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VICTORIA.

ELECTRICITY COMMISSIONERS.

REPORT

ON

KIEWA HYDRO-ELECTRIC SCHEME

TOGETHER WITH

REPORT OF A. G. M. MICHELL, M.C.E.

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ELECTRICITY COMMISSIONERS' REPORT

ON

KIEWA HYDRO-ELECTRIC SCHEME.

The Hon. Arthur Robinson, Attorney-General,
Melbourne.

SIR,

I. SCOPE OF REPORT.

In the Report of the Electricity Commissioners of 26th November, 1919, Section VIII., reference was made to investigations which the Commissioners had then initiated into the feasibility of utilizing certain known water-power resources of the State for the purpose of the production of electrical energy upon a considerable scale. These particular resources comprised the Kiewa River, the Rubicon River, and the Sugarloaf Basin at Eildon Weir.

The investigations referred to have now reached a stage when it has become possible for the Commissioners to arrive at definite conclusions, applicable to existing economic and financial conditions, as to the propriety or otherwise of embarking upon an early realization of such a scheme or schemes, in whole or in part. In accordance with section 10 of the *Electricity Commissioners Act* 1918, we now beg to submit a Report dealing with this matter.

II. CHARACTERISTICS OF HYDRO-ELECTRIC SCHEMES.

For a better understanding of the problems involved in such an inquiry, we venture, in this Report, to set out very briefly some of the principal factors, both engineering, economic, and topographical, which have to be taken into consideration.

In every form of generation of power, the ultimate cost to the public may be divided into two parts, viz., that depending upon capital cost, and that depending upon operating cost. That scheme is the most economic in which the *total* of these two parts is the least.

In a heat-power scheme, the operating cost includes the cost of fuel and of its handling, and is therefore higher than the operating cost of a hydro-electric scheme, which, at its hydraulic end, is to a large extent automatic.

It is this consideration which leads to a belief, widely held, that, broadly speaking, the generation of electric energy from water power is cheaper than its generation by the use of steam. This is, however, erroneous as an abstract proposition, because it omits to take into consideration that part of the cost of energy which depends on the capital cost of the whole scheme.

Now, in the very nature of things, the capital cost of a hydro-electric scheme is, under average Victorian conditions, substantially higher than that of a heat-power scheme. The electrical apparatus (comprising generators, switch-gear, and other auxiliaries), the transmission lines, and the distribution system are common to both. The hydraulic machinery of the one scheme takes the place of the steam raising machinery of the other. But that ingredient of capital cost, which is inseparable from a hydro-electric scheme, and which is entirely absent from a heat-power scheme, is the cost of hydraulic head-works, necessary for the collection, diversion, conservation, conduction, and regulation of the waters of those rivers and streams whose resources are being tapped. Such works, if located in unsettled, mountainous country, difficult of access, are often exceptionally costly.

It is this latter portion of the capital cost which may alone, in a given case, reach such high figures as to have a paramount influence in rendering the hydro-electric scheme uneconomic, as compared with steam; for the reason that the higher annual interest and sinking fund charges would in such a case overshadow any savings in operating charges due to the absence of fuel.

There are other factors also which influence capital cost. Among these are existing market conditions. It is a circumstance of the present times, which operates to the disadvantage of water-power schemes, that the enhancement, above the normal, of the cost of certain important essentials of any such scheme is to-day greater than that of almost any other part of the machinery required. In such articles, for example, as large diameter steel piping, capable of withstanding high-water pressures, and of which a large hydro-electric scheme may require considerable quantities, the present-day cost is more than five times the pre-war cost. It will therefore be seen that, under present-day conditions, for such ambitious hydro-electric schemes as are under discussion, and whose head-works would have to be located, in greater part, in remote and difficult country, the economic advantages popularly associated with water power can by no means be taken for granted.

III. ECONOMICS OF HYDRO-ELECTRIC SCHEMES.

It may also be desirable to point out that as a consequence of the high capital cost, in order to operate economically, a hydro-electric scheme requires a " load " as uniformly distributed throughout the 24 hours as possible. The rate of output at the busiest moment of the day determines the size and cost of the whole plant, and to a very large extent also that of all hydraulic head-works. It would be wasteful, therefore, from an engineering point of view, to employ water power, especially if available only at a distance, for a service which fluctuates throughout the day between a high maximum and a low minimum.

A case in point would be the supply of electricity to a provincial town or group of towns, chiefly for street and residential lighting, but having only a small industrial demand capable of consuming and paying for all the energy available during the hours of daylight.

In support of this aspect of the general question, we quote from the annexed report of our Hydraulic Engineer—

> " It is necessary to the economic soundness of every hydro-electric scheme, comprising extensive hydraulic works and transmission lines, that the demand for, and supply of, power should be approximately continuous and uniform. Otherwise the hydro-electric scheme cannot compete with heat-power generated at the point of consumption, unless in some country where fuel is exceptionally scarce and dear. At present the only market capable of absorbing the output of a large hydro-electric scheme is that of Melbourne."

IV. KIEWA SCHEME NOT SUITABLE FOR PROVINCIAL NEEDS.

These are some of the considerations which have guided the Commissioners into investigating the Kiewa and associated water-power schemes, in the first instance, as a source of power for the metropolis only. Without at this stage anticipating the question whether the auxiliary schemes at Rubicon and Sugarloaf might either or both be made economically applicable to lesser specific objectives, such as the supply of energy to the rural districts within a short range of those particular sources of supply, the Commissioners are able, from the investigations at their disposal, to arrive at the quite definite conclusion that the Kiewa Scheme, as a whole, and particularly as to that part of it which is based on head-works located in the Kiewa River basin, does not at the present day permit of any serious consideration for any other objective than metropolitan supply. In other words, the Kiewa water-power scheme cannot be regarded as an economic or desirable solution of the electrical needs of the provincial districts lying along and to and contiguous to the North-Eastern railway.

In this connexion, it seems also desirable to dispel the belief, widely entertained, that a long transmission line, carrying electric energy to a distant objective is capable of being economically " tapped " for the local service of the towns and districts which lie in the vicinity of its route.

Such a belief is fallacious. Transmission of energy over a long distance (such as 100 miles) is economically possible only at very high voltages (such as 100,000 volts or over). The cost of tapping in and of the transformation of such a high-tension current to the relatively very low voltage suitable for the needs of rural towns and districts, and doing this at many points, and in small quantities at each point, would be prohibitive.

V. ENGINEERING INVESTIGATIONS AND REPORT.

The Commissioners on 1st June, 1919, placed in the hands of Mr. A. G. M. Michell, M.C.E., their Consulting Hydraulic Engineer, the conduct of detailed investigations into the topographical and climatic conditions involved, the preparation of an outline scheme of works, and the framing of estimates for bringing such a scheme into existence at the present day. A copy of his report and estimates is annexed. The Commissioners have, after close consideration, adopted same as a reliable guide to the determination of policy questions involved.

The inquiries into the water-power resources of the districts concerned have been as comprehensive and complete as the time which has elapsed since they were initiated has permitted. They comprised a review of previously acquired data, together with new rainfall observations, stream gaugings, explorations, and surveys. Upon the results of these inquiries a judgment was formed as to the greatest amount of continuous power which could be relied upon, after aiding natural conditions with necessary works of water storage. A definite scheme was then formulated for linking up several sources of power in a manner designed to obtain the greatest combined effect from the point of view of a continuous supply. Each part of this scheme was then studied in sufficient detail to enable reliable estimates of probable cost to be arrived at. These estimates and the conclusions to which they lead are discussed hereunder.

VI. AVAILABLE WATER POWER.

The rivers and streams of this State are characterized by a very wide range in their discharges, due not only to the different seasons of the year, but also to the contrast between drought years and wet years. From the point of view of a reliable continuous supply of electric energy, it is only the minimum power available during a drought year or a sequence of drought years that can be properly taken into account.

The fluctuations in the discharge of any given stream or group of streams throughout a single year can, to a large extent, be met by works of storage; but, in general, such storage, if carried to the extent of attempting to tide over whole drought years, as well as the drought period of every year, would be altogether prohibitive in cost.

Having regard to these limitations, the conclusions which have been arrived at are that the group of streams constituting the main Kiewa Scheme can, after storage regulation, be relied upon for a constant output of not more than 30,000 kilowatts.

The Sugarloaf Scheme and the Rubicon Scheme combined, when similarly regarded, can supply 7,000 kilowatts as a continuous supply.

The total or combined resources of these three schemes, when linked together for the purpose of a continuous supply to one terminal point, for a single objective, may be rated therefore as not exceeding 37,000 kilowatts. This figure forms a convenient standard, for the purpose of making comparisons of capital and operating costs with heat power schemes, either projected or in more remote contemplation.

Attention should be drawn to the fact that the Sugarloaf and Rubicon Schemes have been considered, so far, only as forming part of a combined scheme, that is as being linked up with the main Kiewa Scheme, and in order to enhance the maximum continuous output of the latter. Taken by themselves "they are to a great extent complementary to one another, the former giving a summer, and the latter a winter supply."—(Michell's Report).

VII. ESTIMATES OF CAPITAL COST.

The Hydraulic Engineer's Report annexed contains itemized schedules of estimates for every part of each of the three integral portions of the combined schemes. These schedules are presented for consideration in a compressed form as follows:—

A. Kiewa Scheme—		
(*a*) Hydraulic head-works and general works ..	£1,432,675	
(*b*) Buildings, power stations, and equipment ..	708,400	
(*c*) Transmission line to a point north of metropolis	639,700	
(*d*) Customs duties	188,860	
Total		£2,969,635
B. Sugarloaf Scheme		488,382
Rubicon Scheme		257,510
Grand total		£3,715,527

This estimate does not include either the cost of terminal station and its equipment, or the cost of distribution of energy therefrom to consumers.

Attention is drawn to the very high proportion of the total estimates cost which is absorbed, as already stated, by the item "hydraulic head-works," a feature of hydro-electric schemes which is entirely absent from a heat-power scheme.

VIII. ABNORMAL PRESENT-DAY CONDITIONS.

The same item of capital cost to which attention has just been drawn aptly illustrates the present-day nature of market conditions as being specially unfavorable to an enterprise of this nature. One of the principal sub-items under this head is "pipe lines, £669,485." This abnormal charge is due to the very abnormal current price of such articles.

Similarly, the high cost of labour, particularly in remote and inaccessible mountain regions, at considerable altitudes, under severe climatic conditions for the greater part of the year, and the high cost of transportation of plant and materials into such regions, are other factors which affect unfavorably the economy of such a scheme at the present time.

IX. ANNUAL COST OF KIEWA SCHEME.

From the above estimates it appears that such a scheme, providing for a continuous supply of 37000 k.w., cannot, under present-day conditions, be fully installed for less than £100 13s. 11,d. per kilowatt. Taking interest and sinking fund at 8 per cent., such a scheme would involve an annual cost of at least £8 per kilowatt in respect of capital charges alone, without taking into account annual operation charges, which it is estimated will amount to at least £1 per kilowatt per annum, making a total annual cost of £9 per kilowatt per annum.

X. CONCLUSIONS AS TO THE KIEWA SCHEME.

We have, as already indicated, so far considered the Kiewa Scheme primarily as a means of increasing the supply of electrical energy to the great metropolitan market when the demand therein threatens to exceed the total resources of power from existing generating stations, supplemented by the new (first unit) station in course of erection at Morwell.

We have no hesitation in arriving at the conclusion that there is no present justification for embarking upon the execution of a hydro-electric scheme of the magnitude and nature outlined in this Report.

XI. SUPPLY TO PROVINCIAL DISTRICTS.

The problem of electric supply to provincial towns and districts must be considered from the point of view both of present needs and of future industrial developments.

Under existing conditions, and excluding the larger centres, such as Bendigo, Ballarat, Geelong, and their respective districts, the demand for electric energy in any one locality is so small, and so irregular, and the distance from possible water-power resources in general so great that it may be repeated that, as a general proposition and with due exclusion of a very few special possibilities, rural needs can for many years to come be more adequately and economically met by well-designed and administered local heat-power schemes.

As regards the larger provincial centres, excluded from this statement, the investigations which the Commissioners have so far made give every promise that, as the Morwell Scheme develops, and the high voltage transmission lines are extended westward and northward of the metropolis, these large centres can be more adequately and cheaply served from Morwell than by any hydro-electric scheme, such as Kiewa, at present capital costs. It may indeed be said that a very high percentage of the whole industrial population of the State, as at present distributed, can ultimately be conveniently and efficiently supplied with cheap electrical energy from the Morwell source of supply alone.

XII. THE NORTH-EASTERN DISTRICT.

The Commissioners are fully alive to the special circumstances of the North-Eastern District, which is at present industrially undeveloped, and which contains a number of smaller towns not inconveniently far removed from possible sources of hydro-electric power.

The Commissioners therefore propose to continue investigations directed towards evolving practicable hydro-electric schemes, on a much more modest scale than those considered in this Report, for the service of some of such North-Eastern towns or groups of towns. In this connexion, both the Sugarloaf Weir and the Rubicon River, considered as separate schemes, and not as part of the Kiewa Scheme, offer possibilities which seem sufficiently attractive to justify closer inquiry. Upon such inquiries the Commissioners propose to embark forthwith.

With regard to the remaining portions of the North-Eastern District, not easily accessible by water-power, the alternative of centralized heat-power generation to serve individual towns or groups of towns, is also deserving of and is receiving investigation.

THOS. R. LYLE, Chairman.
GEO. SWINBURNE, Commissioner.
R. GIBSON, Commissioner.

R. LIDDELOW, Secretary.
16th November, 1920.

REPORT

TO

The Electricity Commissioners of Victoria

ON

Kiewa Hydro-Electric Power Scheme, &c.

A. G. M. MICHELL, M.C.E.,
450 Collins Street, Melbourne.

19316.

The Chairman and Commissioners,
Electricity Commissioners,
673 Bourke-street, Melbourne.

Gentlemen,

In accordance with your instructions, I beg to present the following Report on the Kiewa Hydro-electric Power Scheme and auxiliaries.

This Report embodies the results of the various surveys and other investigations made by your staff under my direction since my appointment as your Hydraulic Consulting Engineer in June, 1919, together with outline plans and estimates for the various works proposed for utilizing the hydraulic resources disclosed by the surveys.

As your instructions do not confine the scheme to any particular *rôle* in the supply of electric power in the State, I have assumed that its development would be along the normal lines of hydro-electric practice. This assumption implies the utmost possible continuity of output, and the greatest efficiency and highest load factor of which the conditions will admit.

