1905.
NEW ZEALAND.

NEW ZEALAND WATER-POWERS, ETC.

(REPORTS ON), BY MR. EDMUND ALLO, ELECTRICAL AND HYDRAULIC ENGINEER.

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

SIR,— Wellington, 2nd March, 1903.

I have the honour to forward herewith my reports on available power to be obtained from the Waikato (Huka Falls and Lower Rapids), Hutt, Waimakariri, Rakaia, and Otira Rivers, and also on the question of the transformation of railways by electrical traction.

I have, &c.,
EDMUND ALLO.

The Right Hon. R. J. Seddon, Premier of New Zealand.

HUKA WATERFALLS, WAIKATO RIVER.

The Huka Falls and rapids on the Waikato River, with their central position in the North Island of New Zealand, are ideally situated to be used as a central power-generating station to supply the whole Island. The power to be obtained from the Waikato waters in the neighbourhood of Wairakei should properly be divided into three distinct parts—

THE FALLS,
THE FIRST RAPIDS,
THE SECOND RAPIDS.

The falls are the smallest, but the easiest and cheapest power-factor of the three, nature having provided what man could only have obtained through an immense outlay of capital. The upper rapids of the falls run through two vertical sandstone rocks, in a straight line from A to B (see plan), where the actual fall of the river takes place; on each side of the A B rapids are levels of sandstone about 750 ft. long along the A B rapids, and about 300 ft. wide on each side from the rapids to the hills.

The scheme which naturally presents itself is to cut the race in the sandstone level from C to D to convey the water to the point D, where the sluice-gates deliver the water through the vertical main pipes to the turbines in the power-house built on existing rocks at point G, with a total actual fall of 53 ft. between the points A or C and H. At the point C the upper river has a vertical bank of 11 ft. depth of water with rock bottom, so that no river excavations whatever have to be considered. At the point D, where the head-race ends, there exists at the bottom of the cliff a bank of rocks (G) about 6 ft. above the lower-river water-level which makes an admirable foundation for the power-house (see section K L).

With the able assistance of Messrs. Meddings and Vickerman, of Auckland, I was able to get the following measurements of the water-quantity and waterfall. As already stated above, the total fall from A to H is 53 ft. (see section A H). The river at the bridge E has a width of 46 ft. between two vertical rock banks. The depth of water-measurement at the bridge at several points of the river has given over 20 ft. (exact depth above 20 ft. could not be ascertained because of the powerful current), but, to have a certain all-the-year-round quantum of water, 15 ft. deep has been taken as a safe coefficient. The water-velocity has been measured both above the bridge, from A to E, and below the bridge, from E to B, and has given the following results: A to E, 360 ft. in 28 seconds; E to B, 390 ft. in 36·5 seconds.

The above measurements give us

$$\frac{53 \times 46 \times 15 \times 13 \times 60 \times 62{\cdot}5}{33{,}000} = 53{,}730\text{-horse power},$$

with an efficiency of 85 per cent. for the turbine-power and of 95 per cent. for the electric-generating power

$$53{,}730 \times 0{\cdot}85 \times 0{\cdot}95 = 43{,}386\text{-horse power}$$

available at the power-house.

Dividing this power into four equal quantities of, say, 11,000 h.p. each, the percentage of loss for each quantity delivered in the four cities of Wellington, Auckland, Napier, and New Plymouth would be of an average of 15 to 20 per cent. (according to distances) for the transmission with wires of 0·2 in. in diameter. The up and down transformation of the current-tension from 50,000 to 200 volts would give a loss of 2 × 2 = 4 per cent. The total loss from the power-station to the centre of the towns can be averaged at 20 + 4 = 24 per cent. of the full load (according to the respective distances). The actual power delivered in each of the above-named cities would be not less than 8,750 h.p. for Wellington, 9,000 h.p. for Auckland, and 10,000 h.p. for New Plymouth and districts. It stands to reason that any amount of power taken from the lines between the power-station and the extreme delivery-point would proportionately reduce the loss and increase the available horse-power at the last point.

Power-station.

The power-station would be supplied with the electrical three-phase current system of generators; the tension would be of 2,200 or 5,000 volts, transformed into 50,000 volts tension for transmission purposes. The power-station would be constructed with turbine dynamos of, say, 2,200 h.p., equal to 1,500 kilo-volt-ampères each, and sets could be added from time to time to supply the increased demand of power. All the sets would be available to run in parallel; the main lines would be constructed to carry the whole capacity allotted to each section (about 11,000 h.p.).

This disposes of the power from the Huka Falls, but a far greater power is to be obtained from the rapids below these falls. Each one of these rapids has a fall of 150 ft. The same amount of water calculated in the Huka Falls passes through the rapids. We have, therefore, in each of the rapids a proportional power from 53 to 150, or 128,952 h.p. Taking the three powers together, we have

$$53{,}730 + 128{,}952 + 128{,}952 = 311{,}634 \text{ h.p.}$$

I must, however, draw attention to the fact that each rapid of 128,952 h.p. would, in proportion to the actual Huka Falls power, cost a higher proportional sum per horse-power for the initial cost, as the head-race would have to be carried along very rough mountain-sides; but, of course, the total amount of power obtained from each of the rapids, if able to be used up in the country, would greatly compensate for the extra head-race expense. The machinery cost would, of course, be the same per horse-power.

