

HYDRO-ELECTRIC SURVEY OF INDIA.

Preliminary Report on the Water Power Resources of India.

Ascertained during the season 1918-1919 by the late

G. T. BARLOW, C.I.E.,

Chief Engineer, Hydro-Electric Surveys, Government of India, assisted by

J. W. MEARES, M.Inst.C.E., M.I.E.E., M.Am.I.E.E.,

Electrical Adviser to the Government of India.

Compiled by

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Darjeeling Municipal Electric Works ; the first hydro-electric works in India, erected 1897-8.

Photo-engraved & printed at the Office of the Survey of India, Calcutta, 1916.

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3. Map of Tata hydro-electric layout, showing 3 lakes, tunnel through watershed, canals, forebay, pipe lines and power house (See Plate III and Table 1) *to face page 9.*

INTRODUCTION.

It has always been known that the Indian Empire (has great possibilities in the way of natural water power;) to a limited extent this power has been developed in a few favourable localities, but as hitherto India has not been to any great extent an industrial country no serious interest has been taken in the subject. Practically the whole of the industries that existed in British India, prior to the advent of the Tata Hydro-electric Power Supply Company, were dependant on fuel. Mysore had however developed considerable power for industrial purposes from the Cauvery River at an earlier date, when the only pre-existing hydro-electric installation in India was the small Municipal town lighting plant at Darjeeling. (Frontispiece) A photograph of this pioneer installation, which was erected and set to work by the present writer in 1897, is reproduced as a frontispiece, as even the Indian Industrial Commission's able Report gives precedence to the Mysore installation which started work in the 20th Century, 5 years after Darjeeling.

In September 1905 the Government of India issued a circular letter to the Chief Secretaries to the Governments of Madras, Bombay, Bengal, Burma, the United Provinces and the Central Provinces (but not to the Punjab) enquiring in general terms as to possible sites where water power might be developed, but the information received was for the most part too vague to be of any great value. Owing to the fact that there was at this time no real demand for industrial power on a large scale, except in cases where promoters were already making their own investigations, the matter was not carried beyond the stage of this preliminary circular.

The outbreak of the war rapidly brought matters to a head all the world over, for it was soon found that power was at the root of all war demands and that (electricity was the most adaptable form of power.) And whereas Switzerland and the United States, generally associated in the public mind with the chief developments of water power, have utilized only some 24 per cent of their available resources, Germany has utilized no less than 43 per cent.

In India, the formation of the Indian Munitions Board was the first step in co-ordinating existing industries for war purposes, and this was soon followed by the appointment of the Indian Industrial Commission. In Chapter VI of the Report of the Industrial Commission, 1916-18, the question of power is discussed in all its bearings, and the necessity for a Hydrographic Survey of India is emphasized in paragraph 99. Reasons are also given (Paragraph 100) why the survey should be undertaken by Government rather than by private enterprise. In paragraph 353 a rough estimate of the cost of the survey is given, assuming it to take 5 years. It is unnecessary to recapitulate the recommendations of the Report in question as the whole industrial future of India, foreshadowed therein, is bound up with and dependant upon the provision of cheap power. The Report itself must be studied.

Acting on the above recommendation the Government of India appointed the late Mr. G. T. Barlow, C.I.E., then Chief Engineer, Irrigation Branch, United Provinces, to take charge of the Hydrographic Survey as Chief Engineer, associating with him in the enquiry Mr. J. W. Meares, M.I.C.E., Electrical Adviser to the Government of India. No special instructions were issued to Mr. Barlow, except that he was informed that it was desirable that a preliminary Report should be prepared during the hot weather of 1919; beyond that he was given a free hand and the necessary funds to initiate the work as he thought fit.

The object of this preliminary Report is to explain what has so far been done, and what it is proposed to do in future; and to explain in simple and un-technical language the methods by which every one may assist in the investigation in one way or another. The area to be examined is vast and the work to be done is of great importance; even with the co-operation of the public it cannot be finished for many years, while without that co-operation it will be delayed much longer.

Elsewhere similar work is being carried out either by Government agency or through private enterprise. The Conjoint Board of Scientific Societies in

London formed a Water Power Committee to ascertain "What is at present being done to ascertain the amount and distribution of water power in the British Empire." In July 1918 this Committee (hereafter called the British Water Power Committee) issued its preliminary Report, and this has stimulated an interest in the subject far and wide. The Report states that "With the exception of Canada and New Zealand, Tasmania, New South Wales, and possibly South Africa, practically nothing has been or is being done on any systematic basis to ascertain its true possibilities." A few figures are given relating to the potentialities of India, but these are not always reliable as the Committee had not the information at its disposal for even the roughest approximation, except in one or two places. The British Water Power Committee's Report ends with the following conclusions and recommendations :

Conclusions.