If the scheme were to be designed as the sole source of supply to a defined market or district, or if, on the other hand, it were definitely related to a large heat-power system for a common service, its proper development would be in some respects different from that which I have outlined.

I remain, Gentlemen,

Yours faithfully,

A. G. M. MICHELL.

29.9.1920.

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KIEWA HYDRO-ELECTRIC SCHEME AND AUXILIARIES.

NOTE.—All heights above sea-level in the Kiewa district as stated in the Report are based on an approximate datum, and not having been connected to sea-level by instrumental levelling, are subject to a small correction. Heights given on the transmission line, and in the Sugarloaf and Rubicon area, as well as relative elevations and available falls in the Kiewa area are correct.

Introductory.—The terms of my appointment and your oral instructions call on me to examine and report upon the Kiewa hydro-electric scheme with such other water powers as may be joined to it with advantage. The surveys which have been made have consequently been directed primarily to an examination of the Kiewa watershed and its immediate adjuncts; and, secondarily, to a search for, and investigation of, other areas where additional power could be generated for the supply of the electrical requirements of Victoria. At present, the only demand which exists in the State for any such amount of power as the Kiewa scheme can supply is in the metropolitan district. The only auxiliary schemes which require examination are, therefore, those adjacent to the route between the Kiewa headworks and Melbourne. From this point of view, the following four localities have been investigated, namely—

(1) The Sugarloaf Reservoir on the Goulburn River.
(2) The falls of the Rubicon River and some adjacent streams.
(3) The high tablelands, locally known as the " Snowy Plains " and the " Benison Plains," at the heads of the Macalister and the Wonnangatta rivers.
(4) The Mt. Cobbler Tableland, in the watersheds of the King and Buffalo rivers.

The accompanying map, Drawing No. 1, shows the whole of the above-mentioned localities in relation to existing railways and centres of population.

Several other possible sources of power along the route have had preliminary consideration, but were found to be either not of sufficient size or not to admit of sufficiently economic development for incorporation into the scheme at the present stage.

A preliminary examination of the first two of the four possible auxiliary schemes above mentioned showed that they could be eventually linked to the Kiewa scheme with advantage. In these cases, therefore, investigations have been continued, and the present report contains descriptions and estimates of suitable works in connection with them.

The surveys of the third locality above named show that, while facilities exist for the development of a very considerable amount of power, such development would involve very extensive works in country which is at present without road or railway communication, and which is too distant from the Kiewa transmission route to make a connection with it economical until the system has been extended in other directions.

The fourth locality, Mt. Cobbler, is more favorably situated, and a scheme of works has been roughly drafted, but the information is not yet sufficiently complete to be included in the present report.

As regards any proposals or estimates for the construction of works, the present report is consequently limited to—

(*a*) the Kiewa scheme itself;
(*b*) hydro-electric utilization of the Sugarloaf Weir;
(*c*) proposed works on the Rubicon River,

together with lines of transport and electric transmission for these, treated as parts of a single hydro-electric system.

Sources of Information.—The hydrological data upon which the present report is based have been principally derived from the following sources:—

(1) The surveys and investigations carried on by the Commissioners during the last fifteen months.
(2) The surveys made by the Victorian Hydro-electric Company on the Kiewa scheme proper, since the year 1913; such information having been made available by arrangement between the Commissioners and the directors of the company. The scheme of works for Kiewa set out in this report is, in its main features, identical with that of the company.
(3) Information relating to the Sugarloaf Weir and flow of the Goulburn River, supplied by the State Rivers and Water Supply Commissioners and their Resident Engineer at Sugarloaf, Mr. C. H. Kernot.
(4) Maps and notes relating to the Mt. Cobbler district, supplied by Mr. Herman, the Director of the State Geological Surveys.
(5) The preparation of the estimates has been assisted by preliminary designs and quotations for various portions of the plant which have been supplied by a number of Australian and European firms.

KIEWA SCHEME PROPER.

Topographical Description of Headworks.—The head waters of the Kiewa River drain an elevated district on the northern side of the main Dividing Range of Victoria, between the three ridges which respectively connect the Dividing Range at Mt. Hotham, with Mt. Feathertop on the west, Mt. Hotham with Mt. Cope on the south, and Mt. Cope with Mt. Bogong on the east, the last two of which widen out into extensive tablelands, known collectively as the Bogong High Plains. The peaks of these ridges are the highest mountains in Victoria.

The greater part of the gathering grounds of the scheme (of which Mt. McKay may be taken as the central point) is more than 5,000 feet above sea-level. The principal features of the district and the approximate contours are shown in the accompanying Map Drawing No. 2. As will be seen from the map, the head waters of the river ultimately join to form the main stream at the village of Tawonga, approximately 1,200 feet above sea-level. At this point is the junction of what are known as the East and West Kiewa rivers. The east river, both in catchment area and in average quantity of water discharged, is about half as large again as the west river. The east river is formed by the junction of two main branches, which unite at a point about 2,300 feet above sea-level. The west river is also formed by the junction of two branches, the left-hand branch, known as the Diamantina River, rising at Mt. Hotham and flowing in a narrow gorge until it meets the right-hand branch at the foot of Mt. Feathertop. The combined stream flows through a great gorge between the spurs of the last-named mountain and Mt. Fainter. All these are permanent streams, being supplied throughout the year by numerous springs. Only the East Kiewa, however, drains any extensive high tablelands or presents any facilities for considerable storage at high levels. The whole of the catchment above Tawonga is heavily timbered up to about 4,500 feet above sea-level. Above that elevation the steeper ranges, where not consisting of bare rock, are covered with snow-gum and other scrub to their summits, but the tablelands are, generally speaking, without timber, being covered either with low scrub, or with grass and mosses.

There is no permanent settlement on any portion of the water-shed above Tawonga, but the tablelands are used for grazing between the months of December and March, being let by the Government to a few of the graziers of the lower country on annual leases.

The climate of the tableland, as might be expected from its situation and elevation, is cold and wet. No continuous meteorological observations are on record. From calculation from the mean temperatures of surrounding points at lower elevations, and from data as to the fall of temperature with increase of elevation based on observations in New South Wales and elsewhere, it is calculated that the annual mean temperature of the High Plains, at an altitude of 5,600 feet, is approximately 42° Fahr., and the mean temperatures of the warmest and coldest months respectively 56° and 27° Fahr.

Snow usually lies on the higher ridges and tablelands from May until December, and occasional snowfalls and frosts occur during the remainder of the year.

The wettest month on an average is June, but the precipitation is, as a rule, heavy during all the months from May to October, and, in many years, in November and December also. The streams usually attain their greatest volumes between September and November in each year, when the rain-water discharged from the lower portion of the valleys is supplemented by the melting of the snow on the High Plains, due to the increasing warmth of the season. The dry season normally extends from January to April, but, as will be seen from the tables below, a considerable amount of rain usually falls during this period. In dry years the rivers are usually at their lowest stages some time in April, the rainfall in April being on an average lower than that of March.

It has long been known that the Kiewa River maintains its flow better during droughts, and that it discharges a larger volume of water relatively to its catchment area than any other of the rivers of Northern Victoria. Details of the flow of the streams and of the precipitation in the water-shed are given below in connexion with the estimates of output of power, and are further discussed in Appendix 2.

The total area of the catchment above Tawonga may be divided into three main sections indicated on Drawing No. 2, as follows :—

(1) An area of 12,600 acres in the High Plains at an average elevation of about 5,600 feet, most of which is comprised in what are known as the Pretty and Rocky Valleys, the lowest points of which are more that 5,300 feet above sea-level. The run-off from most of this area can be collected into large storage basins in the valleys named, and the whole can be collected in a race-line at 5,300 feet elevation and thence diverted into the West Kiewa Valley, and utilized in an Upper Power Station with a gross head of about 2,800 feet.

(2) An area of 45,600 acres drained by the upper West Kiewa and its tributary, the Diamantina, and by the East Kiewa River and its branches below 5,300 feet down to points about 2,400 feet above sea-level on each of the main streams. This area has an average elevation of 4,400 feet. The whole of its run-off, together with that from area No. 1, can be collected and utilized with a gross head of approximately 1,100 feet in a second or lower Power Station situated on the West Kiewa above Tawonga.

(3) Areas drained by the East and West Kiewa Rivers and their branches between 2,400 feet above sea-level and Tawonga. It is not proposed, at present, to make use of the run-off of these areas (except such portions amounting to 4,100 acres as are intercepted by the races to the Lower Power Station) as no facilities for storage exist, and the run-off from this lower country is much smaller and subject to much greater seasonal variation than that of the high country.

In addition to the areas above mentioned as belonging to the natural catchment of the Kiewa River, there are possibilities of diverting some of the adjacent streams which belong naturally to the Mitta basin into the head waters of the Kiewa, so as to utilize their discharge in the lower of the two proposed power stations. In particular, the upper portion of the Cobungra River can easily be diverted at the point marked C in Map No. 3, into the West Kiewa River near its source, and it is believed that the Big River can be diverted from a point near that Marked B in the same map, into the East Kiewa River above the junction of its two main branches. Smaller areas of the High Plains may have their drainage diverted by collecting races into the High Plains Storage Reservoirs. Such possibilities for increasing the available power of the water-shed have, however, not yet been investigated in detail, and are neglected in the present Report.

Description of Proposed Works, Kiewa.—The general scheme of works proposed for the utilization of the hydraulic possibilities as outlined above is shown on the Map, Drawing No. 2, and to a larger scale in Drawing No. 3.

The water-power would be developed in two large Power Stations, both situated on the West Kiewa River. The Lower Station, which would be the main and controlling station, operating throughout the year, would be situated at the point where the river-gorge opens out to the flat valley about 4 miles above Tawonga village. The ground level at this point is 1,265 feet above sea-level. The other Station would be located in the river-gorge some 5 miles above the Lower Station, and 2,540 feet above sea-level.

The Upper Power Station would derive its water from head works on the High Plains, and chiefly from two large storage basins situated in the Pretty and Rocky Valleys (see Drawing No. 3). The Pretty Valley Storage Reservoir would have a capacity of 16,000 acre feet, which can be secured by means of a dam 68 feet in effective height above the bed of the river. The capacity of the Rocky Valley dam is taken provisionally, for the reasons given below, at 8,280 acre feet, retained by a dam of 55 feet effective height. The crests of these dams would be respectively 5,486 feet and 5,275 feet above sea-level. It is proposed to utilize the water of the Pretty Valley Reservoir at the full elevation of its offtake, viz., 5,450 feet, and to lift the water stored in the Rocky Valley dam into the Pretty Valley Reservoir by means of an electrically-driven pumping plant, which would normally operate at times when the variations of demand left a surplus of power available from the system for the purpose.

The alternative of fixing the outlet of the Storage Dams at the level of the Rocky Valley dam instead of that of the Pretty Valley dam, and so avoiding the use of a pumping plant, has been rejected on account of the consequent loss of the available head on the Pretty Valley and the considerable additional length of race through rough country necessary to effect the connection of the Rocky Valley storage which would be thereby involved. This, like other power schemes, must be expected to operate at less than unity load factor, and the power required for the pumping, if within the capacity of the generating plants, would be obtained practically without cost, except the standing charges on the pumping plant, which, as will be seen from the estimates appended, are not heavy.

The pumping plant would be installed immediately below the Rocky Valley dam, and the water would be raised through piping to a point on the slope of the water-shed sufficiently high to be delivered by gravitation through a race directly into the Pretty Valley Reservoir. This race would be about 15,500 feet in length, and would traverse comparatively easy country, but would involve two lengths of tunnelling. The longitudinal section of the pipe-line, race, and tunnels, is shown in Drawing No. 4. The maximum rate of pumping provided for is 70 cubic feet per second, requiring about 3,200 horse-power intermittently.

In normal operation the Rocky Valley Storage Dam would be full at the beginning of the summer, and the times of pumping would be arranged so that the Rocky Valley storage was depleted during the summer at about the same proportionate rate as the Pretty Valley Dam. The average consumption of power would be approximately 1,400 kilowatts. The pumping plant would also be operated during the wet season, if at any time there appeared to be a likelihood of the Rocky Valley storage overflowing before the next summer.

The examinations which have been made (by the Victorian Hydro-electric Company) of the sites of the dams on these storages, have shown, in the case of the Pretty Valley Dam, that solid rock can be reached across the whole width of the section at a depth nowhere exceeding 20 feet, and in most places considerably less; with the exception that there is a reef of decomposed material (apparently a dyke) on one bank about 7 feet wide. It is not expected, however, that the existence of this reef will constitute any very serious difficulty in the construction of the works. In the case of the Rocky Valley site the exploratory work reached solid granite over the whole of the central part of the site, but on the higher parts of the eastern bank the trial shafts and trenches were left incomplete in decomposed rock, extending in one place 40 feet below the proposed crest level. This site is, therefore, less satisfactory than that of the Pretty Valley Dam, and for this reason the crest height has been provisionally limited to 55 feet above the river bed in place of 68 feet at Pretty Valley.

If further exploration shows that the solid rock approaches the surface again at a short distance further east, as appears probable from surface indications, it would be desirable to increase the height and capacity of the dam to practical equality with the Pretty Valley dam, as the total available power would thereby be materially increased.

The type of construction proposed for both dams is that known as "Rock-fill," with reinforced concrete core-walls.

Sections of the sites and exploratory works, as reported to the Victorian Hydro-electric Company by Mr. H. Crowther, M.C.E., are shown in Drawing No. 5.

Outlines of the proposed designs are given in Drawing No. 6.

The offtakes in both cases would be through pipes laid in culverts through the solid rock, and the by-wash weirs, for which natural facilities exist, would be solid concrete walls.

From the Pretty Valley offtake the main race, which is designed for a capacity of 150 cubic feet per second to carry the water from both dams, would follow the western side of the valley of the left-hand branch of the East Kiewa and its tributaries, on a falling contour, as shown in Plan No. 3, in a direction at first westerly and then northerly, until it reached the northern side of Mt. Fainter, where a natural saddle exists enabling it to discharge into the valley of the West Kiewa. The total length of the race would be approximately 50,000 feet, this length including various tunnels and inverted siphons, a longitudinal section of the whole work being shown in Drawing No. 4. The race being situated near the edge of the tableland and the summit of the Mt. Fainter ridge, the side slopes are in most parts comparatively moderate, and this constitutes one of the reasons for fixing the offtake at the level of the Pretty Valley dam rather than that of the Rocky Valley dam, as the latter would traverse the lower and steeper flanks of the range and would be considerably longer.