In the Huka Falls no dam would be required, as the upper rapid makes a natural dam, and the 11 ft. of depth in C would deviate all the necessary water. The dams for both of the rapids would not be expensive, as they would only be of insignificant height, the present rocks making part of it, and plenty of rock material being at hand.

With regard to the cost of construction of the first plant—that is, the Huka Falls—the following would be the rough and average prices of two units of 2,200 h.p., or 1,500 kilo-volt-ampères each:—

	£
Two main pipes, complete	1,000
Two turbines, 2,200 h.p.	6,000
Two generators, 1,500 k.v.a.	8,000
One switchboard	500
Transformers	4,000
	£19,500
Buildings and race	£1,000

The lines to carry the whole power would cost about £300 per mile; therefore the initial cost would be,—

	£
626 miles × 300	187,800
Two sets turbine generators	19,500
Buildings and race	1,000
	£208,300

To increase the plant about £10,000 should be added for each unit of 2,200 h.p. The consumers of power would buy their motors and pay for the installation. In the cities the current would be delivered at a reduced voltage of, say, 2,000 or 200 volts for power or lighting purposes. For railway purposes the current would be transformed by means of rotary transformers from 50,000 volts three-phase current to 550 volts direct current, or, as has been done with great success in the construction of the Jungfrau Mountain Railway, Switzerland, where three-phase current of 550 volts has been used, this system simplifying matters greatly, in giving better motors for the cars, having an easier start, and doing away with the rotary transformer stations, which means labour and cost saved, the current from the primary 50,000 volts three-phase transmission being simply reduced by ordinary transformers from 50,000 volts to 550 volts on the locomotive itself.

I believe that the above deals with the whole of the preliminary report on the falls, and I am quite at the disposal of the Government should any further information be required.

Financial Results.

It may be interesting to have a few figures as to the financial results that can be obtained from the undertaking. The power being sold at an average of £7 per horse-power per annum, which is a very low figure compared with the price of steam in this country, it will be easy to calculate the income from every part of the line. Of course, for lighting purposes the unit would be sold at a much higher price. With regard to the running-expenses, the following would be the cost of the whole generating-station and lines:—

	£
Chief engineer at, say, £500 a year	500
Two assistants at, say, £250 a year each	500
Three men at £2 per week each	300
One chief lineman at, say, £3 per week	150
Four linemen at, say, £125 per annum each	500
Office expenses and management	2,000
Total	£3,950

Admitting that at the start only 10,000 h.p. should be used all over the North Island, we would then have an expense of £340,000 for installation, which, at 4 per cent. interest, 4 per cent. sinking fund, and 2 per cent. repairs and other costs, would make £34,000.

	£	£
10,000 h.p. at £7 per annum		70,000
Less working-expenses	3,950	
„ oil, waste, &c.	1,050	
„ interest, &c., as above	34,000	
		39,000
		£31,000

It will be seen that a yearly amount of £31,000 still remains as a margin on the business, and it stands to reason that this, being profit margin, would be increased proportionately to the amount of horse-power used, as the primary cost of wire is calculated for the total amount of power, or about 40,000 h.p.

HUTT RIVER.

At the invitation of His Worship the Mayor of Wellington, accompanied by Mr. R. S. Rounthwaite, Engineer of the City of Wellington, and Mr. Barton, Engineer at Upper Hutt, we visited the Hutt River.

This river has a slow run between very steep, practically inaccessible banks, consisting of very high vertical rocks on one side, and on the other side very steep broken mountain-sides running at angles from 60° to 75°, and sometimes 80°. The water-measurements have been taken on a spot where the river runs between two rocks and where the flowing water has a width of 78 ft. The average depth has been found to be 1 ft. 7½ in., and the mean velocity of the water 0·7 ft. per second. This gives us

$$78 \times 1 \text{ ft. } 7\tfrac{1}{2} \text{ in.} \times 0{\cdot}7 = 91 \text{ cubic feet per second.}$$

This head of water would give us, with 100 ft. fall, 810 h.p.; with 200 ft. fall, 1,620 h.p.; and with 300 ft. fall, 2,430 h.p. at the power-station. To obtain these waterfalls, in the first case about two miles and a half, in the second case about three miles and a half, and in the third case about four miles and a half to five miles of race would have to be constructed, and this in a very rough, broken, mountainous country with no roads to bring material, and which presents any amount of technical difficulties that only capital could overcome.

