five chains in length, had to be constructed, and also sixteen aqueducts, which are of timber. The largest of them has a maximum height of 95ft., and 480ft. in length, carried in eight spans of 60ft. each; the works for the remaining distance being open conduits, constructed 2ft. 6in. wide at the bottom, and 4ft. deep, having a slope of 1 in 1 on the sides. To take the water out of the reservoir there is a tunnel constructed at one end of the embankment six chains in length, and in this an oval pipe 37in. by 22in. is placed, at the end of which there are two mains connected, of pipes 18in. and 24in. respectively. At the reservoir end of the tunnel a concrete valve-tower is erected, and the supply is regulated from this tower to meet the requirements in the town. The greatest depth of water in the reservoir is 45ft., and when full it is capable of holding 80,000,000gal. The length of the main supply from the reservoir is about two miles, having a maximum head of 270ft., and a minimum head of 20ft., above the level of the town. In connection with this water-supply there are fourteen miles of cast-iron main service-pipes, varying from 18in. to 3in. in diameter, and seven and a half miles of wrought-iron and galvanized-iron pipes from $2\frac{1}{2}$ in. to $\frac{1}{2}$ in. in diameter. The rate charged for water for domestic purposes ranges from 5 to 6 per cent. on the annual rateable value of the property, and the rates charged for driving machinery are as follows: One-quarter horse-power and under, per annum, £5; one-quarter horse-power to one-half, £7 10s.; one-half horse-power to one, £12 10s., and up to four horse-power at this rate; above four horse-power, £10 per horse-power for twelve hours per day, and £12 10s. per horse-power for twenty-four hours per day; all charges being based on theoretical horse-power. The total cost of constructing this water-supply, including the purchase of land, was £137,000.

Wellington Water-supply.—The water-supply of this city is obtained from two sources—one from the Kaiwarawara Creek and the other from the Wainuiomata. The source of the former is about two miles distant from the centre of the town, or post-office, and is 310ft. above the lowest city level. The works in connection with this supply consist of a reservoir about twelve acres in extent, formed by a natural basin, in which the water is retained by the construction of a concrete weir across the stream. From this reservoir the water is conveyed, partly by a tunnel and partly by pipes, for a distance of thirty chains, into a storage or distributing reservoir, which is constructed of concrete at a height of 258ft. above the lowest town level. From this reservoir the water is conveyed through the city in main-service cast-iron pipes, varying from 10in. to 5in. in diameter, according to the quantity of water required to be supplied in different parts of the town, and from these mains smaller pipes are used in distributing the water through the various streets. This supply was the first that was constructed; but it was found inadequate to meet the requirements of the city, and is only now used in cases where the bursting of a pipe or other exigency necessitates the shutting-off the Wainuiomata or main supply. The latter supply has its source about sixteen miles distant from the centre of the town, and has now been in use for two years and a half. The works in connection with this supply consist of a reservoir, formed by a concrete dam being constructed across the bed of the Wainuiomata River, 395ft. above the lowest level in the town, at a narrow gorge, which forms a reservoir in a natural basin of fifteen acres in extent. From this reservoir the water is conveyed in a concrete-covered race, a mile and a quarter in length, into a concrete well 63ft. in depth; thence it is conveyed in cast-iron pipes 30in. in diameter for three and a half miles. In this distance the pipes are carried through a tunnel fifty chains in length. For the next eight miles and three-quarters the pipes are 24in. in diameter; thence 21in. in diameter for the next mile and a half, and 15in. for the next twenty chains; after which the main service-pipes are 12in. in diameter, to which distributing-pipes are connected, varying from 8in. to 3in. in diameter, to convey the water through the various streets in the city, the principal streets having two mains, which can be connected or shut off from each other, or can be supplied with water from either reservoir, as may be required. The rates charged for water are as follows: For domestic use, 5 per centum of rateable value of property if water is supplied; if water is not supplied the rate is 2½ per centum on rateable value of property; for stores and warehouses, 2½ per centum on rateable value of property; for motive-power, 4d. per 1,000gal.; for trade purposes, 1s. per 1,000gal. The cost of the first supply was £80,000, and the cost of the latter £135,000; making a total of £215,000.

Rotorua Water-supply.—The Government, about four years ago, commenced the construction of baths and a sanatorium for invalids in the Hot Lakes District at Rotorua, where hot mineral springs abound which have proved very efficacious in curing and relieving persons afflicted with gout, sciatica, rheumatism, paralysis, stiffness of joints, and skin diseases. The number of persons and invalids frequenting these springs from all parts of this and the neighbouring colonies—which number is daily increasing, necessitating the enlargement of the accommodation that has been provided—and also the large number of tourists frequenting the Hot Lakes yearly from all parts of the world, have induced a permanent population to settle, causing the place to become a small township.

The Government are now constructing a cold-water-supply for the use of the inhabitants, and also for the sanatorium and baths that have been erected. This supply is taken from the Paueranga Stream, at a point about three and a half miles from the township, and will be conveyed in a wooden flume for the first seventy-six chains, where a small concrete tank will be constructed. Thence the water will be conveyed in cast-iron pipes, 8in. in diameter, to the township, where branch pipes will be connected to convey the water through the different streets. The contracts at present entered into provide for about three miles of cast-iron pipes, of various diameters, being laid, and also fire-plugs and risers, connected at different points, to be used in case of fire. The mean head of water above the township will be about 84ft., and the cost of the supply when completed is estimated to be £8,000.

The total cost of the water-supplies as enumerated and described is as follows:—

Water-supplies for Goldfields, by Government.—Waimea Water-race, £118,576; Kumara Water-race, £54,601; Nelson Creek Water-race, £90,152; Charleston Water-race, £14,183; Mount Ida Water-race, £65,766; Thames, £80,709; Totara, £25,624; subsidies, £45,235; departmental expenses, £6,515: total, £501,361.

Water-supplies for Agricultural Pursuits.—Malvern Water-race, £20,460; Greendale Water-race, £202; Hororata Water-race, £7,407; Waireka Water-race, £158; Ashburton, £22,500: total, £50,727.

Water-supplies for Cities and Towns.—Auckland, £125,000; Dunedin, £240,257; Wellington, £215,000; Nelson, £24,860; New Plymouth, £22,000; Timaru, £70,000; Oamaru, £137,000; Rotorua, £8,000: total, £842,117. Grand total, £1,394,205.

I have, &c.,

HENRY A. GORDON,
Inspecting Engineer.

The Hon. the Minister of Mines.