"The main conclusions to be drawn from the evidence available to the Committee are :—

- (1) That the potential water-power of the Empire amounts in the aggregate to at least 50 to 70 million horse-power.
- (2) That much of this is capable of immediate economic development.
- (3) That except in Canada and New Zealand, and to a less extent in New South Wales and Tasmania, no systematic attempt has as yet been made by any Government Department to ascertain the true possibilities of the hydraulic resources of its territories, or to collect the relevant data.
- (4) That the development of the Empire's natural resources is inseparably connected with that of its water-powers.
- (5) That the development of such enormous possibilities should not be left to chance, but should be carried out under the guidance of some competent authority.

In view of these conclusions the Committee would submit the following recommendations :—

Recommendations.

1. That the British Government bring before the notice of the Indian Government, of the various Dominion Governments and of the Governing Bodies of the Crown Colonies, the necessity for a close systematic investigation of all reasonably promising water-powers, and of their economic possibilities.
2. That the British Government take steps to ascertain whether the Governments concerned are prepared to undertake this work.
3. That where such an enquiry is beyond the powers of any governing body, the British or Imperial Government place the work under the direct control of an "Imperial Water Power Board" or "Conservation Commission."
4. That the Government take steps to initiate the formation of such an "Imperial Water Power Board" or "Imperial Conservation Commission," to include a representative from each of the Dominions and Dependencies.
5. That this Board act in an advisory capacity. It should decide on the sequence of such investigation work as comes under its purview. It is suggested that all schemes for the development of which local resources are inadequate, should be submitted to the Board by the Governments concerned, and that the Board should make recommendations on which the Imperial Government might take action. Such a Board would be able to take a broad and comprehensive view of the advantages to the Empire as a whole, attending the development of any given scheme, and would be able to form a reasonable decision as to the relative advantages of such different schemes as might be brought forward from different parts of the Empire.
6. That since it is unlikely that private capital will be available for many years for hydraulic development on any large scale, powers

should be obtained to enable the State to assist or to undertake such development if thought advisable.

It is suggested that much might be done to attract private capital, if the State, after careful investigation, were to guarantee a suitable minimum interest on the necessary capital, sharing at the same time in any profits beyond the amount necessary to provide that interest. By this method of assistance private enterprise would be untrammelled, and the management of the concerns so assisted would remain in private hands.

As the Report of this British Water Power Committee may not have been as widely circulated as is desirable the following additional extracts from it may with advantage be given here :

"The World's Present Power Demand.—It is impossible to estimate with any pretensions to accuracy, the power now being used in the various countries of the world. Independent estimates, based on such data as are available, tend, however, to show that it is of the order of 120 million horse-power made up approximately as follows :—

World's factories, including electric lighting and street railways	75 million horse-power.
World's railways	21 " "
World's Shipping	24 " "
Total	120

This includes all steam, gas, and water-powers.

"Cost of Hydraulic Power.—It must be realised that the cheapness or dearness of energy is purely relative, and hydraulic powers which are not at present able to compete economically with steam, may in the not distant future be able to do so. Even now in favourable localities, the cost of electric power generated from hydraulic installations compares favourably with that of steam or oil power. The cost of such power is made up mainly of charges against capital, interest, depreciation, sinking fund charges, taxes and insurance, which are usually much greater than water charges and costs of operation, maintenance and supplies. These capital charges vary widely with the local circumstances and physical characteristics of the site. Where the available head is great and the storage reservoir is provided by some natural lake, they may be comparatively small. Where, on the other hand, extensive works are required to bring the water to the power house, and where the transmission line is long, the overall cost of power may be largely in excess of that generated by a steam plant.

"An examination of some 120 European installations shows that for large installations of upwards of 10,000 electric horse-power the minimum cost of the hydraulic works is £8·4 per horse-power installed, and the maximum, £79·6 per horse-power. For the majority of the installations the cost lies between £25 and £45. The cost of the electrical generators, switch boards, &c., and transmission lines, also varies greatly, ranging from £1·25 to £28·4 per horse-power, while the cost of the turbines ranges from £4 to £8 per horse-power. The working costs vary between £1·3 and £6·8 per electric horse-power year, with an average value of £3. From these figures it appears that on the average, making an allowance of 15 per cent. for interest and depreciation, the cost per electric horse-power per annum is in the neighbourhood of £10·5.