Taking the efficiency of the turbines at 0·85, of generator 0·95, and taking transmission line and transformation loss at 10 per cent., we would have with the largest computed fall, in Wellington, 1,600 h.p. This small amount of power is of no avail whatever for a city of the size of Wellington, where at the present day there would be a demand for electric power of about 1,500 h.p. for electric railways, about 2,500 h.p. for city lighting, and about 3,000 h.p. for industrial power—a total of about 7,000 h.p.

It stands to reason that with these figures it would not be of any advantage to the City of Wellington to put up any power scheme for practically one-fifth of the necessary power at present required by the town, without leaving any margin for the certain increased demand for power for industrial purposes. Of course, Mr. Barton has shown us, according to his idea, the best spot from where the river should be studied, and I may state that these points are exclusive of the waters of the Mungaroa and the Akatarawa. Even if these two waters were taken in there would only be about 2,500 h.p. available in Wellington, but technical difficulties below the Mungaroa would make the whole scheme practically impossible, both from a technical and financial point of view, as by this time the Hutt River has left the gorges and runs in flat open fields.

It would be difficult at the present day to give even a rough estimate of the cost of the scheme, but I consider that the plant could be put in for nothing below from £150,000 to £200,000, because of the great technical difficulties to be overcome by building the head-race. Of course, 1,600 h.p. at £7 = £11,200 would never pay as a financial scheme. Taking £200,000 at 4 per cent. interest, 4 per cent. sinking fund, and 2 per cent. repairs and maintenance, we get 10 per cent. on £200,000, which amounts to £20,000. To this we must add about £3,000 or £4,000 working-expenses, which gives us £10,000 more expenses than we have income. I believe that these figures alone are sufficient to dismiss the whole scheme, as it shows the impracticability of using the Hutt River for any scheme such as proposed.

WAIMAKARIRI RIVER.

Accompanied by Messrs. W. H. Hales, Engineer-in-Chief of the Public Works Department, and A. Dudley Dobson, City Engineer for Christchurch, I visited the Waimakariri River, both at the gorge near the railway-bridge and at a point six miles higher.

I will first report on the upper scheme.

UPPER SCHEME AT ROCK FORD.

At this point the river has a shingle bed of about one mile wide. The banks are low—not above 20 ft. above the river-bed. Making a dam with a high fall is out of the question. Only a race could be considered. This race would have to be about five miles in length to obtain the necessary fall, and would have to be built capable of delivering 2,000 cubic feet per second, with a water-velocity of 4 ft. per second. The cross-section of the race would have to be about 50 ft. wide and 10 ft. high —10 × 50 × 4 = 2,000 ft. per second. The building of such a race with necessary lining and upkeep would be very expensive; besides, a low dam about 8 ft. high would have to be built at a 45° angle up the river, to drive the water into the race. To run this dam across the river would mean (at 45°), taking 20 ft. depth of shingle, a wall of

28 ft. × 20 ft. × 7,800 ft. = 161,777 cubic yards.

161,777 × 2 = £323,554. This alone, without going further, should condemn the scheme, as it costs more than the whole gorge scheme running.

THE GORGE SCHEME.

As can be seen from the annexed plan, the river about 4 chains above the railway-bridge and a few yards below the irrigation intake has its narrowest part between two solid rock walls. I propose to have a dam built at this spot 90 ft. high, so as to insure a 90 ft. waterfall. This is the most economical and most simple way of creating a power-station, as will be seen from the following report:—

The banks have a height on both sides of the river of 108 ft. above the river-bed, or low-water mark. The width of the river is at water-level 4 chains, at 90 ft. high 6 chains, giving a mean of 5 chains = 330 ft.

The dam should be built with slanting faces on both sides; on the low-water side a slanting shelf (about 20 ft.) should protrude to catch the falling water, preventing the river-bed rock being damaged, and insuring the solidity of the foundations of the dam. The dam would rest on the rock bottom of the bed, which would necessitate removing about 16,000 cubic yards of shingle, to be used for the concrete. This would cost about £1 per cubic yard, or £16,000.

The dam, which would contain about 45 × 110 × 400 = 73,500 cubic yards of concrete masonry, can be reckoned at £1 5s. per cubic yard, the small shingle in the bed of the river being used, and the railway bringing cement, &c., alongside.

73,500 × £1 5s. = £91,875.

A tunnel could be cut in the rock, or the present small irrigating tunnel could be enlarged to deal with the water while building the dam, although the whole work could be done by "caissons," which would give us a total cost for the dam of 16,000 + 91,875 = £108,875. (See plan section.)

The objection that the shingle will interfere has not to be considered, as the shingle piling up against the dam will only strengthen the latter and heighten the river-bed up to the 90 ft. dam level, which does not inconvenience us, as the river (taking a level from the 90 ft. dam to a point six miles up) would take 34,640,000 cubic yards before the shingle would run over the dam, and then only follow its natural run down the river, as it does at the present day, without interfering with our race intake, which would be protected against large boulders entering, and small shingle would run through with the water. To fill the river with shingle level with the dam would take at 2,000 cubic yards per annum 17,320 years.