The heaviest piece of work along the race line would be a tunnel through the spur on the western side of the Pretty Valley dam. This tunnel would be 2,350 feet in length, and would be probably in hard rock throughout, but would obviate the necessity of constructing a contour race around the spur which would be about 10,000 feet in length on very steep sidings. Two other tunnels and three comparatively short siphon lines (as shown in Plan No. 3) would be the only other special works along the race, with the exception that automatic intakes would be provided for collecting the rainfall and snow-water from the gathering grounds on its upper sides, which constitute an addition of 3,300 acres to the catchment area.

Several of these streams from this area flow strongly throughout the summer, and one or two of them offer useful storage facilities for regulating their storm discharges. At its discharge end the race would be connected to the pipe-head basin supplying the pipe-lines of the Upper Power Station by an inverted siphon extending across two saddles known respectively as the Fainter and Bogong Jack's saddles. This is referred to below as the Bogong Jack's Siphon, the race from Pretty Valley being called the Bogong Jack's Race-line. The pipe-head basin itself would be situated on the summit of the range immediately north of Bogong Jack's Saddle at an elevation of 5,330 feet above sea-level, and would have a capacity of approximately 9 acre feet.

This basin would be of the type commonly employed for service reservoirs, being partly excavated in the schistose rock (of which the hill is composed) and partly formed in embankment with concrete lining. Its depth would be approximately 10 feet, and it would have sufficient capacity to supply the Upper Power Station at full load for approximately one hour.

The pipe-line from the pipe-head basin last mentioned to the Upper Power Station would consist of three parallel pipe columns 10,000 feet in length, measured on the incline, and having a total vertical difference of elevation of 2,790 feet, the elevation of full supply in the pipe-head basin being 5,330 feet and the floor level of the Power Station 2,540 feet. Deduction being made for pipe friction, the effective working head on the turbines would be 2,600 feet. Although a working pressure of this intensity is exceptional, it is by no means unprecedented in hydro-electric work. Notable instances of plants working under similar or greater pressures are the Orlu plant in the Pyrenees (with 3,100 feet head), the Fully plant in Switzerland (with 5,400 feet head utilized in one Power Station supplied through pipes 15,000 feet in length), and the Aura Station in Norway which has units of 23,500 kilowatts capacity working under 2,350 feet head. There are several other installations in operation with heads from 2,000 to over 3,000 feet. The well-known Big Creek system in California has two Power Stations in series, utilizing a total head of 4,000 feet. The construction, however, of pipe columns for plants of this character is work of a very special character, and is at all times expensive. With present abnormal conditions of metal markets and manufacture, the pipe column becomes the most expensive portion of the whole work, as will be seen from the estimates below.

The precise design of the pipe columns must be left, to a large extent, an open question depending on the prices of various classes of materials at the time when actual construction was undertaken, but the estimates have been prepared on the assumption that wood pipes would be used for the upper sections, steel piping manufactured in Australia for moderate pressures, and welded steel piping (which must be imported) for the heaviest sections at the bottom of the columns.

The precise location of this pipe line has not yet been definitely selected, that illustrated on which the estimates have been prepared being the more favorable of two surveyed trial lines.

It is proposed to instal one pipe for each of the three turbines in the Upper Station without any interconnections between them.

The Upper Power House will be situated immediately on the East bank of the West Kiewa River, and is designed to contain three turbo-generator units, each of 8,000 kw. capacity at maximum efficiency. Each unit would consist of a single impulse turbine direct coupled to a generator. The provisional layout of the Power Station is shown in Drawing No. 7. The current would be generated at a standard generator voltage, and would be transformed up to the main line voltage by means of transformers permanently connected to the generators, all switching being effected on the high tension side.

The water discharged from the turbines of the Upper Power Station would be delivered directly into the West Kiewa River, and would be picked up, together with the natural flow of the river, at a point about a mile below the Power Station, where a good natural site for a diversion weir exists at 2,330 feet above sea level, and would be thereby diverted along a race on the West side of the river to a point on the range known as Holland's Hill, where it would command the Lower Power Station with a head of approximately 1,000 feet. This race line would be designed to carry 250 cubic feet per second, and would be 26,000 feet in total length. It would be of an ordinary type of construction, the only considerable special works involved being an inverted siphon 3,650 feet in length across what is known as Young's Gap, in the range, and a tunnel 850 feet in length through a spur of Holland's Hill. This race line would supply, under winter conditions, about two-fifths of the total water of the Lower Power Station.

The remaining three-fifths of the water supply for the Lower Power Station would be derived from the East Kiewa River through a race which would deliver the water to the station at the same head as the West Kiewa race just described.

The primary offtake of the East Kiewa race is situated on the right hand or Rocky Valley branch of the East Kiewa River, about ½ mile above its junction with the left hand or Pretty Valley branch, and at an elevation of 2,450 feet. At this point a very favorable site exists for the construction of a storage dam and diversion weir.

From the offtake of the weir the water would be delivered through a tunnel 1,320 feet in length through the spur between the two branches of the river into another dam at 2,353 feet elevation on the left-hand branch. Here, also, a favorable site exists for the construction of a storage basin, which would have ample capacity for balancing the daily load of the Lower Power Station as well as affording opportunity for retaining detritus carried down by the rivers, and preventing its entry into the races and pipe lines.

From the second storage basin the water would be taken by a race along the West side of the East Kiewa River (hereafter called the East Kiewa race) to a point known as Mt. Beauty, immediately opposite to and on the same elevation as the Holland's Hill pipe head above mentioned, viz., 2,265 feet.

This race line would also be designed for 250 cubic feet per second, and would be nearly 40,000 feet in total length from the offtake of the second storage basin to Mt. Beauty. It would be for the most part in rather steep sidling ground, which, in parts, has been affected by ancient land slips. For greater security portions of the race would require to be carried in flume, or replaced by wood-pipe line. The risk of future land slips may be largely removed if the destruction of the vegetative covering of the slopes by fires is prevented. At the Mt. Beauty end the race would terminate in a siphon 2,105 feet in length, delivering into a pipe-head basin on the summit of the hill. The basin would have a capacity of 5 acre feet, which would form the pipe head basin for the pipe lines of the Lower Power Station. These pipe lines would consist of four pipes forming continuous mains from the Mt. Beauty pipe head basin to the race from the West Kiewa on Holland's Hill, where a smaller pipe-head basin of about one-third of an acre foot capacity would be excavated. Each of the four pipes would have a total length of 8,820 feet, the static head at their lowest points where they cross the West Kiewa River being 1,040 feet. Like the pipe column of the Upper Power Station, they would preferably consist of wooden pipes in their upper portions, and steel pipes in the portions carrying heads exceeding about 200 feet, the precise design depending on a comparison of prices of the various classes of pipes at the time of construction.

The Lower Power Station, which is shown in outline in Drawing No. 8, would be situated on the flat on the West side of the Kiewa River immediately below the point where it issues from its gorge, and would have its floor level at approximately 1,255 feet above sea level. Allowance being made for pipe friction, the minimum working head of the turbines would be 970 feet. Provision would be made for utilizing the whole head down to the water level of the river by the use of siphon pipes as indicated in the drawing.

In this Lower Power Station four turbo generator units would be installed, each of the same capacity as those at the Upper Power Station, viz., 8,000 kw., and each turbine would be connected to one of the pipe mains, no interconnections being provided.

As in the case of the Upper Power Station, each generator would be coupled to a step-up transformer, all switching being done on the high tension side. The Lower Power Station would be the controlling station of the whole system. During the summer it would utilize the water discharged from the Upper Power Station, together with the natural flow of both the West and East Kiewa Rivers. As will be seen from the diagrams in Drawings Nos. 9, 10, and 11, the latter is a varying quantity, and falls at times of extreme drought to about 20 cubic feet per second in each river. During winter, on the other hand, when the Upper Power Station would be developing comparatively little power, both rivers are normally of sufficient capacity to supply the whole output of the system from the Lower Power Station alone, and, under these conditions, all four turbines there would operate at full load.

Power Plant for Constructional Work.—In a scheme such as the present, it is necessary to have a considerable amount of power available for the execution of the permanent constructional work, in order to carry it on efficiently and rapidly. In the present case power would be required, amongst other purposes, for rock drilling work in the races, dam excavations, Power House sites and on the tramway line, for rock crushing plant at the dam sites and Power Houses, for winches for the pipe haulages, for saw-mills, and for pumping from excavations and coffer dams. For all of these purposes electric power is more convenient than any other, apart from the advantage that an electric plant is useful also for lighting, and that, after completion of the constructional work, most of its constituent parts could be turned to account in the permanent scheme.

It is proposed, for the generation of this electric power, to install a Power House of 250 kw. capacity on the West Kiewa River about midway between the Upper and Lower Permanent Power Houses. This point, as will be seen from Plan No. 3, is almost central for distribution to the various parts of the work, from the head works at Rocky Valley on the one side to the Freeburg outlet of the tram line on the other. For the supply of this Power Station water would be taken from a temporary weir on the West Kiewa at about 2,150 feet R.L., and diverted through a race to command the Power House site, which is at 1,850 feet. This race would preferably be constructed on the East side of the river, so as to be free from disturbance by the construction of the permanent works on the West side. The flow of the Wset Kiewa is ample at all times for generating the required power without storage. The generating plant proposed is a single three-phase unit, and the current would be transformed to a voltage suitable for conveying the power to the most distant parts of the works. The principal transmission lines would be—

(1) To Pretty and Rocky Valleys, following generally the Bogong Jack's Pipe and Race Line. This line would be permanent, being used later to convey power to the pumping station at Rocky Valley. It would be tapped at the Upper Power Station for the power required for constructional work there.

(2) To East Kiewa Race and Dams.—This line would branch from line No. 1 at Bogong Jack's Pipe Head Basin, and would then run direct to the East Kiewa offtake, and thence about half way along the East Kiewa Race Line towards Mt. Beauty.

(3) Freeburg Line.—This would serve the West Kiewa Race Line, and the tram line, following the general route of the latter from near Young's Gap to Freeburg. It might ultimately be used for the supply of power to Bright and the Ovens Valley.

(4) Lower Power House Line.—This would branch from line No. 3, near Young's Gap, and would traverse the works on Holland's Hill, the Lower Power House, Mt. Beauty, and would extend along the East Kiewa Race Line to meet line No. 2 at about the middle point of the race.

An estimate for the constructional plant is included below, the amount set down for the power plant proper being based on an offer by an Australian firm.

Means of Access and Communication.—The upper watershed of the Kiewa River above Tawonga is not at present accessible to wheeled vehicles, but can be reached by three bridle tracks, namely—

(1) From the North, through Tawonga, which can be reached either by the road which runs by the Kiewa Valley from Yackandandah, or by a road (shown on Plan No. 3) from Bright over the dividing spur between the Ovens and Kiewa Valleys.

(2) By the South from the Omeo-road at a point near Mt. Hotham, or

(3) From the East *viâ* Glen Wills.

Of the roads to Tawonga, that from Yackandandah is 40 miles in length, and has easy grades, while that from Bright is only 24 miles in length, but involves a rise from Bright of nearly 2,000 feet, and an almost equal descent to Tawonga. The route *viâ* the Omeo-road involves a road journey of about 35 miles, and a rise of 5,000 feet from Bright to Mt. Hotham, portions of the road being very rough and steep. The Glen Wills route involves longer road journeys than any of the above to the railway system at either Tallangatta or Bruthen.

It will be seen, therefore, that access to the locality of the proposed works for the purposes of construction is, at present, inadequate. There exists, however, a favorable route from Bright which can be made available at a reasonable cost by the construction of a tramway. This route (shown in Drawing No. 3) would follow the road from Bright to Harrietville as far as Freeburg, and thence the valley of the Snowy Creek to a pass known as Simmond's Gap, between the Ovens and the Kiewa Valleys, having an elevation of 1,765 feet above Bright, and would thence descend to Young's Gap. From the latter point one branch would be carried to the pipe-head at Holland's Hill, and the other up the West Kiewa Race Line and river valley to the Upper Power House.

The proposed tramway would serve to convey all the plant and materials for both of the proposed Power Stations and for the pipe lines and other works. The length of tram line from Bright to Young's Gap would be 21 miles, and the branches to the Power Houses 7 miles. The pipes would be delivered from the terminals of the tramway by means of haulage lines constructed along the pipe tracks to the pipe heads of the Mt. Beauty, Holland's Hill, and Bogong Jack's pipe lines respectively. These haulage lines would also serve to deliver at the same points materials for the race lines from the East and West Kiewa, and for the dams and other works on the High Plains. Such materials would have to be carted from the pipe heads named along roads which would be formed approximately parallel to the race lines.

Effect of Proposed Works on Hydraulic Régime.—As all the water diverted from the tributaries would be returned to the main branches of the Kiewa above their junction at Tawonga, the only effect of the proposed works on the main river would be that produced by the storages on the High Plains. By the use of these storages, the flow of the river will be reduced while they are being filled, and increased while they are being emptied. The periods of filling will coincide with those when the flow of the river is strong. The periods of emptying will be those during which the natural flow of the river is less than about 450 cubic feet per second, and (as will be seen from Table II., Appendix 2) will vary from a few months in a wet year to nearly the whole of a dry season. The addition to the flow of the river due to the emptying of the storages will vary with the output of the Upper Power Station up to a maximum of 132 cubic feet per second. As a result the flow at Tawonga would never be less than about 150 cubic feet per second, as compared with the present drought minimum of about 40 cubic feet per second.

As regards the main stream, therefore, the effect of the works would be wholly beneficial, and the increase in summer flow would be sufficient to be of appreciable benefit not only to riparian owners on the Kiewa, but to irrigation interests on the Murray itself.

Above the junction of the main branches at Tawonga, the West Kiewa would be augmented at all seasons by the total discharge of both Power Houses by an amount varying from 132 cubic feet as a minimum to about 480 cubic feet as a maximum. As, on the one hand, the stream is naturally perennial, and on the other hand the increased winter flow is not sufficient to seriously augment natural floods, the effect of the works on this stream would not be important.

The East Kiewa above the Tawonga Junction would be depleted by the combined intake of the High Plains Storages and of the East Kiewa Race Line. It would remain a strong stream in normal winter and spring seasons, but would be reduced in dry periods to the flow of the tributaries which enter it below the intake of the race, that is to say, to a few cubic feet per second. The whole of this flow would probably be absorbed into the ground from the point where the river enters the junction of the Mountain Creek, and riparian owners would thus be deprived of the advantage of frontage to a perennial river.

As already mentioned, there is no occupation above the point where the river enters the plain.