"In many installations, however, the cost is very much less than this. The Ontario Power Company, for example, is able to supply power to the Hydro-Electric Commission of Ontario at £1·8 per electric horse-power per annum. It is estimated that many of the large powers in Canada can be developed at a total cost, including all generating machinery and transmission lines, ranging from £12

to £20 per electric horse-power in which case the cost per horse-power per annum should not exceed £2 to £3.

"Necessity for Preliminary Investigations.—In spite of the great importance of water-power, many of the potential powers in existence must of necessity prove economically useless, either on account of their great distance from centres of industry, the lack of transport facilities, or from the fact that the storage necessary to give a continuous or fairly continuous supply would be too costly. Of many potential powers it can be said without further investigation that for the present this is, and for a long period to come will be, the case. Of others the reverse is true, and it is evident that the scheme will amply repay development. But in the majority of cases the extent to which a scheme is capable of economic development can only be determined after a careful examination of the catchment area and of the site of the proposed works; after a careful and prolonged investigation of the rainfall and run-off records; and, especially in an undeveloped country, after an investigation of the mineral and forestal or agricultural possibilities of the surrounding region.

"It has usually been understood that the usefulness of a water supply depends on the possibility of maintaining its uniformity over the whole period of the year, and that the maximum useful power is strictly limited by the minimum power which, by the aid of any suggested storage system, will be available towards the end of the longest probable period of drought.

"Where the power is utilized for the supply of some industrial centre this is undoubtedly true, but if the idea were to be generally adopted, it would cut out an enormous aggregate of potential power, more particularly in tropical and semi-tropical countries. The possibility of utilizing flood supplies for seasonal operations in connection with mining, agriculture and forestry, or for the production of nitrates in such cases, would appear to be worthy of close consideration.

"In any case, the possibilities of a given scheme can only be determined after a prolonged hydrographical and meteorological investigation of the site and surroundings. To be of real value such an investigation should extend over a long series of years. Rainfall records, though forming the basis of any such investigation, are only of partial assistance in dealing with water-power questions. The actual run-off from the catchment area is the all important factor, and the ratio of run-off to rainfall varies with the physical characteristics of the area, the vegetation, and the climate so that rainfall gaugings cannot be substituted for the more laborious and costly collection of continuous records of river levels, combined with frequent gaugings of flow. It must be emphasized that each scheme of development requires independent investigations to determine completely the local conditions governing the flow from the area intended to be utilized.

"Much can be done to ascertain the approximate possibilities of a potential scheme before deciding to incur the heavy cost of a detailed survey by—

- (1) Installation and continuous recording of river gauges on all likely channels.
- (2) Installation and recording of rainfall gauges at suitable places.
- (3) Observation of river discharges for a series of gauge readings.

"If a reasonably long record of rainfall exists, the determination of the run-off for a few years will serve to give a relation between precipitation and run-off which can be carried back as far as the rainfall records go. The initiation of operations (1)—(3) costs little, and no time is lost in collecting the more important data.

"While this is true, it should be borne in mind—

- (1) That to be of reliable value from a commercial point of view the hydrometric studies must give a continuous record for a number of years, and show not only the minimum low water flow, but also

the maximum flood conditions that have to be met in designing the head works.

- (2) That the investigation of suitable rivers should include contour plans of the sites, profiles along the entire power reach of the river, and along the banks; also studies of lakes or lochs for storage, where they exist, and of the possibility of inter-connecting two or more such lakes to feed one large project. These studies should be in sufficient detail to allow of preparing preliminary plans and estimating capital and operating costs, in order to demonstrate the capacity available and the commercial feasibility of development.
- (3) That to develop the most obvious power site on a river without full investigation of the whole power reach of the river may not secure, and may make it impossible to secure, the maximum advantageous use of the river by the development of two or more sites.
- (4) That to secure the maximum possible use of a river the investigations should therefore be made by the Government rather than by private interests.
- (5) Especially is this the case where storage may be developed, in order that the maximum possible storage may be secured, and that the water may be equitably distributed to, and the cost of the works equally borne by, the various interests benefited. Proper storage may greatly improve flood conditions and enhance the value of land as well as increase the power available.
- (6) That, without complete surveys the capacity of a river cannot be accurately judged. The pondage created by the dam will in many cases more than take care of the daily peak load, thus increasing the power available beyond that due to the minimum low water flow, and this may be still further increased by storage at the head waters. The power capacity of a river may sometimes be increased by such means by 100 or 150 per cent or more."