The turbines would be immediately under the lower side of the dam, and the water from the top of dam would be carried to the turbines through steel pipes, having each a sluice-valve at the top and bottom. Horizontal turbines with vertical shafts supporting the generators could be used, and the water when leaving the turbine would flow through an open tail-race and be returned to the river at the foot of the dam, thus not creating any disturbance in the natural run of the river.

Water-power.—The water has been very carefully watched and measured by Mr. Dudley A. Dobson, of Christchurch, for several years, and the lowest quantity of water has been computed at 2,000 cubic feet per second. The figures of Mr. Dobson can therefore be taken as correct, and would give us

$$\frac{2{,}000 \times 90 \times 60 \times 62\cdot5}{33{,}000} = 20{,}454 \text{ h.p.},$$

giving an efficiency of 20,454 × 0·85 × 0·95 = 16,500 h.p. at the power-station.

The loss along the line with a drawn copper wire of $\frac{2}{10}$ in. diameter would be,—

$\frac{11{,}000{,}000 \times 64{,}000 \times 100}{57 \times 78\cdot5 \times 2{,}500{,}000{,}000 \times 0\cdot64}$ = ...	.. 9 per cent.
Transformation up	= 2 „
„ down	= 2 „
	13 per cent. loss,

or 16,500 h.p. − 13 per cent. = 14,500 h.p. available in the City of Christchurch.

POWER-STATION.

The power-station, which would be situated at the foot of the dam, would be built on strong concrete foundations and of stone walls, with iron roofing (no frost being feared in the country). It would be of sufficient dimensions to contain the whole of the machinery to take up the $\frac{20{,}454}{2{,}200}$ or eleven to twelve sets, allowing two or three sets as spare in case of accident to some units. This would require a building of about 30 ft. wide by 180 ft. long and 20 ft. high, containing a 5-ton-capacity travelling-crane for mounting the machinery, and units consisting each of one turbine of 2,500 h.p. complete; one generator three-phase alternating current taking 2,200 h.p., and delivering at 0·95 efficiency on full load 1,500 kilo-volt-ampère, with 3,000 to 5,000 volts potential; six transformers to raise the tension from 5,000 to 50,000 volts for transmitting purposes; and switchboard complete.

Cost of each unit about £10,000.

Transmission Line.

The line would be supported on strong wooden poles, about thirty to the mile, and at least 25 ft. high above the ground-level. The line would consist of three wires of $\frac{2}{10}$ in. in diameter, or six wires of $\frac{1}{10}$ in. in diameter, of soft-drawn pure copper.

The insulators would be of the large apron three-bell type, and capable of insulating up to 100,000 volts (the line being 50,000 volts). The line would be provided with at least one lightning-arrester to each wire every mile, and all the necessary safety fuses, &c.

The transformers to reduce the potential from 50,000 to 200 volts would be placed in different parts of the town in neat iron constructions, and well insulated. No sub-station would be required for the light or power. Only the street railway would require a sub-station to transform the three-phase into direct current at 550 volts tension by means of rotary transformers. Each group of rotary transformers would cost complete £2,000 for a power of 350 h.p., two or three sets being sufficient for the service of the town with thirty miles of road and a ten-minutes service. Forty-five cars at 20 h.p. = 900 h.p. But these come under a separate consideration.

This concludes every point of the Waimakariri scheme. Any further information which may be desired I shall gladly furnish.

Cost of line, £300 × 40 = £12,000.

The whole plant as enumerated above could be put in for a capital of £250,000.

	£
Taking interest at 5 per cent., sinking fund at 5 per cent., repairs, &c., at 2 per cent., equal to 12 per cent., or £30,000	30,000
Working-expenses—	
Chief engineer, salary	500
Two assistants at £250 each	500
Three men at £125 each	375
Three linemen at £150	450
Office expenses and management	1,000
Oil, waste, &c.	1,175
	£34,000

	£
The sale of 14,000-horse power at £7 per annum gives	98,000
Less deductions of working-expenses	34,000
Leaves a profit of	£64,000

The town would require at the present time—	
For lighting	2,000 h.p.
For tramways	1,000 „
For power, about	3,000 „
Total	6,000 h.p.

6,000 h.p. at £7 = £42,000, or sufficient to pay for the interest and expense of the whole plant. Of course, only part of the machinery can be put in at first, and units could gradually be added to satisfy the demand, which would decrease the interest account for the first years. It may therefore be said that the whole scheme is on a good financial basis.

RAKAIA RIVER.