The diversion of the heads of the Big and Cobungra Rivers into the Kiewa (which has been suggested above as a possible auxiliary work) would deplete, to a small extent, the Mitta River and the large storage reservoir which is being constructed by the Inter-State Murray Waters Commission at the junction of the Mitta and Murray Rivers. The total quantity which would be diverted would not exceed, on an average, 40 cubic feet per second. At least one-half of this flow is probably at present absorbed or evaporated on its way to the Murray. The storage reservoir would consequently be deprived of not more than 15,000 acre feet per annum of its proposed 1,000,000 acre feet capacity.

Estimates of Power.—In the Lower Power Station the total normal discharge of the four turbines proposed would be 450 cubic feet per second, corresponding to a normal output under 970 feet effective head of 28,125 kw. In the Upper Power Station the three turbines would have a combined normal full load discharge of 132 cubic feet per second, which, with 2,600 feet effective head, would develop 21,500 kw. The total installed capacity of the two power stations would consequently be approximately 50,000 kilowatts, but this amount of power would not be practically available, because there is not, in normal years, sufficient water to produce it continuously, and the installation of transmission cables to convey it intermittently would not be economically warranted.

Inspection of the Tables and Diagrams of the flow in the Kiewa Rivers, more particularly Diagrams Nos. 9 and 10, and Tables I. and II. (Appendix 2), will make it apparent that the power available in the great majority of seasons is much greater than that in the occasional drought years, such as 1902, and 1914 and 1915. The capacity of the plant which can be legitimately installed, and its output, are limited by the latter.

As above stated, the period which would impose the greatest restriction on the output of the plant (so far as records hitherto have shown) is the drought of 1914–1915. Detailed consideration has, therefore, been given to the run-off and *régime* of the storages for this period. The chief results are embodied in diagram form in Drawing No. 12. The lower portion of this diagram shows the total natural discharge in the drought period named of the East and West Kiewa Rivers available for power purposes at the Lower Power Station, together with a corresponding curve of the natural run-off of the High Plains available for generating power in the Upper Power Station. The latter curve has been computed from the former on the basis of the comparative run-offs discussed in Appendix 2. These curves are in the main derived from the Victorian Hydro-electric Company's gaugings (Drawings 9 and 10), which began in May, 1914, but, in order to deal with the possibility of a deficiency having been carried over from the previous summer, they have been extended back to the 1st December, 1913.

By comparison with the State Rivers and Water Supply Commission's gaugings at Kiewa, and consideration of the run-off factors discussed in Appendix 2, it is estimated that the average discharge of the East and West Kiewa combined from 1st December, 1913, to 31st April, 1914, was 218 cubic feet per second, and the corresponding mean discharge from the High Plains during the same period is estimated at 78 cubic feet per second.

The upper portion of the diagram (Drawing No. 12) shows, in the first instance, the fluctuating total power which could have been derived from the proposed plants at the two Power Stations from the natural discharge of the streams during the whole period comprising the two drought years. In these calculations, the efficiency of the turbines at the Lower Power Station has been taken as 84 per cent., and at the Upper Power Station 80 per cent., that of the generators with exciters and transformers at 92 per cent. Any reduction of these efficiencies at reduced load would on an average be more than compensated by the lesser friction losses in the pipe columns with the correspondingly reduced flow.

It will be seen that, beginning in December, 1913, the power available from the assumed constant discharge during the following summer would have been about 26,250 kw. This natural discharge might have been supplemented by the storages on the High Plains, which would certainly have been full at the end of November, 1913, and a mean continuous output of 28,500 kw. could have been maintained during the summer, the depletion of the storages being made good by the winter flow which was recorded from May to September, 1914. The most severe period of the drought commenced in the latter month, and the natural flow of the streams progressively diminished to a minimum late in March, 1915. At the latter date the total power which could have been derived from the natural flow of the streams was only slightly over 5,000 kw., and during the greater part of the period from September, 1914, to May, 1915, the generating plants would have had to depend chiefly on the water stored on the High Plains. Assuming dams to have been in existence in the Pretty and Rocky Valleys, as shown in the accompanying Drawing No. 6, that is to say, with a total capacity of 24,000 acre feet, and that these storages had been full at the end of September, 1914, a total continuous load could have been maintained during the dry season of 25,750 kw. The greater part of this load would, of course, have been carried by the Upper Power Station, which would have been loaded at times to its full capacity, while at the Lower Station, two out of the four units would have consumed all the water available during practically the whole period. The winter of 1915 gave abundant rainfall after the month of May. The natural discharge would have been sufficient for the full normal capacity of the plants after the middle of June, and the storages would have been re-filled about the middle of August.

If storages of a total capacity of 30,000 acre feet had been in existence, corresponding to dams 60 feet high on both the Pretty and Rocky Valleys, a load of 28,500 kw. could have been carried continuously through the whole dry period beginning on 1st December, 1913, and the depletion of the storages which would have occurred in the early part of 1914 would have been practically made good by September, 1914. During the driest period of 1915, however, the Upper Power Station would have been required to operate on a slight overload at times, in order to make up the above-mentioned total output. In this case, also, the reservoirs would have been very rapidly re-filled in the winter of 1915, and would have been overflowing before the end of August of that year.

As it is improbable that the markets for power in the State will be capable of absorbing the possible output of the Scheme with a load factor of more than 75 or 80 per cent. for many years to come, the dry season capabilities of the catchments and storages, after allowing for the power required by the Pumping Plant at Rocky Valley and other local requirements, correspond to a full load output of about 32,000 kilowatts.

A similar calculation to that embodied in Drawing No. 12 shows that there is sufficient water in all ordinary seasons to develop considerably more than 30,000 kw. throughout the year, a fact which is indeed fairly obvious from mere inspection of the Tables of River Discharges in Appendix No. 2, comparing average seasons with 1914–1915. While, however, the quantity of water in most seasons might be sufficient for the generation of much more than 30,000 kw., it must not be assumed that so much power would be actually available, even if plant of greater capacity than is now proposed were installed. In all, or in almost all years, the storage would have to be drawn upon for a shorter or longer period in the autumn to maintain the output, and whenever the dams were being depleted, and until they were re-filled, the output of power would have to be restricted to the amount which can be carried through drought periods on account of the impossibility of predicting seasonal conditions ahead. Practically, therefore, the hydrological conditions, so far as yet proved, limit the capacity of plants which can be warrantably installed to such as will give a combined output at all seasons of about 32,000 kw., but this could be raised to about 35,000 kw. whenever the storages were overflowing. If it should prove practicable to increase the height of the Rocky Valley Dam to 60 feet without undue expense, these figures would each be increased by about 3,000 kilowatts.

Hydro-Electric Utilization of Sugarloaf Weir.

Hydraulic Conditions.—The Sugarloaf Weir is a Storage Weir which is under construction by the State Rivers and Water Supply Commission, on the Upper Goulburn immediately below its junction with the Delatite River, and 19 miles above the town of Alexandra. The Weir, when completed to the first stage, now in progress, will impound 300,000 acre feet of water, the crest of the Weir being 135 feet above the bed of the river, which, at this point, is 700 feet above sea level.

The catchment area of the river above the Weir is, approximately, 1,500 square miles of timbered country, with an average rainfall varying in different parts from a minimum of 30 inches to a maximum of probably 70 or 80 inches.

Records which have been kept at the site of the Weir since December, 1915, show a mean monthly flow varying from 215 cubic feet per second in March, 1916, to 12,000 cubic feet per second in June, 1917. A copy of these records is given in Table I., Appendix 3. As the period named does not include any severe drought, the record has been extended by inference from the State Rivers and Water Supply Commission's gaugings on the Lower Goulburn at Murchison. A copy of the latter record for the years 1911 to 1919 inclusive (which include the protracted drought of 1914–1915) is given in Table II. of Appendix 3. Comparison between the records for the years 1916 to 1919 at Murchison and the site of the Sugarloaf Weir enables an approximate ratio to be established between the discharges at the two points for various stages of the river, and the probable flow at Sugarloaf for the years 1911 to 1919, deduced in this way, is shown in Table III.

The accompanying diagram (Drawing No. 13) shows the quantities of water which could be drawn off from the reservoir for the whole period of 1911 to 1919 without depleting the storage and without interfering with the irrigation requirements for which the reservoir is being constructed.

The State Rivers and Water Supply Commissioners have allowed it to be stated, for the purpose of this Report, that they expect that, on completion of the Weir, water would be drawn off from it at a uniform rate of 50,000 cubic feet per minute for the eight months September to April inclusive in each year, but that, in order to conserve the flow for irrigation, it is not intended to allow any water except a small compensation flow to pass the Weir during the months May to August inclusive, unless the dam is overflowing.

Diagram No. 13, referred to above, shows that the capacity of the river during the years in question was sufficient to allow of this programme being carried out without seriously depleting the storage at any time, except in the month of April, 1915, at the end of the long drought, when it would have been practically emptied. In the Diagram, however, the discharge has been taken as slightly less than that allowed by the State Rivers and Water Supply Commission, viz., 800 cubic feet per second.

The water drawn off for irrigation is to be allowed to flow into the natural channel of the Goulburn, by which it will be carried to the irrigation districts about 200 miles down stream. The full head of the water stored in the reservoir will, therefore, be available for power purposes. Two different conditions will occur. When the dam is full, the natural flow of the river will be discharged over a bywash, and the head available will be the full height of the dam, subject to deduction for frictional losses and the height of the flood level in the river below the dam. The normal effective head would be 103 feet. When stored water is being drawn upon, on the other hand, the head available for power will vary with the falling level of the storage. In Table IV. (Appendix 3) are shown in the first column the average quantity of water available in each month for power purposes, subject to the irrigation requirements mentioned above; in column 2, the quantity which would be passed through the main turbine units (allowance being made for the consumption of exciter units and other services); in column 3 the net available head at the turbine during each month.

Description of Works.—The type and arrangement of the Hydro-electric Plant which would be installed for developing power from the Weir are determined by the site and type of construction adopted for the Weir itself. When completed to the stage now under construction, it will consist of a rock-fill dam across the river valley, having slopes of 1 on 2 on both the up and down stream sides, and made watertight by a concrete core wall through its centre. The water will be drawn off by a tunnel through the base of this dam, the flow in the tunnel being controlled by valves operated from a valve tower on the up-stream side. The tunnel has already been completed, and the off-take pipes, consisting of four cast-iron pipes, each 4 ft. 6 in. in diameter, have been built into it.

The Hydro-electric Plant, which is proposed to meet the conditions above described, is shown in plan and section in the accompanying Drawing No. 14. As will be seen, it consists of four main turbo-generators located in a Power House on the South bank of the Goulburn immediately below the dam. In order to utilize the outlet pipes which have been already constructed, it is proposed to connect the turbines with them by means of four independent pipe lines carried in a tunnel branching from the main discharge tunnel of the dam, and in order to avoid undue loss of head by friction, the diameter of the pipes would be increased from 4 ft. 6 in. at the centre of the dam to 5 ft. 6 in. in the remainder of their lengths. Each pipe would supply one of the turbines without cross connections, but would have a branch near the Power House for returning the water to the main tunnel (if required) at such times as the turbine attached to the pipe was not in operation. As will be seen from Table IV. (Appendix 3), the net head available at the turbines would vary from the maximum by 103 feet down to a minimum of 63 feet. In order to operate with such varying heads without undue loss of efficiency, each turbine would be provided with two interchangeable runners, the first suitable for low heads, and the second for use when the head exceeded 80 feet. Each unit of the plant would be capable of utilizing 500 cubic feet of water per second at all heads exceeding 63 feet, so that two units would be normally in operation during the irrigation season, and the four units together would make use of any increased flow in wet seasons up to 2,000 cubic feet per second. The utilization of the output in conjunction with the Kiewa and Rubicon plants is discussed more fully below.

By the use of the two rotors, the water available could be utilized with a good efficiency at practically all times, as is shown in the fifth column of Table IV. The remaining columns of that Table show also the efficiency which the alternators would give under the varying conditions, and the output of the whole plant in turbine horse-power and in kilowatts.

Table V. and Drawing No. 15 give the total power in average kilowatts, which the plant would have developed in each of the years 1912–1919, the mean being 6,550 kilowatts.

The drawing of the proposed plant (Drawing No. 14) shows the arrangement of the Power House with turbo-alternators, exciters, and transformers. The latter would be arranged to raise the voltage of generation to the transmission voltage of the Kiewa Scheme, and switch gear would be provided to enable connection and disconnection to be effected.

In addition to the supply of power to the main transmission line, the Sugarloaf Power House would probably be arranged to give the supply at low voltage for the immediate neighbourhood, and for the operations of the tool shops, &c., of the State Rivers Commission at the dam itself.

Future Extensions.—It is understood to be the intention of the State Rivers and Water Supply Commission to raise the dam at a later date, so as to make the fullest possible use for irrigation of the flow of the Goulburn at this point. This would involve an increase of capacity from 300,000 to 900,000 acre feet, and the raising of the dam from 120 feet to 190 feet above the bed of the river. Such increase of capacity would, of course, allow the power of the Hydro-electric Plant to be greatly increased, although limitations are imposed by the existing outlet works above described, the alteration of which would involve considerable expense.

The amount of power which could be developed after such increase, and the design of the plant which should be installed to develop it, would depend essentially upon whether the increase was undertaken in the interests primarily of irrigation or of electric power supply, and upon what restrictions were imposed on the use of the water for the latter purpose in the interests of the former. It has been, therefore, considered premature to discuss in detail the output which could be expected from the Scheme after such increase, or to make any design or estimates for additional hydro-electric work. Any hydraulic plant, however, which may be installed in the first instance, should be designed to be of sufficient strength to withstand the full head to which the dam may be raised, and the power units should be capable of ready alteration so as to operate efficiently with the increased head.

Rubicon Scheme.

Topographical Conditions.—The Rubicon River is a southern tributary of the Goulbourn, into which it flows about 3 miles above the town of Alexandra. The Rubicon is formed by the junction of two main branches, which will be called hereinafter the Rubicon and the Royston Rivers. Both rise in the high ranges which connect the main Dividing Range at Mt. Arnold and Mt. Torbreck. The last-named peak is over 5,000 feet high, and several other points about the sources of the Rubicon and Royston Rivers have nearly the same elevation. The greater portion of the watersheds is elevated and usually snow-covered from June to September. The rivers flow in narrow gorges, and there is no level ground. The catchment area of these rivers has not yet been accurately defined, but as far as it has been surveyed is shown in Drawings Nos. 1 and 16. The total area of catchment above the proposed offtakes approximates to 20 square miles. With the exception of a few ridges and peaks above the winter snow line the whole area is covered with extremely heavy forest.