On his appointment as Chief Engineer of the Hydrographic Survey of India, Mr. Barlow decided to make a preliminary tour over India and Burma, in company with Mr. Meares, in order to get in touch with those who could further his enquiries, to explain the objects in view, and to visit any special localities to which his attention might be drawn, if time could be found for this.

In the period available it was only possible to spend a long time in one Province by omitting others, so it was decided to visit the headquarters of all and to allot what time remained during the season 1918-19 mainly to Burma. As a preliminary step, and in order that engineers in the Public Works Department might know where best to look for possible sites within their divisions, all Chief Engineers were asked to distribute copies of a note on "Practical Conditions in determining the value of Water Power for Electrical Purposes" prepared by the Electrical Adviser to the Government of India. At a later date Mr. Barlow himself prepared a less technical note for the use of officers of other services who might be able to assist in the enquiry, and this has also been circulated extensively. It is reprinted in Appendix I.

The following is a brief diary of the places visited during the cold weather of 1918-19.

1918	November 15 to 17 . . .	Delhi	Preliminary meeting of the two officers.
	November 25 to 27 . . .	Cawnpore	Mr. Barlow and Mr. Meares.
	November 30 to } December 3 }	Nagpur	Ditto.
	December 4 to 8 . . .	Bombay	Ditto.
	December 10 to 14 . . .	Madras	Ditto.
	December 16 to 20 . . .	Calcutta	Ditto.
	December 21 to 22 . . .	Patna	Ditto.
1919	January 2	Delhi	Mr. Barlow only.
	January 4 to 6	Lahore	Ditto.

INTRODUCTION.

January 7 to 8	. . . Peshawar	. . . Mr. Barlow only.
January 16 to 17	. . . Shillong	. . . Mr. Barlow and Mr. Meares.
January 18 to 19	. . . Cherrapungi	. . . Ditto.
January 20	. . . Shillong	. . . Ditto.
January 22 to 23	. . . Jatinga river	. . . Ditto.
January 26 to 28	. . . Nagrakata (Jaldaka R)	. . . Ditto.
January 30 to 31	. . . Calcutta	. . . Ditto.
February 4 to 6	. . . Rangoon	. . . Messrs. Barlow, Meares and Raikes.
February 7	. . . Toungoo	. . . Ditto.
February 8	. . . Thandaung	. . . Ditto.
February 9	. . . Toungoo	. . . Ditto.
February 10 to 13	. . . Kalaw and Toungyi	. . . Ditto.
February 14 to 16	. . . Mandalay	. . . Ditto.
February 17 to 18	. . . Maymyo	. . . Ditto.
February 20	. . . Naymyou	. . . Ditto.
February 22	. . . Maymyo	. . . Ditto.
February 24 to 25	. . . Mandalay	. . . Ditto.
February 28 to March 1	} . . . Yenangyaung	. . . Ditto.
March 3 to 7	. . . Rangoon	. . . Ditto.
March 28	. . . Jalpaiguri	. . . Mr. Meares only.
March 29 to 31	. . . Darjeeling	. . . Ditto.
April 1 to 2	. . . Jalpaiguri	. . . Ditto.
April 3 to 7	. . . Jaldaka River	. . . Ditto.
March 10	. . . Calcutta	. . . Mr. Barlow only.
March 13 to 20	. . . Meerut	. . . Ditto.
March 21	. . . Bholā	. . . Ditto.
March 26	. . . Aligarh	. . . Ditto.
March 30 to 31	. . . Amritsar	. . . Ditto.
April 2	. . . Lucknow	. . . Ditto.
April 4	. . . Narora	. . . Ditto.
April 9	. . . Narora	. . . Mr. Barlow died.
April 14	. . . Simla	. . . Report begun.

During the visit to Burma Mr. B. Raikes, Deputy Controller of Munitions, and formerly Electrical Engineer to the Government of Burma, was placed on special duty to accompany the Chief Engineer; his knowledge of the country proved most valuable. During this period a certain number of promising sites were examined, though only cursorily; and local officers supplied much useful information and promised to furnish more if their ordinary duties enabled them to spare the time.

On the conclusion of the month in Burma, the objects of the whole preliminary tour having been accomplished as far as was possible in the time, the Chief Engineer decided that he and Mr. Meares should separate and work independently until April when the report would be prepared; it was his intention that he himself should pay more particular attention to localities where storage reservoirs were likely to be required while Mr. Meares investigated high fall projects.

At this stage of the enquiry Mr. Barlow contracted small-pox and died suddenly at Narora, on the 9th April 1919. His loss to the Government of India is very great, for, despite his extreme care in recording every item of information received, his unrecorded impressions of localities and of men would have proved invaluable when he came to compile his report. Furthermore the late Chief Engineer's special talents, both of engineering and organization, resulting from 33 strenuous years in India, are lost to this important investigation. Pending fresh arrangements Mr. Meares received instructions to carry on the work and to write this preliminary Report.