Besides the Waimakariri, I have also inspected the Rakaia River at the point called "the Gorges," where an island is situated in the middle of the river and is connected on each side with the mainland by Government bridges. The quantity of water running through the river can be estimated at at least 6,000 cubic feet of water per second. By building dams across the two arms of the river on each side of the Island, each dam about 300 ft. long, and would require to be 42 ft. high above water-level, they would therefore contain about the same amount of concrete as the Waimakariri scheme dam, and the price can be put down as being about the same, or £110,000. This 6,000 cubic feet of water with 42 ft. fall would give us about 20,000 h.p. delivered in the City of Christchurch at practically the same total cost. The water in the river should be banked up 42 ft., and surveys should be made to ascertain the value and area of Mr. McLean's property, which is situated behind the second gorge, and which will be partly swamped, and for which damages will have to be paid.

This Rakaia scheme certainly presents advantages over the Waimakariri in so far that it would be much easier to build the whole hydraulic works, having the two arms of the river; the water could be ejected by one arm while the other was being built—facilities which we have not got in the Waimakariri scheme. The power-station could be installed at the bottom of the cliff on the small terrace standing about 10 ft. above water-level. Across the second bridge a race could be cut, to deal with about 6,000 cubic feet of water per second. A bridge should be built over this race to connect with the road, and from the end of the race through valves the water would go direct to the turbines standing on the terrace below.

Although this spot is fifteen miles further away from Christchurch than the Waimakariri Gorge scheme, the small increase of transmission line would hardly have to be considered in view of the larger amount of horse-power to be delivered in Christchurch—about 20,000 as against 14,500 h.p.

Mr. Dudley Dobson and Mr. Hales both concur with me in my opinion that the Rakaia would be the easier scheme of the two. I should therefore strongly recommend that the City of Christchurch should give Mr. Dobson the necessary instructions to have a total and careful survey made of the Rakaia, as he did of the Waimakariri Gorge. I shall then be able to give a fuller report upon the Rakaia River than what I could do at present, when effective figures are failing. The plans and sketches are those that were drawn up to build the bridges in the Rakaia Gorge, and have been given to me by Mr. Hales.

I shall at any time be pleased to put myself at the disposal of the Government.

OTIRA RIVER.

Accompanied by Mr. Hales and Mr. Dobson I visited the Otira Gorge with the view of ascertaining what water-power could be got from the Otira River. The Otira Gorge is a very rough piece of country, where a great many difficulties and expenses would be met in making a race of sufficient length to assure the fall sufficient to have any power to transmit. Under these circumstances I do not think the Otira Gorge can be used for large energies, as the capital cost would be too heavy to give any satisfactory financial returns.

Below the zigzag of the main road and close to the big shingle slip, and right at the foot of the rock in which it is proposed to cut the Midland Railway tunnel, there is a very narrow gorge not more than 24 ft. wide through which the Otira waters rush. The computation of these waters give the possibilities of getting a few hundred horse-power out of this place, but I should propose that this power should be used to run the trains through the tunnel by means of electrical traction, which would be of very great advantage, doing away with smoke in the tunnel. Locomotives with 2 × 64 = 128 h.p. would be sufficient to do the work on that line. Higher up, close to the source of the Otira, the falls are very rapid, and a certain amount of power—say, from 800 to 1,000—could be procured; but, taking into account the rough country, it would be rather expensive as a scheme. Unless hard pressed for power, I should not entertain any ideas of using the Otira waters in any other way than for the tunnel-construction, traction, lighting, and ventilating.

TRANSFORMATION OF RAILWAYS BY ELECTRICAL TRACTION.

The transformation of the present system of steam railways into electrical-traction railways would certainly require a vast amount of capital, but it would also give good returns, and very greatly improve the train system of the whole country. Instead of running on the steep grades which I have noticed, combined with which steepness are many rather sharp curves, small trains either for passengers or freight, or preferably mixed trains, could be run at short intervals, thereby giving much better passenger facilities. The water-power has not to be reckoned as the present steam-power, which means outlay of coal expense for every horse-power used. Communication between north and south by several trains a day would add to the convenience of passengers and business in general.

The cost of equipping the present 3 ft. 6 in. line electrically would be the cost of trolly-wire overhead and the copper bondage of the present road-bed, which can be calculated at about £300 per mile.

The electric locomotives, containing each 2 × 64 = 128 h.p., would be sufficient to run all your ordinary trains on the existing grades. I understand that the present power used in the whole of the North Island for the railway-engines amounts to about 4,000 h.p. By taking rotary transforming units of 500 h.p. at a cost all complete of about £4,000 per unit, eight units would be required for actual working and two units as a reserve—that is, in case the whole of the transformation from steam to electricity would be made at once. As previously stated, the three-phase alternating current with 50,000 volts primary potential could be transformed on the electric locomotives into 2,000 or even 550 volts alternating three-phase current, doing away with the rotary transformers which change the alternating three-phase into 550 volt direct current, thereby saving expense and simplifying the whole system. Of course, if only part of the lines should be equipped, from one to several rotary transformation units could be put up. The electric locomotive would pull the present cars. All over the world the economy of electrical power over steam has been calculated at 40 per cent.