There is no settlement or permanent occupation in the area, which is let by the Government on short leases for grazing purposes. Saw-milling is, however, at present carried on in the area by two companies working on the Rubicon River.

The portions of the streams which offer the greatest advantages for power purposes under present conditions are those extending a few miles above the junction, which is 1,273 feet above sea-level. It is proposed to fix the offtakes on the Rubicon and Royston respectively at 2,673 feet and 2,725 feet above sea-level, as above this elevation the main branches break up into a number of tributary streams.

Hydrological Conditions.—Both the Rubicon and Royston are perennial streams, each with a strong flow throughout the year. A temporary measuring weir was constructed by the Commissioners' officers on each stream near the junction at the end of 1919, and continuous records of the flow have been kept by a local resident up to the present month, with the exception of an interruption of a few weeks in April, when the weirs were damaged by freshets, and had to be repaired. These records are given in the form of a diagram in Drawing No. 17.

The autumn covered by the records was (as shown by the rainfall records of neighbouring stations) one of the driest on record, and the recorded flows may be taken as practically the minima to which these streams are subject. The total flow (as will be seen from Drawing No. 17) fell as low as 21 cubic feet per second. The net fall available at the Power House being 1,260 feet, the output which could have been developed during the past nine months has been calculated, and is shown in Drawing No. 18.

Three Nipher rain gauges have been established in the watershed during its investigation. Only one of these, however, has been under observation for a sufficient length of time to furnish an estimate of annual rainfall. It is situated at the Rubicon Lumber and Tramway Company's saw-mill, and below the proposed offtake. The fall recorded between November, 1919, and June, 1920, is intermediate between the records at the official stations at Marysville and Walsh's Creek, pointing to an annual mean of about 48 inches.

As already stated, the precipitation is undoubtedly much heavier on the higher parts of the watersheds, and in order to determine it two automatic Nipher gauges have been recently erected on main dividing spurs at the sources of the Rubicon.

The Rubicon Lumber and Tramway Company and Messrs. Clark and Pearce have at present licences for the diversion of portions of the flow of the Lubra Creek below the proposed race from the Rubicon. The quantities, however, are not sufficient to affect materially the approximate estimates of power given below.

The proposed diversions to the Power House would lay the rivers practically dry in summer for a few miles above their junction, abolishing the waterfalls which are to some extent tourists' resorts.

Description of Proposed Works.—In the scheme proposed, as already stated, the Rubicon and Royston would be tapped respectively at points 2,673 feet and 2,725 feet above sea-level. From the former point a race would be run on the Western slope of the spur which separates the two rivers on a continuously falling grade, as shown in Drawings Nos. 16 and 19. This race would terminate in a pipe-head basin at 2,600 feet above sea-level on the point of the spur immediately above the junction of the rivers, and from it a pipe-line would be led down the spur to the Power House at the junction. This pipe-line would consist partly of wood and partly of steel piping, and would average about 33 inches in diameter. The power plant being an auxiliary only, it has not been considered economical to subdivide this pipe-line.

The race from the Royston River would be of similar construction to that from the Rubicon, following a falling contour on the eastern side of the dividing spur to a point where a gap enables it to be diverted to the western side, where it would connect with the Rubicon race already described. A longitudinal section of the races and pipe-line is shown in Drawing No. 19. Each of the races is designed for a flow of 44 cubic feet per second, giving a total (maximum) of 88 cubic feet per second at the Power House.

The Spur consists of a grano-diorite rock, which forms a deep and heavy soil in decomposing, and the races would be easily excavated except in a few places where rock outcrops near the surface. The chief difficulties presented by the diversion works and race lines would arise in dealing with the extremely heavy timber, particularly in places where it has been brought down by fires. The prevention of forest fires after the execution of the works would also require the most careful atttention, in order to insure their security.

The Power House, which is shown in Drawing No. 20, would contain two turbo-generators, each of 3,500 kw. capacity, operating from the single main pipe-line. The Power House would also contain two separately driven exciting units, and transformers for stepping up to the transmission voltage of 132,000 volts. An outdoor switching system would control the high-tension lines.

It is proposed, in the present scheme, to operate this Power Station in parallel with the Kiewa and Sugarloaf Stations, the generators being of synchronous type, controlled by a station staff in the usual way. The circumstances are such, however, that there would be considerable advantages in arranging and operating the station as an automatic station with non-synchronous generators. Such an arrangement would admit of the station being run practically without any skilled staff, with consequent considerable saving in operating expenses, and a decision between the two types of stations should have careful re-consideration before the development is undertaken.

The Power House proposed for housing the plant (as will be seen from Drawing No. 20) is a reinforced concrete building approximately 107 feet x 56 feet in plan. This building would contain, in addition to the turbo-generator and transformer plant, accommodation for workshops and stores. Provision is also made in the estimates for accommodation for the staff on the assumption that the Power House would be a synchronous station.

The transmission line from the Power House would follow the valley of the main river, joining the main transmission line from Sugarloaf and Kiewa, as shown in Map No. 1.

A tram line belonging to the Rubicon Lumber and Tramway Company is at present in existence connecting the State Rivers and Water Supply Commission's line at Thornton with the proposed Power House site. Allowance is made in the estimates for the securing the use of this line, and strengthening it for construction purposes.

Estimates of Ouput.—As already mentioned, and as shown in Diagram Drawing No. 18, the maximum power of the station would be 7,000 kw., which would be developed continuously for at least four months of an average year, the minimum falling, as shown in the same diagram, to 1,400 kw. at times of extreme drought. In this case the plant would have to be operated on a load factor practically of unity in order to make use of the full amount of power available, as no means of storing water are provided. In the estimates of total power given below, it is assumed that it would operate at 75 per cent. load factor, which is as high as can be expected.

The Rubicon Scheme admits of extension by the installation of a second Power House about 2 miles below the Rubicon junction, which would make available an additional head of about 350 feet. The district contains also other power possibilities, the stream immediately to the east of the Rubicon (known as Snob's Creek) in particular having, at one point, a fall of several hundred feet, and it is probable that the upper courses of the Rubicon and Royston also afford facilities for economical generation of considerable amounts of power. Each of these localities, however, would only admit of the installation of a plant of comparatively small magnitude, that is to say of the order of 1,000 or 2,000 kw., and their development would probably only be economical if carried out by means of automatic stations linked to the main station. The proximity of the district to Melbourne and to means of transport and communication makes it very well worthy of further investigation.

It will be seen on comparison of the diagrams of output given for the Sugarloaf and Rubicon (Drawings Nos. 15 and 18) that these two schemes are to a great extent complementary to one another, the former giving a summer, and the latter a winter, supply.

Transmission Line.—Practicable routes of transmission from Kiewa to Melbourne at the voltage adopted are three in number. The first section, namely, from the head-works to a point near Alexandra, would be common to all three. From the latter point the line might be taken across the Dividing Range either by the route through Narbethong and Healesville, or by the Yea Valley and Kinglake Gap, or it might follow the Goulburn Valley to a point near Tallarook, and thence run parallel to the North-Eastern railway line to Melbourne. The last-named route would have advantages if the electrification of the Melbourne to Seymour railway were to be undertaken in the near future. It is, however, considerably longer than either of the other two routes, and offers no engineering advantages. The Kinglake route is, according to present information, the best, and is approximately shown in the Map, Drawing No. 1.

The location of the first portion of the route from the Kiewa to Alexandra is determined, as far as the neighbourhood of Mansfield, by the existence of the main Dividing Range and its spurs on the south, which makes a more southerly route impracticable, and by the Buffalo Mountains, the Tolmie tableland, and other high ranges on the north, which make a more northerly route than that selected considerably more indirect and expensive.

The route *viâ* Mansfield also presents the advantage of enabling the Sugarloaf and Rubicon auxiliary schemes to be connected to the trunk line by very short branches.

Only the first portion of the above-mentioned route, namely, from Kiewa to Mansfield, has been surveyed in detail, as this portion passes through previously unsurveyed country at present wholly unoccupied with the exception of a few small river flats met with at intervals. This portion of the route crosses a series of ranges which run northerly from the main Dividing Range. A longitudinal section of the surveyed line is given in Drawing No. 21. The country is broken, but the ranges are not of great elevation, the highest being that which connects Mount Buffalo with the Main Divide, having an elevation of nearly 3,500 feet where it is crossed by the line. The whole country is thickly timbered, but the forest is, in general, not heavy. The remainder of the route from Mansfield to Melbourne (whichever of the above-mentioned lines is followed) would run for practically the whole distance through settled but sparsely-populated country, offering comparatively slight engineering difficulties.

The total distance from the Lower Kiewa Power Station to the Melbourne Receiving Station (measured on a great circle) is 138 miles. The principal deviation from this direct line would be near Mansfield, where the line would turn from an approximately westerly direction to a general south-westerly direction. The distance from Freeburg to Mansfield, in a direct line, is 50·6 miles, and from Mansfield to the proposed sub-station at Melbourne 78·8 miles. The surveyed route made of the first portion of the line has a total length of 53 miles, and it may be assumed that the deviations in the Mansfield to Melbourne section would not be proportionately greater, assuming that either the Healesville or the Kinglake route were followed. On the latter assumption the total length of the route would be 145 miles, and allowing for slopes and sag, the total length of the conductors 148 miles from Power Station to Receiving Station.

The construction of the line would be different in the two sections, Kiewa to Sugarloaf and Sugarloaf to Melbourne. The first section would carry the power generated at Kiewa only, which, for the reasons discussed under the heading "Estimates of Power," is limited on the present scheme to a maximum of about 35,000 kw., and, with allowance made for probable auxiliaries in the immediate neighbourhood of Kiewa, may be taken as 40,000 kw. In the second section of the line this power would be supplemented by the output of both the Sugarloaf and Rubicon auxiliaries, and both of these plants might (if the demand were sufficient) be in operation at full power simultaneously. This section of the line must, therefore, be designed to carry 40,000 plus 13,500 plus 7,000, or a total of 60,000 kw. The efficiency of transmission would be 94 per cent.

For both sections of the line it is considered necessary for security of operation to provide two distinct lines of towers with six conductors in all. This decision involves the use of different materials of construction in the two portions of the line. In the section nearest Melbourne the recognised advantages of copper for overhead construction would, under all ordinary market conditions, insure its adoption. In the Kiewa to Sugarloaf section, the division of the conductors into six cables would involve the use of copper conductors so small, if economically designed, as to incur heavy leakage losses through the formation of corona discharges, and it is therefore proposed, for this portion of the route, to adopt the otherwise less desirable aluminium conductors.

In another respect different types of construction have been adopted for the two sections. Throughout most of the sections nearer Melbourne, facilities of transport are available for the economical construction of a line of steel towers, and their greater durability would give them the preference. On the section of the line from Kiewa to Sugarloaf, or at least to the termination of the rough country near Mansfield, difficulties of transport would make it very much more economical to construct the towers of timber (which is abundant throughout the route) than of steel. Drawing No. 22 shows in outline the type of tower which is proposed. Each of these towers would be constructed close to its point of erection from timber growing on the spot, and the only materials which would be required to be transported would be the cables themselves, insulators, suspension arms, and subsidiary steel work, such as bolts and straps for connecting the timbers. At one or two points, such as the Ovens and Buckland Valleys (where the route crosses cleared country and good roads are available), steel towers would be used in this section also, it being expected that the whole line would be gradually re-constructed with steel towers, when the life of the original wood towers was ended, and the opening up of the country had made the substitution of steel towers economical.

The standard lengths of span proposed are 750 feet for the wood towers and 1,000 feet for steel towers. In the broken country, however, the location of almost every tower would be determined by the natural features of the ground, and provisional positions are set out in the longitudinal section in Drawing No. 21. At a few places it would be economical to adopt single spans of considerably greater than standard length, and special towers for these positions would be designed. It is proposed to adopt a standard width of clearing in the timbered country of 250 feet. It is considered that such a clearing would give ample protection from damage by bush fires, but periodically re-clearing and continuous patrol would be necessary in both the timber and steel tower sections. In the Kiewa to Mansfield section there is, as a rule, very little grass or light scrub on the ground, as the steepness of the ground and the comparative dryness of the climate do not permit of the accumulation of soil.

Provision has been made in the estimates for the construction of patrol men's cottages and huts alternately at intervals of 7 miles along the whole route, and for the construction of necessary bridges and bridle paths to enable all sections of the line to be easily inspected.

The design of the steel towers would follow standard practice, two lines of towers being used with three conductors on each in equilateral arrangement. A separate line of poles for telephone wires would be run parallel to the steel towers.

The Melbourne terminus of the line has been provisionally fixed at a point near Thomastown by the Commissioners' Chief Engineer, who has prepared provisional designs and estimates for this station. These are, therefore, not dealt with in the present Report and Estimates. The periodicity and voltage of the Hydro-electric Scheme have also been adopted from the proposals of the Chief Engineer. If there is a probability of the hydro-electric system being extended, or of other more distant head-works than Kiewa being connected at a later date, it may be desirable to consider the application of a still higher voltage than the 132,000 volts provisionally adopted in the present Report.

Estimates of Cost.

Estimates of the cost of the various sections of the Scheme, if executed under present conditions, are given in Appendix I.

In preparing these estimates, manufacturers' and merchants' quotations of August or September, 1920, have been used when obtainable, otherwise estimates have been derived from published prices and costs of the last three months. It is hardly necessary to state that these are much higher than corresponding figures even a few months older, and are from one and a half to five or more times greater than the normal costs of former years.

Estimates prepared under such circumstances can have, of course, no practical significance except for comparison *inter se* or with others of the same date.

In Drawing No. 23 are shown the courses of prices of some of the commodities chiefly in question from 1914 to June, 1920. At the right-hand side of the diagram are given prices which have been adopted for the estimates, in cases where calculations have been based on prices of raw materials. The price of copper (standard, not electrolytic) has been taken as £100, and that of aluminium (British, home consumption) as £160 per ton. Rails have been estimated at £19 2s. 6d. per ton, Newcastle, New South Wales. The cost of work in the field has been based on unskilled labour at 14s. per day, but for all labour on the Bogong High Plains 33⅓ per cent. has been added to allow for losses of time and efficiency to be expected from the climatic conditions.

The cost of temporary workshops, buildings, plant, and camp equipment has been included in the estimate, as well as that of a construction power-plant at Kiewa. No capital cost has been set down, however, for quarrying, saw-mill, and similar plants which would probably be supplied by contractors, and of which the operating and maintenance charges are included in the prices allowed for the work.