There are about a thousand miles of railways in the North Island south of Auckland. The equipment without the power-station can be reckoned at about £500 per mile. One thousand miles would therefore cost £500,000. As already referred to, this would greatly improve the Railway service in so far that along the trolly any number of trains could be pushed through at short intervals, increasing the number of services and the speed, and therefore the convenience of the passengers and goods carried over the line, and all this with a reduction in the present cost of railway-running.

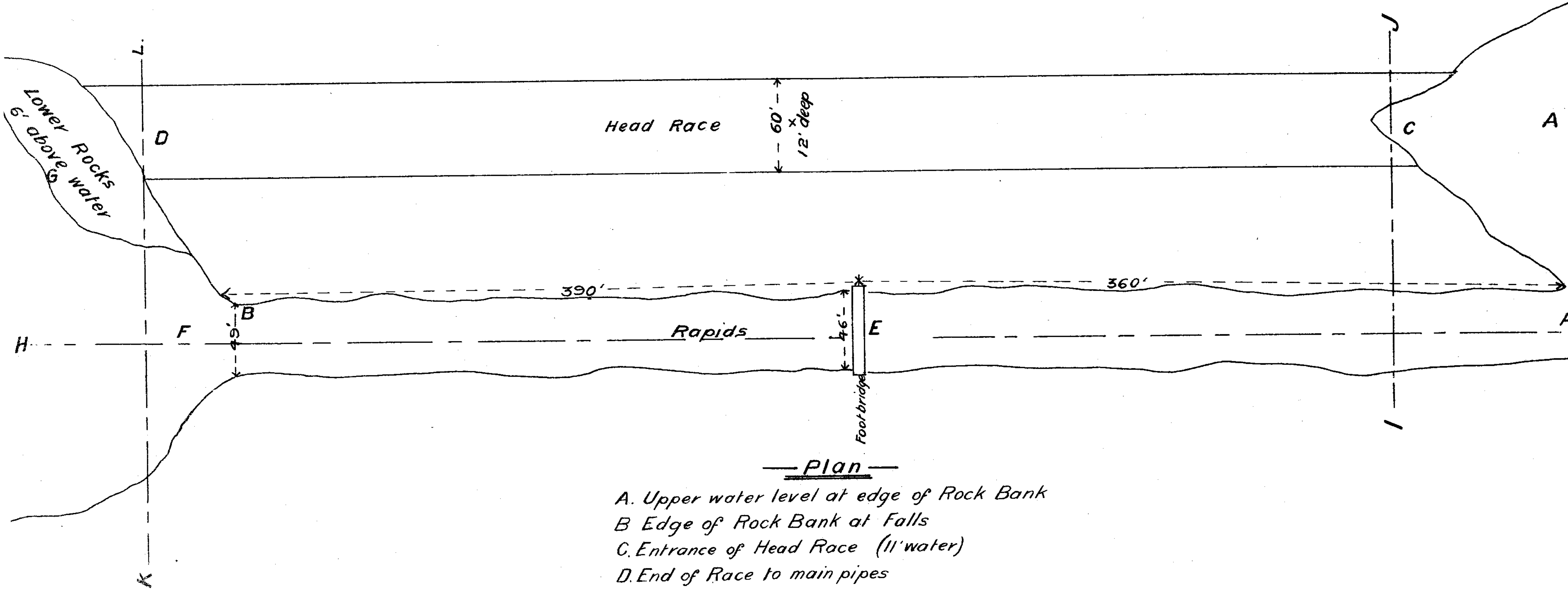
Approximate Cost of Paper.—Preparation, not given; printing (1,425 copies), £3 15s. 6d.

By Authority: John Mackay, Government Printer, Wellington.—1905.

Price, 6d.]

Huka Falls, Waikato River

Scale 80ft = 1 Inch



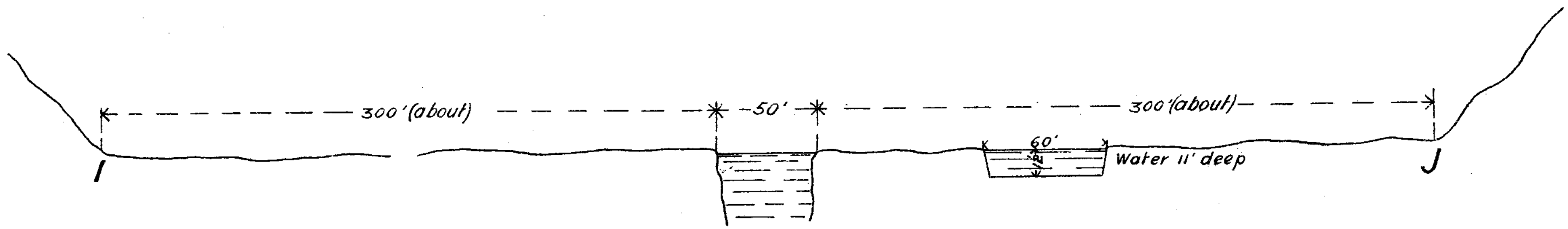
Plan

A. Upper water level at edge of Rock Bank
B Edge of Rock Bank at Falls
C. Entrance of Head Race (11' water)
D. End of Race to main pipes
E. Bridge
F. Huka Fall
G. Rocks, site for Power Station
H. Lower Water Level

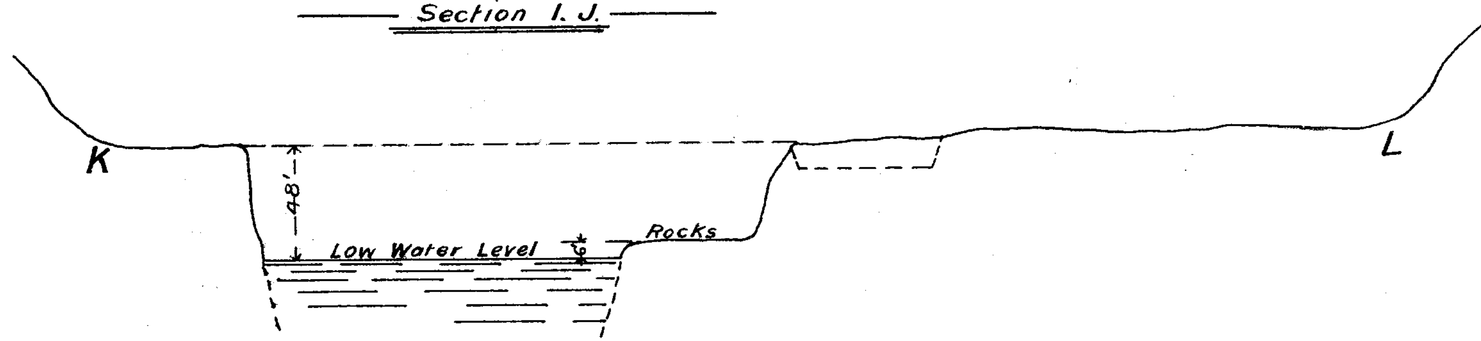
Copy of P.W.D 20408

Huka Falls, Waikato River

Scale 80ft = 1 Inch



Section I. J.



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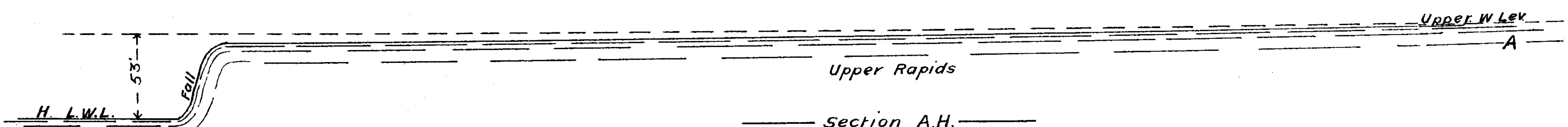

Section A.H.