No amounts have been set down for riparian compensation, as on the whole the works will be of benefit to land-owners and irrigation interests on the rivers below them. The total costs are intended to include all charges of an engineering nature from the present stage to completion, but do not cover purely administrative or financial charges, nor have any amounts been included on account of work already done on the Scheme.

In view of the difficulty of ascertaining what machinery is, or is likely to be, subject to Customs duties, and at what rates, separate lists are given of the amounts which are understood to be at present chargeable on various parts of the plant which would probably be imported.

Summary and Conclusions.

It is necessary to the economic soundness of every hydro-electric scheme, comprising extensive hydraulic works and transmission lines, that the demand for, and supply of, power should be approximately continuous and uniform. Otherwise the hydro-electric scheme cannot compete with heat-power generated at the point of consumption, unless in some country where fuel of all kinds is exceptionally scarce and dear. At present the only market in Victoria capable of absorbing the output of a large hydro-electric scheme is that of Melbourne.

The Melbourne demand may be expected to offer in the early future a load factor of about 75 or 80 per cent. for a plant of 30,000 kilowatts capacity. For any additional output the probable load factor diminishes rather rapidly. Any public supply given to the smaller centres of the State would be on a much lower load factor, and would, therefore, be (at least from the purely engineering point of view of the present report) unsound.

The Kiewa Scheme proper, according to the hydrographic records available, is capable of supplying the prospective load above stated, which is, however, about the limit of its capacity in a season similar to that of 1914–1915.

This scheme, as outlined in the report, provides for a constant full load of 30,000 kilowatts at the receiving station, but the transmission line is designed for 40,000 kilowatts, the difference allowing for some extension, besides giving higher efficiency.

The Sugarloaf and Rubicon auxiliary schemes provide additional maximum supplies of 13,500 and 7,000 kilowatts respectively.

The common transmission line to Melbourne for conveying the combined power of the three sections of the scheme is designed for 60,000 kilowatts, and the total annual supplies of power available for the city, on the assumptions made as to the continuity of its demand, would be—

Kiewa proper	210 million kilowatt hours.
Sugarloaf	40 million kilowatt hours.
Rubicon	22 million kilowatt hours.
Total	272 million kilowatt hours.

The total capital costs of the three sections, as shown in the attached estimates, are roughly proportional to these total outputs, the ratio for the Kiewa section being the highest of the three. This higher cost is compensated for by the Kiewa section being the only one which affords a constant supply of power throughout the year.

Each of the three sections of the scheme admits of extension. In the case of the Kiewa and Rubicon schemes the extensions would probably be relatively more expensive than the initial works herein proposed. In the case of the Sugarloaf Scheme, extensions would involve discussion of the relative benefits to irrigation and hydro-electric interests, and of the proper apportionment of the costs between the respective Commissions.

APPENDIX 1.

ESTIMATES OF COST OF PROPOSED WORKS.

(Based on average prices June–September, 1920.)

I. Kiewa Scheme.

	£	£	£
Roads and Transport—			
Railway Siding and Store, Bright		2,000	
Tramway, steam, Bright to Lower and Upper Power Stations, 28 miles (3-ft. gauge, 40-lb. rails), with terminals, 2 locomotives and rolling stock		92,000	
Roads, connecting Power Stations, Dams, &c., 25 miles		37,500	
Haulage Lines—			
Upper Pipe-line	15,400		
Lower Pipe-lines	15,100		
		30,500	
Cost of Transport on Tramway Haulages and Roads—			
Tramway, 700,000 ton miles	8,750		
Haulages, 43,500 tons	3,900		
Roads, 55,000 ton miles	5,500		
		18,150	
Total—Roads and Transport			180,150
(Note.—Railway freight is included in cost of various materials. Freight and haulage of transmission line material is included under that item.)			
Hydraulic Construction—			
Races (with tunnels, flumes, inverted siphons, &c.)—			
Rocky Valley Race	18,750		
Bogong Jack's Race	125,815		
West Kiewa Race	30,840		
East Kiewa Race	45,360		
		220,765	
Pipe-head Basins—			
Bogong Jack's	6,200		
Holland's Hill	600		
Mt. Beauty	3,700		
		10,500	
Dams (with by-washes, valve towers, &c.)—			
Rocky Valley	74,000		
Pretty Valley	61,000		
West Kiewa	2,650		
East Kiewa (2)	24,500		
		162,150	
Total—Hydraulic Construction			393,415
Pipe-lines and inverted siphons at pipe-heads (laid complete)—			
Bogong Jack's Inverted Siphon	30,600		
West Kiewa Inverted Siphon	37,735		
East Kiewa and Mt. Beauty Inverted Siphon	28,440		
		96,775	
Upper Station Pipe-line—			
Wood	21,040		
Light steel	48,975		
Heavy steel (seamless)	272,640		
		342,655	
Mt. Beauty Pipe-line—			
Wood	32,900		
Steel	60,125		
		93,025	
Holland's Hill Pipe-line—			
Wood	26,000		
Steel	77,800		
		103,800	
Rocky Valley Rising Main, wood		7,410	
Intake Screens to Pipes		1,020	
Scour-pipes and valves, spare pipes, valves, electric motors for valves, control panels for valves, Venturi meters, coating compound, spanners and tools—			
For Upper Power Line	15,150		
For Lower Power Lines	9,650		
Total—Pipe-lines			669,485

APPENDIX 1.—ESTIMATES OF COST OF PROPOSED WORKS—*continued.*

I. KIEWA SCHEME—*continued.*

	£	£	£
Power Plant, Upper Power Station—			
Main turbines, with governors, couplings, deflector-plates, &c., on site, 3 at	7,020	21,060	
Spares for ditto	..	5,880	
Exciter turbines, complete on site, 2 at	1,400	2,800	
Spares for ditto	..	1,050	
Generators on site, 3 at	20,628	61,884	
Exciter dynamos, 2 at	2,025	4,050	
Spares for generators and exciters	..	4,900	
Transformers, with spares, oil, water-pipes, and connexions	..	30,600	
Switch gear, erected and wired complete, including oil switches; lightning arresters; Tirrell regulators; choke coils; potential and current transformers; indicators; generator, transformer, line, exciter and local panels; cables, conduits and insulators	..	61,020	
Total—Power Plant, Upper Station			193,244
			1,436,294

(NOTE.—Erection of Generating Plant included under "Buildings.")

Power Plant, Lower Power Station—			
Main turbines, with governors, couplings, deflector-plates, &c., on site, 4 at	11,560	46,240	
Spares for ditto	..	11,030	
Exciter turbines, complete on site, 3 at	1,200	3,600	
Spares for ditto	..	2,060	
Generators on site, 4 at	20,628	82,512	
Exciter dynamos, 3 at	2,038	6,114	
Spares for generators and exciters	..	6,650	
Transformers, with spares, oil, water-pipes, and connexions	..	40,550	
Switch-gear as for Upper Power Station	..	77,325	
Total—Power Plant, Lower Station			276,081

(NOTE.—Erection of Generating Plant included under "Buildings.")

Pumping Plant, Rocky Valley—			
With step-up and step-down transformers, and switch-gear	..	22,050	
Transmission Line to ditto from Upper Power Station	..	19,325	
Total—Electric Pumping Plant, Rocky Valley			41,375

Buildings, permanent, complete, including machinery foundations, cranes, ladders, gantries, excavations and clearing sites, and erection of machinery—			
Upper Power House	64,100		
Lower Power House	82,430		
Rocky Valley Pump House	3,525		
		150,055	
Stores, offices, and workshops, with fittings and plant—			
At Upper Power Station	3,750		
At Lower Power Station	24,100		
		27,850	
Quarters for staff, including clearing, buildings (mess-rooms and meeting hall), roads, grounds, water service, and sanitary services—			
At Upper Power Station	4,650		
At Lower Power Station	9,600		
		14,250	
Cottages at Rocky and Pretty Valleys, Bogong Jack's Pipe-head, and East Kiewa	..	5,000	
Offices at Bright	..	600	
Total—Permanent Buildings			197,755

APPENDIX 1.—ESTIMATES OF COST OF PROPOSED WORKS—*continued.*

I. KIEWA SCHEME—*continued.*

Power Plant for Construction—			£
Weir, race, power house, turbine, generator, transformers, switch-gear, lighting plant, step-up and step-down transformers, motors on construction plant, transmission and telephone lines, also stores and huts			25,750
(NOTE.—Cost of Portable Construction Plant, other than motors, included in cost of respective works.)			
Construction Plant and Temporary Buildings and Services—	£	£	
Workshops and Stores at Lower Power Station, Upper Power Station, and High Plains ..		5,350	
Drawing offices and instruments		1,100	
Engineers' quarters, mess-rooms, &c.		3,750	
Camp equipments, barracks, mess-rooms, &c.		13,000	
Lighting, sanitary and water services, and supervision		8,800	
			32,000
Land Purchase—			
Lower Power House, roads, and tram line			3,000
Detailed surveys, not including transmission line			4,500
			2,016,755
Supervision and clerical expenses			124,320
Total Cost of Scheme (not including Customs duties on plant or cost of Transmission Line) ..			£2,141,075
Transmission Line—			
Kiewa Power Stations to Sugarloaf Junction, 88.8 miles—			
Aluminium cable and aluminium wire, 380 tons		106,660	
776 wood towers erected with lightning protection	70,340		
644 steel towers erected	127,350		
		197,690	
Insulators and section switches	34,000		
Testing apparatus	1,000		
		35,000	
Clearing 2,700 acres, at £4		10,800	
Freight and haulage of material plant and camp equipment		7,600	
Stringing conductors		2,250	
Patrol cottages, 14 at £200	2,800		
Gates, 50 at £3	150		
Bridle-paths, 150 miles, at £15	2,250		
Bridges, 70	4,800		
Horses, harness, &c.	1,000		
		11,000	
Right-of-way, 30 miles		1,000	
Telephone line, wire, and instruments complete		12,450	
Total to Sugarloaf Junction			384,450
Sugarloaf Junction to Melbourne, 65 miles—			
Copper cable and copper wire, 895 tons	158,800		
All other costs, cable and telephone line (route not yet surveyed), 65 miles, at £2,500	162,500		
Total cost Sugarloaf Junction to Melbourne		321,300	
Portion of ditto chargeable to Kiewa Scheme Proper, two-thirds			214,100
Total cost Transmission Line Kiewa Power Scheme			598,550
Land purchase, or easements capitalized	6,000		
Ditto, chargeable to Kiewa Proper			4,000
			602,550
Supervision and clerical expenses			36,150
			639,700
Total Cost of Scheme (not including Customs Duties on Plant, £2,141,075 and £639,700)			£2,780,775

Appendix 1.—Estimates of Cost of Proposed Works—*continued.*

I. Kiewa Scheme—*continued.*

	£	£	£
Transmission Line—*continued.*			
Customs Duties on portions of Plant assumed in above estimates to be imported—			
Heavy piping, 30 per cent on £244,035			73,210
Turbines, 30 per cent. on £108,500			32,550
Generators, &c., 33 per cent. on £176,050			58,100
Switch-gear			25,000
			188,860
Total Cost of Scheme, if Customs Duties charged on Plant			2,969,635

II. Sugarloaf Plant.

Transport of Materials—			
Tramway, 17,500 ton miles, at 6d.		440	
Road, 22,500 ton miles, at 1s. 6d.		1,690	
			2,130
(Railway freight included in prices of various materials.)			
Piping and Valves—			
Pipes and valves and connexions to turbines and existing pipes		23,510	
Intake Screens, &c.		2,000	
			25,510
Power Plant—			
Turbines (4 6,300 h.p.), 2 exciter-turbines with governor gear and spares, on site; Generators (4 3,250 k.w.) 2 exciter-dynamos and spares, on site		162,952	
Transformers, with oil, spares, and water connexions		20,800	
Switch-gear, lightning arresters, regulators, cables and conduits		34,000	
Total—Power Plant			217,752
(Erection included under " Buildings.")			
Power House Building and Foundations—			
Including machinery foundations, cranes, ladders, gantries, clearing site, and erection of machinery			76,200
Stores, Offices, and Workshop		5,260	
Quarters for Staff (including Resident Engineer for Sugarloaf and Rubicon)		6,000	
			11,260
Construction Plant and Temporary Buildings and Services			3,000
Transmission Line branch, 3 miles		9,500	
Proportion (2/9ths) of main Transmission Line to Melbourne		71,400	
Proportion of cost of land (2/9ths)	6,000	1,330	
			82,230
			418,082
Supervision and clerical expenses			23,200
Total Cost of Scheme, not including Customs Duties			441,282
Customs Duties—			
Turbines, 30 per cent. on £80,000		24,000	
Generators and electrical plant, 33 per cent. on £70,000		23,100	
		47,100	
Total Cost of Plant if Customs Duties charged			488,382

III. Rubicon Scheme.

Roads and Transport—			
Road and bridge		4,100	
Tramways (use and extension and strengthening of existing tramway)		3,750	
Haulage line		7,550	
Transport on tram line, 44,000 ton miles	1,100		
Transport on haulage line	300		
Transport on road	200		
		1,600	
Total—Roads and Transport			17,000

(Railway freight is included in the cost of various materials.)