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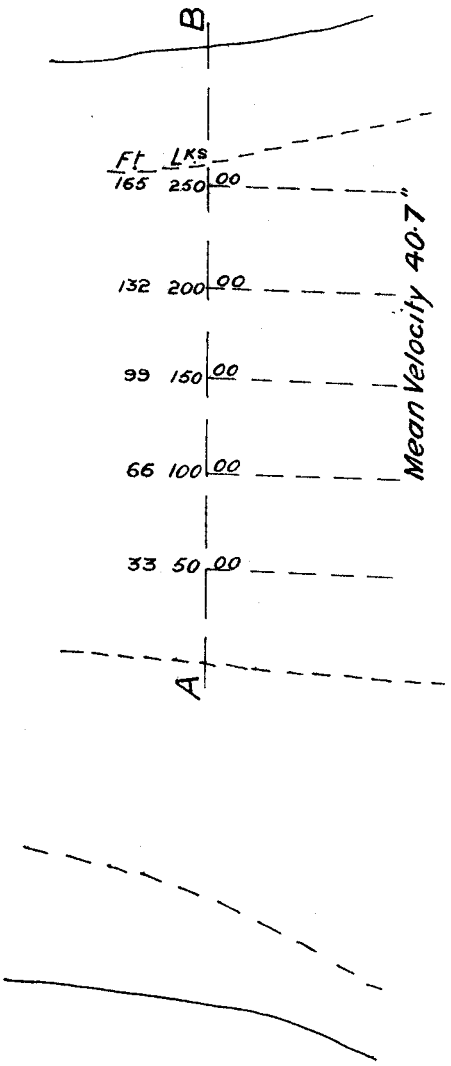
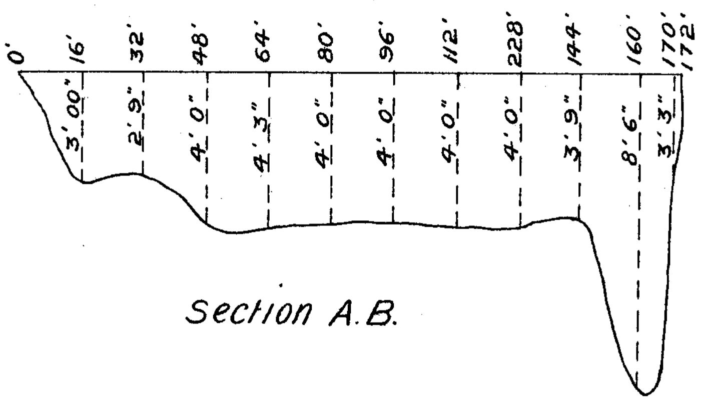
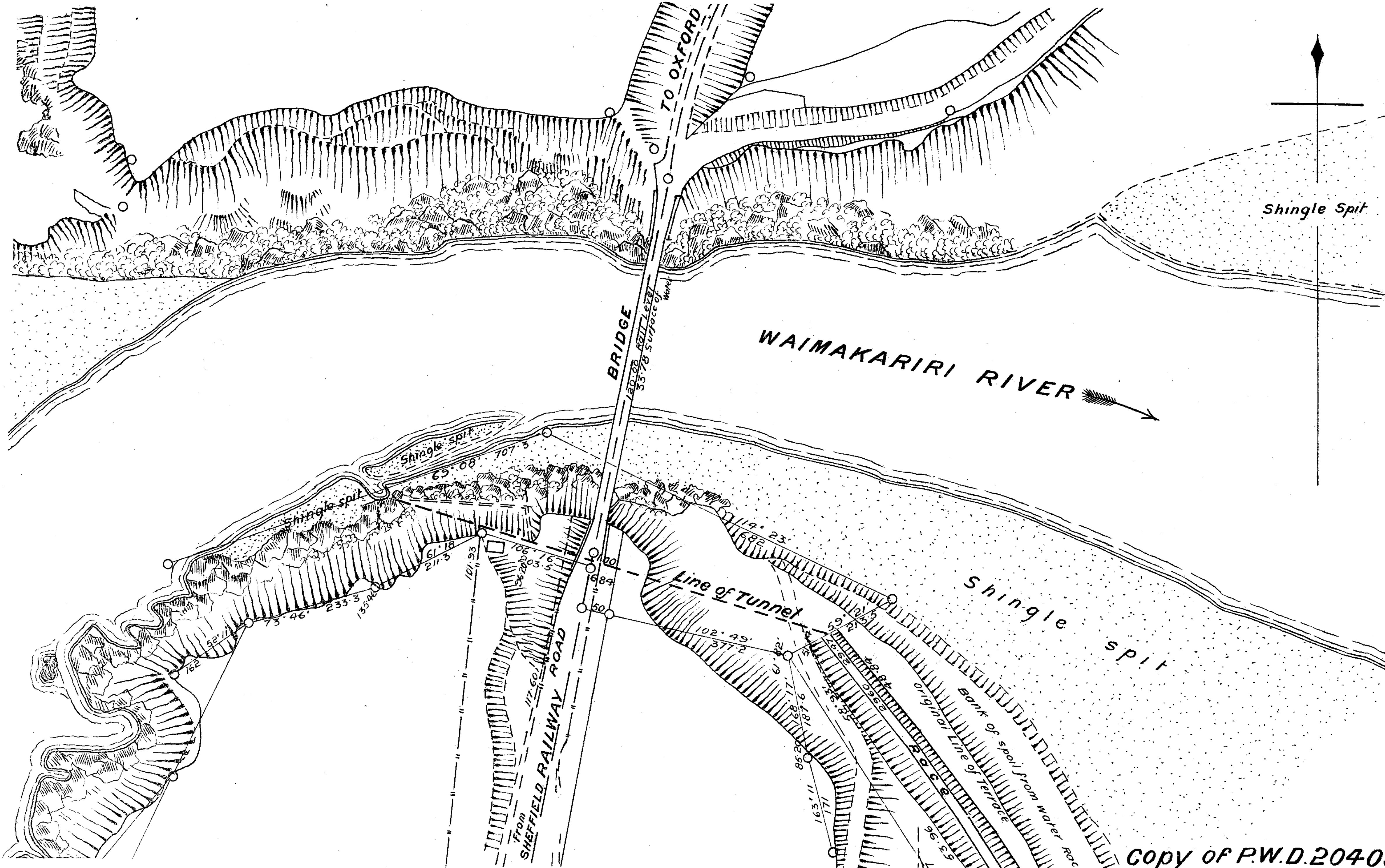


Scale 1 Chain to an Inch

Areas ------------------------ 705 C.F. Velocity 3 FT per sec.



Section A.B.



WAIMAKARIRI RIVER
BRIDGE
120.00 Rail Level
33.78 Surface of Water
TO OXFORD
From SHEFFIELD RAILWAY ROAD
Shingle Spit
Shingle spit
Line of Tunnel
Race
Original Line of Terrace
Bank of spoil from water Race
Copy of P.W.D. 20409