APPENDIX 1.—ESTIMATES OF COST OF PROPOSED WORKS—*continued.*

III. RUBICON SCHEME—*continued.*

	£	£	£
Hydraulic Construction—			
Races, clearing, excavation	..	19,600	
Storage Basin	..	600	
Dams	..	1,600	
Inverted siphons, flumes, overflow weirs, and drop on Royston Race	..	3,055	
Total—Hydraulic Construction		..	24,855
Pipe-line—			
Wood pipe (laid complete)	..	6,760	
Steel pipes (laid complete)	..	19,780	
Scour-pipe and valve, spare pipes, valves and motors, control panel, coating compound, Venturi meters	..	1,725	
Total—Pipe-line		..	28,265
Power Plant—			
Turbines, on site, 2 at	4,925	9,850	
Spares, &c., for ditto	..	2,805	
Exciter turbines, 2 at	1,100	2,200	
Spares, &c., for ditto	..	610	
Generators, on site, 2 at	11,375	22,750	
Spares for ditto	..	1,600	
Exciters, 2 at	1,700	3,400	
Spares for ditto	..	240	
Transformers, with oil, water-pipes and connexions	..	14,320	
Switch-gear, erected and wired, oil switches, lightning protection, regulators, choke coils, potential and current transformers, indicators, generator, transformer, line and service panels, indicators, cables and conduits	..	16,650	
Total—Power House		..	74,425
Buildings—			
Power House buildings, super-structure	..	6,190	
Clearing site, excavating for foundations	..	450	
Foundations	..	2,390	
Crane, ladders, and gantries	..	3,200	
Erection of machinery	..	7,000	
Stores, offices, and workshop, with fittings and tools	..	3,750	
Quarters for staff, clearing, buildings, roads, grounds, water, fire, and sanitary services	..	4,650	
Cottages at weirs	..	700	
Total—Buildings (permanent)		..	28,330
Temporary Buildings and Constructional Plant and Equipment—			
Power plant, steam, and operation of same, workshop, stores, drawing office, engineers' quarters, camp equipments, lighting, water and sanitary services, and supervision	..	..	12,000
Detailed surveys	..	..	500
			185,375
Transmission Line—			
Branch line, 3 miles, single steel tower line	..	12,360	
Main line, proportion of cost 1/9th of £321,300	..	35,700	
Main line, proportion of cost of right-of-way	..	665	
			48,725
			234,100
Supervision and clerical expenses 6 per cent.	..	..	14,050
Total Cost of Scheme (not including Customs Duties)		..	248,150
Customs Duties—			
Turbines, 30 per cent. on £9,200	..	..	2,760
Generators, 33 per cent. on £20,000	..	..	6,600
			9,360
Total Cost of Scheme if Customs Duties charged on Plant		..	257,510

APPENDIX I.—ESTIMATES OF TOTAL COSTS.

KIEWA HYDRO-ELECTRIC SCHEME, WITH SUGARLOAF AND RUBICON AUXILIARIES.

Capital Costs, including full Customs Duties—

Kiewa Proper	£2,969 635
Sugarloaf	488,382
Rubicon	257,510
Total Capital Cost ..	£3,715,527

Annual Charges—

Capital Charges, 8 per cent. on Cost	£297,242
Operating Costs	38,651
Total	£335,893

APPENDIX 2.

RAINFALL AND STREAM DISCHARGE DATA, KIEWA WATERSHEDS.

Estimates which are given below of the quantities of water available from the various parts of the catchment areas at different seasons are based, partly upon direct records of stream discharge, and partly upon deductions from measurements of precipitation.

Records of river discharge have been kept by the State Rivers and Water Supply Department for over 30 years at a point near the township of Kiewa. This point, however, is situated about 40 miles below Tawonga on the lower course of the river after it has flowed through pervious and rather dry country, and the records mentioned do not enable any reliable estimates to be made of the discharge of the stream in its upper portion, where alone it is of any value for power purposes. The records which are given in Tables I. and II. in this Appendix are, however, of value as showing that the year 1914 (during which observations of both the East and West Kiewa were recorded above Tawonga by the Victorian Hydro-electric Company) may be taken as representative of the most severe droughts to which the district is subject.

From Table No. I. below it will be seen that the only year since 1886 when the flow at Kiewa fell below that of 1914 was the year 1902, the difference being about 3 per cent. The drought of 1902 was much less protracted than that of 1914–1915.

More directly available records are those which were kept by the Victorian Hydro-electric Company on both the East and West Kiewa at Tawonga during the years 1914, 1915, and 1916. These records fortunately cover the greater portion of the protracted drought of 1914–1915, having been begun in May, 1914. The situation of one of the gauging stations, however, namely, that of the West Kiewa, was unfortunately chosen, being about one mile below the point where the river enters upon its alluvial plain. This plain in its upper part consists chiefly of heavy shingle and boulders, and the Commissioners' own gaugings, during the present year, have shown that there is considerable loss of water between the two points mentioned. The Company's records are given in the form of diagrams, in Drawings Nos. 9 and 10.

The Company's gauge staffs on both rivers were carried away during the flood season of 1917, and no observations were recorded between the years 1916 and 1919, when the Commissioners' own investigations were commenced. In August of the latter year, new gauge staffs were fixed on the East and West Kiewas, close to the sites of the Company's gauges, and as soon afterwards as opportunities occurred, an additional gauge was placed on the West Kiewa above the point where it enters the alluvial plain, and near the offtake of the proposed West Kiewa race. Gauges were also established on the branches of the East Kiewa near the proposed offtakes on that river, as well as on the two main streams on the High Plains. These various gauges have been observed and calibrated at various stages as opportunities have occurred for the Commissioners' surveyors to do so, but it has not been practicable to obtain continuous records.

Diagrams of the observations of the East and West Kiewa at the lower gauging stations are given in Drawings Nos. 9, 10, and 11. Simultaneous gaugings of the West Kiewa at the proposed race offtake show a loss between the two gauging points in dry weather of 5 cubic feet per second, which exceeds the total volume of the tributaries of both rivers between the gauging points, and all the comparative measurements so far made show greater discharges of both rivers at the points of proposed offtake than at the Tawonga stations. The opposite condition must hold at times of actual flood, but as the dry weather condition is the ruling consideration, an error on the safe side will be made by assuming that the drought discharges at the points of offtake are equal to those recorded at Tawonga. The records at the upper gaugings so far made are not sufficiently numerous, or continuous, to be of use except for purposes of comparison.

Rainfall.—The only records of rain and snow fall which have been taken in the Upper Kiewa watershed, are those which have been obtained by the surveying parties of the Commission and of the Victorian Hydro-electric Company.

The Victorian Hydro-electric Company placed gauges on the High Plains in 1915, and obtained a few broken records which are referred to again below. Measurements by the Commissioners' officers were started in November, 1919, by means of reservoir gauges, fitted with Nipher rain and snow shields, which are capable of storing the precipitation of a full year. The design of these gauges was settled, after discussion with Mr. H. A. Hunt, the Commonwealth Meteorologist.

The localities at which gauges were erected are shown in Map No. 2. The records of the gauges, as far as yet observed, are given in Tables No. III. Check gauges of the same construction were established at Tawonga, Glen Wills, and Kiandra, New South Wales, alongside Commonwealth Bureau gauges of standard construction, and arrangements were made to have the former read periodically by the Commonwealth observers at those places. These arrangements have been satisfactorily carried out at Kiandra, and the comparative readings are shown in Table No. IV. They show that the readings of the two types of gauge are very consistent, and that the reservoir gauges may be depended on as giving records of quite sufficient accuracy. The agreement is almost perfect when the precipitation is wholly in the form of rain, but during heavy snowfalls the reservoir gauges give a slightly higher reading than the standard gauges. The reading of the reservoir gauge is probably the more correct, as it has been noted by the Kiandra observer that the standard gauge does not collect the whole of the snow which falls in heavy storms. The weather conditions at Kiandra are similar to those on the High Plains.

APPENDIX 2—*continued.*

The reservoir gauges have been read at intervals when the Commissioners' surveyors found it practicable to visit them, but those on the High Plains have not been visited since 31st May, 1920.

The period during which these gauges have been established is, of course, altogether too short to give direct information as to the precipitation which can be depended upon for supplying the streams. The observations, however, can be employed to establish an approximate ratio between the precipitation at various points of the Kiewa watershed and those of other points in the surrounding district where reliable records have been kept over a number of years, and on the assumption that the ratio remains constant in different seasons, an approximation to the precipitation in the Kiewa watershed can be arrived at. The stations selected for establishing this comparison are Bright and Mt. Buffalo respectively 19 and 27 miles distant from the centre of the watershed in a north-westerly direction, Harrietville 11 miles south-west, and Glen Wills 14 miles east. The distribution of these stations would appear to make deductions derived from the whole of them free from serious error, due to any peculiarities of exposure or situation of the gauges.

Rainfall records have also been kept for a number of years at Tawonga and at Mt. St. Bernard. The records at these stations have not been continuous, and for other reasons are not considered so reliable as those of the four stations above named.

The average elevation of the four selected official stations is 2,500 feet, which is, of course, much less than the average elevation of the Kiewa catchment, even the highest of those stations (Mt. Buffalo, 4,700 feet) being about 1,000 feet lower than the average elevation of the High Plains. As was to be expected, therefore, the observations which have been made on the Kiewa give considerably higher records than those at the official stations.

Tables are given below (Nos. V. and VI.) of the average rainfall at each of the four stations, and of the fall recorded at each of them during periods when simultaneous observations were made of the Commissioners' gauges on the Kiewa. In Table VII. are given the factors which have been adopted for computing the precipitation of the High Plains from that of the others, and in Table VIII. the computed average rainfalls for the Kiewa stations for each month of an average year, and for a drought year, adopting, for this purpose, the year 1914 as having been the driest on record at each of the four standard stations.

Computed on this basis, the average annual precipitation on the High Plains is found to be 93 inches, and that of the drought year 51 inches. For the lower portions of the Kiewa gathering grounds the corresponding figures are 75 and 42 inches. These deductions are supported by the observations of the Victorian Hydro-electric Company, which show that, in April and May, 1915, the mean fall of two stations on the High Plains was 164 per cent. of the simultaneous fall at Harrietville, and 104 per cent. of that at Mt. Buffalo.

The estimation of probable run-off from the catchments from the rainfall figures involves, of course, assumptions as to the percentage of loss by evaporation or percolation. The figures which have been adopted for this purpose for summer and winter periods of average and drought years are shown in the Table IX. of Appendix II. In the actual calculation of discharge these figures have only been used for the purpose of determining the probable ratio of discharges of various portions of the Kiewa catchments, the actual quantities of water discharged being calculated directly from the flow of the main streams as observed at the gauging stations above Tawonga. For their use in this way only the relative values of the percentages of run-off assumed are of importance. In support of the assumption that the whole of the rainfall as measured by standard methods would be discharged by the streams of the High Plains, the percentage of run-off being assumed as 100 per cent., it may be mentioned that in the case of the Lake Margaret Scheme in Tasmania it has been found that the apparent coefficient of discharge is about 110 per cent. Comparative data as to areas and climatic conditions of the two watersheds are given in Table X. Similar results have been observed on the catchment of the Capetown Water Supply Scheme on the summit of Table Mountain and elsewhere.

The climatic conditions on the Kiewa High Plains appear to be as favorable for a high coefficient of run-off as in the case of Lake Margaret, the mean annual temperature being considerably lower and the rainfall comparable, as will be seen from Table X. in Appendix II. The assumption of 100 per cent. discharge has, however, only been made for winter conditions, that for the summer being taken as 70 per cent. The explanation of the apparent paradox of a coefficient of run-off equal to or greater than unity, is believed to be, in part, that snowfall is never fully accounted for by the precipitation measured in rain gauges, and, in part, that under winter conditions in these localities there is a great deal of direct condensation from the air upon the ground and vegetation, which is not recorded at all by rain gauges.

The coefficients of run-off of the whole Kiewa valley above Kiewa, about 70 per cent. of which is below 3,000 feet elevation, are stated in the published " River Gaugings " of the State Rivers and Water Supply. In the period 1886–1918 the coefficients varied from 22 per cent. in 1902 and 26 per cent. in 1914 to 88 per cent. in the wettest year, the mean coefficient of the whole period being 50 per cent.

Corresponding coefficients for the whole valley, calculated from the proportionate areas at various elevations and the factors given in Table IX., are, for dry weather conditions, 24 per cent., and for average winter conditions, 63 per cent.

NOTE.—Since the above was written readings have been obtained of Gauges Nos. II. and III. for the four months, May to August, inclusive. The records are :—

Gauge No. II.	47·2 inches
Gauge No. III.	48·4 inches.

The falls recorded during the same period at the reference stations were :—

Harrietville	32·29 inches.
Bright	25·03 inches.
Mt. Buffalo	36·84 inches.
Glen Wills	20·84 inches.

APPENDIX 2—*continued.*

RAINFALL AND STREAM DISCHARGE DATA.

TABLE No. I.—GAUGINGS OF THE KIEWA RIVER AT KIEWA BY STATE RIVERS AND WATER SUPPLY COMMISSION.

Drainage Area, 434 square miles.

Year.	Total Annual Discharge.	Mean Annual Rainfall Drainage Area.
	Acre Feet.	Inches.
1886	351,859	50
1887	629,888	65
1888	355,578	38
1889	622,612	65
1890	524,219	60
1891	410,674	47
1892	431,280	51
1893	530,140	62
1894	677,360	68
1895	441,840	54
1896	291,390	54
1897	339,761	49
1898	408,356	56
1899	304,017	54
1900	471,395	65
1901	310,284	62
1902	161,180	30
1903	403,053	42
1904	480,739	44
1905	563,429	48
1906	1,100,000	65
1907	439,000	32
1908	346,790	36
1909	810,610	51
1910	611,290	45
1911	573,190	42
1912	576,870	48
1913	430,447	42
1914	166,723	27
1915	625,420	52
1916	893,565	56
1917	1,725,259	84
1918	859,652	48

TABLE No. II.—MEAN DISCHARGE, CUBIC FEET PER SECOND.

Month.	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.
January ..	175	365	230	123	134	465	153	422	171	65	206	1,208	552
February	102	170	155	80	99	886	93	164	118	47	205	487	702
March ..	888	102	105	175	108	795	96	755	80	29	127	412	405
April ..	299	192	84	141	71	432	179	446	216	70	154	518	306
May ..	940	348	250	1,240	253	475	95	289	401	268	240	1,426	2,939
June ..	1,851	645	361	2,873	456	1,467	213	367	275	893	457	4,204	2,004
July ..	1,925	653	547	1,581	1,114	1,279	617	423	321	1,144	1,941	4,219	2,229
August ..	1,761	970	493	3,317	793	1,001	543	612	298	1,435	1,770	3,699	1,472
September	2,954	1,142	1,224	1,335	3,164	1,309	3,765	1,524	383	2,041	3,314	3,857	1,507
October ..	4,780	1,089	1,448	1,668	1,903	926	1,642	1,182	198	2,710	2,897	4,733	917
November	1,463	1,201	639	589	1,438	263	734	670	137	1,205	2,245	2,557	778
December	1,013	376	187	195	583	221	1,414	260	157	404	1,188	1,145	387

APPENDIX 2.—RAINFALL AND STREAM DISCHARGE DATA—*continued.*

TABLE No. III.—RAINFALL RECORDED BY NIPHER RAIN AND SNOW GAUGES.

Period.	No. of Gauge.	Position.	Rainfall Recorded.
			Inches.
21.1.20 to 31.1.20	I.	On ridge east side of Rocky Valley	1·125
31.1.20 to 1.5.20	I.	On ridge east side of Rocky Valley	7·750
15.11.19 to 31.1.20	II.	On ridge between left and right hand branches of East Kiewa River	16·000
31.1.20 to 1.5.20	II.	On ridge between left and right hand branches of East Kiewa River	3·875
10.11.19 to 31.1.20	III.	Near junction left and right hand branches of East Kiewa River	14·625
31.1.20 to 1.5.20	III.	Near junction left and right hand branches of East Kiewa River	6·125
20.1.20 to 31.1.20	XII.	On ridge west side of Pretty Valley	0·438
31.1.20 to 1.5.20	XII.	On ridge west side of Pretty Valley	7·688

TABLE No. IV.—NIPHER RAIN GAUGE AND COMMONWEALTH STANDARD RAIN GAUGE, KIANDRA, NEW SOUTH WALES.

Height above sea level, 4,650 feet.

Date.	Reading of Nipher Gauge.	Reading of Standard Gauge.
	Inches.	Inches.
31.12.19	Records commenced	
31.1.20	4·5	..
29.2.20	5·06	5·03
31.3.20	8·88	8·92
30.4.20	11·40	11·37
31.5.20	14·60	..
30.6.20	30·40	27·81
31.7.20	39·75	37·21
31.8.20	50·75	46·79

TABLE No. V.—COMMONWEALTH RAIN GAUGE STATIONS ADJACENT TO KIEWA WATERSHED.

Station.	Harrietville.	Bright.	Mt. Buffalo.	Glen Wills.
Direction and distance from centre of watershed ..	11 miles S.W.	19 miles N.W.	27 miles N.W.	14 miles E.
Elevation above sea level	1,300 ft.	1,000 ft.	4,700 ft.	2,700 ft.
Years of record	20	20	6	12
Average rainfall	58·70	44·65	78·93	53·91

TABLE No. VI.—COMPARISON OF RAINFALLS RECORDED ON KIEWA WATERSHED AND AT ADJACENT RAIN GAUGE STATIONS (SEE TABLE V.).

Period.	Kiewa Stations.				Adjacent Stations.			
	No. of Gauge.	Position of Station.	Height above Sea Level.	— —	Harrietville.	Bright.	Mt. Buffalo.	Glen Wills.
				Rainfall Recorded—Inches.				
			Feet.					
21.1.20 to 1.5.20 ..	I.	On High Plains east of Rocky Valley	5,600	8·88	7·00	3·29	5·23	6·43
20.1.20 to 1.5.20 ..	XII.	On High Plains west of Pretty Valley	5,970	8·13	7·00	3·29	5·23	6·43
15.11.19 to 1.5.20	II.	On East Kiewa catchment	4,096	19·88	16·47	9·63	16·05	17·21
10.11.19 to 1.5.20	III.	Do., at junction right and left hand branches	2,300	20·75	17·96	10·73	18·00	18·58

Appendix 2.—Rainfall and Stream Discharge Data—*continued.*

Table No. VII.—Rainfall at Kiewa Stations, 1919–20, Expressed as Percentages of Rainfalls at Adjacent Stations in Same Period (See Tables V. and VI.).

No. of Station.	Height Above Sea Level.	Rainfall as Percentage of Fall at—			
		Harrietville.	Bright.	Mt. Buffalo.	Glen Wills.
	About				
I.	5,600	127	270	170	138
XII.	5,970	116	247	155	126
II.	4,096	121	206	124	115
III.	2,300	115	193	115	112
Mean of Stations above 5,000 ft. ..	..	121	258	162	132
Mean of Stations 2,300 and 4,096 ft. ..	..	118	199	119	113

Table No. VIII.—Monthly Rainfall in Average and Drought Years at Kiewa Stations, Computed from Fall at Adjacent Stations (See Tables V., VI., and VII.).

Month.	Monthly Rainfalls, Kiewa Stations.			
	High Plains, above 5,000 Feet.		East Kiewa Catchment, 2,300 to 4,000 Feet.	
	Average Year.	Drought Year.	Average Year.	Drought Year.
January	4·13	4·20	3·39	3·44
February	4·63	0·26	3·73	0·22
March	5·46	4·65	4·48	3·76
April	4·96	7·63	4·02	6·23
May	8·95	9·96	7·28	8·13
June	12·83	2·64	10·45	2·19
July	10·93	6·09	8·93	5·02
August	9·52	0·87	7·79	0·72
September	10·31	4·23	8·37	3·43
October	8·34	0·25	6·75	0·21
November	6·64	4·39	5·38	3·56
December	6·47	6·47	5·26	5·31
Total for year	93·17	51·64	75·83	42·22

Table No. IX.—Assumed Ratios of Run-off to Rainfall Measured by Rain Gauge.

Elevation of Catchment.	Season.	
	December to April.	May to November.
	Per cent.	Per cent.
Above 5,000 feet	70	100
Between 3,000 and 5,000 feet ..	40	80
Below 3,000 feet	10	50

Table No. X.—Comparison of Hydrological Conditions of Kiewa Scheme and Lake Margaret Scheme, Tasmania.

—	Kiewa Power Scheme.		Lake Margaret Scheme.
	Upper.	Lower and Upper Combined.	
Area of watershed, acres	12,600	62,275	4,800
Area of storage basins, acres	1,200	1,200	315
Mean elevation of do., feet above sea level (approximate)	5,600	4,600	3,000
Mean annual temperature, degrees Fahrenheit	42	45	44
Do., January	56	60	55
Do., July	27	30	32
Approximate mean annual rainfall, inches	93	78	130

APPENDIX 3.

Table No. I.—Goulburn River at Sugarloaf Reservoir.—Mean Discharges in Cubic Feet per Second.

(Gaugings by Mr. C. H. Kernot, State Rivers and Water Supply Commission.)

Month.	Year 1915.	Year 1916.	Year 1917.	Year 1918.	Year 1919.
January	..	277	683	439	232
February	..	234	375	284	217
March	..	215	472	390	316
April	..	228	819	287	243
May	..	301	3,812	6,277	666
June	..	613	12,127	5,312	1,541
July	..	3,396	9,180	6,799	2,504
August	..	5,231	7,168	3,456	2,477
September	..	7,885	9,535	3,286	3,475
October	..	6,000	8,651	886	1,333
November	..	5,036	2,363	761	427
December	433	2,543	861	341	393
	433	31,959	56,046	28,518	13,824

Minimum rate of flow, 210 cubic feet per second.
September, 1916, maximum rate of flow, 80,000 cubic feet per second for three hours.
June, 1917, maximum rate of flow, 70,000 cubic feet per second for three hours.

Table No. II.—Sugarloaf Reservoir.—Gaugings of Goulburn River at Murchison by State Rivers and Water Supply Commission.

Mean Discharge in Cubic Feet per Second.

Month.	Year 1911.	Year 1912.	Year 1913.	Year 1914.	Year 1915.	Year 1916.	Year 1917.	Year 1918.	Year 1919.
January	256	236	524	140	44	67	276	367	92
February	1,916	137	148	120	38	61	128	547	83
March	2,027	111	637	90	23	42	510	1,015	273
April	788	119	571	72	20	49	1,350	530	84
May	1,611	123	1,155	509	501	420	4,343	8,873	82
June	14,954	660	3,266	211	1,669	420	20,125	9,463	1,355
July	7,420	1,703	2,645	1,033	7,550	5,170	13,762	14,229	3,707
August	6,712	539	4,457	682	11,671	6,081	15,647	8,871	..
September	1,998	8,571	2,608	62	7,720	16,752	21,210	8,080	..
October	1,622	2,250	1,513	51	5,971	13,568	15,160	1,128	..
November	348	1,589	2,080	51	2,222	10,870	4,427	916	..
December	318	2,083	588	52	219	5,073	1,047	106	..
	39,970	18,121	20,192	3,073	•37,648	58,573	97,985	54,125	5,676

Table No. III.—Sugarloaf Reservoir.—Mean Discharge in Cubic Feet per Second.

Based on flow of Goulburn River at Murchison.

Comparative Years 1916–1919 (7 months).

Month.	Year 1911.	Year 1912.	Year 1913.	Year 1914.	Year 1915.
January	435	472	466	420	176
February	1,399	425	444	396	160
March	1,459	363	522	324	99
April	623	393	485	266	86
May	1,192	406	866	463	456
June	7,447	535	2,254	464	1,235
July	3,933	1,243	1,878	785	4,002
August	3,692	474	2,897	552	5,836
September	1,459	4,371	1,852	241	5,636
October	1,200	1,620	1,120	199	3,463
November	418	1,176	1,498	199	1,600
December	413	1,500	500	203	460
	23,670	12,978	14,782	4,512	23,209

Appendix 3.—Table No. IV.—Sugarloaf Reservoir, Goulburn River.—Water and Power Available.

Reservoir Capacity, 300,000 acre-feet. H.W.L., 823.

Month.	Net Discharge, Cubic Feet per Second.		Net Head.	Efficiency Turbines.	Output.	Efficiency Generators.	Output.
	Whole Plant.	Main Units.					
1912.			Feet.		H.P.		KW.
January	800	776	94	78	6,465	94	4,534
February	800	776	88	79	6,130	93	4,253
March	800	776	84	79	5,851	93	4,060
April	800	776	82	79	5,710	93	3,961
May	..	..	..	..	..	..	..
June	..	..	..	..	..	..	..
July	..	..	..	..	..	..	..
August	445	428	103	80	4,007	95	2,840
September	2,000	1,952	103	82	18,735	96	13,418
October	1,590	1,550	103	77	13,970	94	9,796
November	1,145	1,114	103	76	9,908	94	6,948
December	1,470	1,433	103	81	13,586	96	9,729
1913.							
January	800	776	101	77	6,858	94	4,801
February	800	776	97	78	6,672	94	4,679
March	800	776	94	78	6,465	94	4,534
April	800	776	90	79	6,270	93	4,350
May	..	..	..	..	..	..	..
June	1,770	1,627	103	78	14,854	95	10,529
July	1,845	1,800	103	80	16,855	95	11,945
August	2,000	1,952	103	82	18,735	96	13,418
September	1,815	1,771	103	80	16,582	95	11,751
October	1,090	1,060	103	75	9,305	93	6,456
November	1,470	1,433	103	81	13,586	96	9,730
December	800	776	100	77	6,790	94	4,762
1914.							
January	800	776	97	78	6,672	94	4,679
February	800	776	94	78	6,465	94	4,534
March	800	776	89	79	6,200	93	4,302
April	800	776	84	79	5,851	93	4,060
May	..	..	..	..	..	..	..
June	..	..	..	..	..	..	..
July	..	..	..	..	..	..	..
August	170	159	103	65	1,209	86	776
September	800	776	98	77	6,652	94	4,665
October	800	776	93	78	6,396	93	4,438
November	800	776	87	79	6,060	93	4,205
December	800	776	81	79	5,643	92	3,873
1915.							
January	800	776	73	80	5,150	92	3,535
February	800	776	63	80	4,445	91	3,018
March	800	776	..	..	..	..	..
April	800	776	..	..	..	..	..
May	..	..	..	..	..	..	..
June	..	..	..	..	..	..	..
July	670	649	103	74	5,621	92	3,853
August	2,000	1,952	103	82	18,735	96	13,418
September	2,000	1,952	103	82	18,735	96	13,418
October	2,000	1,952	103	82	18,735	96	13,418
November	1,570	1,531	103	77	13,798	94	9,676
December	800	776	103	77	6,994	94	4,905
1916.							
January	800	776	97	78	6,672	94	4,679
February	800	776	90	78	6,190	93	4,295
March	800	776	84	79	5,851	93	4,060
April	800	776	80	80	5,645	92	3,873
May	..	..	..	..	..	..	..
June	..	..	..	..	..	..	..
July	1,570	1,531	103	77	13,798	94	9,676
August	2,000	1,952	103	82	18,735	96	13,418
September	2,000	1,952	103	82	18,735	96	13,418
October	2,000	1,952	103	82	18,735	96	13,418
November	2,000	1,952	103	82	18,735	96	13,418
December	2,000	1,952	103	82	18,735	96	13,418

APPENDIX 3.—TABLE NO 4.—SUGARLOAF RESERVOIR, GOULBURN RIVER.—WATER AND POWER AVAILABLE—*continued.*

Month.	Net Discharge, Cubic Feet per Second.		Net Head.	Efficiency Turbines.	Output.	Efficiency Generators.	Output.
	Whole Plant.	Main Units.					
			Feet.		H.P.		KW.
1917.							
January	800	776	99	77	6,721	94	4,713
February	800	776	97	78	6,672	94	4,679
March	800	776	92	78	6,328	93	4,391
April	800	776	92	78	6,328	93	4,391
May	2,000	1,952	103	82	18,735	96	13,418
June	2,000	1,952	103	82	18,735	96	13,418
July	2,000	1,952	103	82	18,735	96	13,418
August	2,000	1,952	103	82	18,735	96	13,418
September	2,000	1,952	103	82	18,735	96	13,418
October	2,000	1,952	103	82	18,735	96	13,418
November	2,000	1,952	103	82	18,735	96	13,418
December	830	776	103	77	6,994	94	4,905
1918.							
January	800	776	97	77	6,586	93	4,569
February	800	776	91	78	6,260	93	4,343
March	800	776	89	79	6,200	93	4,302
April	800	776	84	79	5,851	93	4,060
May	2,000	1,952	103	82	18,735	96	13,418
June	2,000	1,952	103	82	18,735	96	13,418
July	2,000	1,952	103	82	18,735	96	13,418
August	2,000	1,952	103	82	18,735	96	13,418
September	2,000	1,952	103	82	18,735	96	13,418
October	855	830	103	78	7,578	95	5,372
November	800	776	102	77	6,926	94	4,857
December	800	776	98	77	6,652	94	4,665
1919.							
January	800	776	93	78	6,396	93	4,438
February	800	776	87	79	6,060	93	4,205
March	800	776	81	79	5,643	92	3,873
April	800	776	73	80	5,150	92	3,535
May	..	..	..	..	..	..	..
June	..	..	..	..	..	..	..
July	1,770	1,727	103	79	15,968	95	11,315
August	2,000	1,952	103	82	18,735	96	13,418
September	2,000	1,952	103	82	18,735	96	13,418
October	1,303	1,269	103	79	11,733	95	8,316
November	800	776	97	78	6,672	94	4,679
December	..	776	94	78	6,465	93	4,534

TABLE NO. V.—MEAN OUTPUT OF HYDRO-ELECTRIC PLANT AT SUGARLOAF WEIR.

Year.	Mean Output.
	KW.
1912	4,960
1913	7,250
1914	2,960
1915	5,440
1916	7,810
1917	9,750
1918	8,270
1919	5,980

Average 6,550

Total average output, 57,000,000 kilowatt hours per annum, at unity load factor.

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