It will be realized that, owing to the absence of many officers of the Public Works and other Departments on war service, it has been no light

matter for those who remain to give time to the special investigations required on the Survey. In many cases the sites where power is likely to be found are only accessible with difficulty, and their examination may involve several days' journey in country where there are no communications. Gauging operations require technical knowledge and take up considerable time, but-unless the *minimum* discharge of a river or stream is known with some approach to accuracy any computations based on it may be very misleading. The discharges of the main rivers already used for irrigation purposes are known, but this is not the case with their tributaries—often likely to be of value—nor with the innumerable mountain streams that have hitherto not been used at all. It is unfortunate that such records have not been kept in the past, as the records of a single year, even if an exceptionally dry year, are a very uncertain guide.

Much valuable work has however been done in these unfavourable circumstances, and in the normal years of the future it is to be hoped that it will be carried to a successful conclusion. It will be observed that owing to vague statements a good number of possible sites for power have not yet been identified. A site should be located either by the exact map square in which it is placed, in the 1 inch to the mile series, or by latitude and longitude. Negative results are in many cases entered in this Report, as they will save useless investigations in the future.



Simla Hydro Electric Works; The Head Works.



Simla Hydro Electric Works; Power House and Pipe Line.

APPENDIX I.

Elementary notes by the late Mr. G. T. Barlow, C.I.E., Chief Engineer, dated 23rd March 1919, on the Preliminary Investigation of Water Power Sites for Electrical Purposes.

1. *Object of the investigation.*—The chief sources of energy which are at present known are coal, oil and water power. The two former are easily handled and transported, and in most places are more convenient and cheaper than water power, but their supply is limited, and their cost must sooner or later increase. A knowledge of the water power potentialities of the country is therefore of the greatest importance, not only in the conservation of energy, but also in the economic development of the country.

At present very little is known about the water power resources of India and Burma, because they mostly lie in the hills and jungles which are sparsely inhabited, and rarely visited by any officials; only rough survey maps exist of many parts.

The object of the preliminary investigation is therefore to locate the favourable areas and sites, to ascertain the discharges of the perennial rivers, and to collect other information through the Local Officers, which will enable detailed surveys to be carried out expeditiously by a special staff during the cold weather.

The object of the survey is *not* to prepare estimates for town lighting and electric fans, but to obtain details regarding favourable sites that can be made of general use to the Public. These details will show where and approximately how much power is available, and will also give other useful information which will enable any Company that requires power to know where and how to set to work to prepare the detailed plans.

To discover the localities of all the existing water power resources of the country is desirable whether a demand for power exists at present or not. The most unlikely places to-day may in a few years' time be the centres of Industrial, Agricultural or Mining activity. India and Burma are immense countries, but even though this is so, if intelligent and willing assistance is given by the Local Officers it will be possible to eliminate the useless areas, and to concentrate the survey work in the promising localities.

2. *Definitions of technical terms, etc.*

(a) *A typical Hydro-Electric Scheme* consists of a perennial river or of a reservoir or both for the supply of the water; this water, except where a natural fall already exists, is diverted into a separate channel by means of weirs or regulators, and is then run in an open channel along the hill side at an easy slope, or in a tunnel through the hill, till a suitable site has been reached for running the water down the hill slopes and obtaining the requisite fall for power purposes. The water is then run down the hill side in steel pipes to the power house which is situated at the bottom of the hill above the High Flood Level, and finally the water is escaped back into river; sometimes the water is diverted through a watershed into another river. From the power house transmission lines are constructed to convey the current to the factory or to other consumers. In the preliminary investigation only the details regarding the *supply of the water* and the *height of the fall* are required though details regarding other relevant points will be welcomed.

(b) A *Cusec* means a cubic foot per second.*

(c) *Head.*—The vertical difference in level (in feet) *i.e.*, the height of the fall between the inlet and outflow of water used for power purposes is called the *Head*. In all preliminary works it is sufficient to note the actual head available.

*NOTE.—The small water driven flour mills, found in the Himalayas, take from 3 to 4 cusecs. J. W. M.

- (d) For water power purposes the "fall" means the difference in height between the level of the water where it will be taken from the stream and that at the place where it will be returned to the stream and it may be made by:—
- (i) a vertical drop in a river or canal,
 - (ii) a series of rapids making, in a short reach of one or two miles of a river, a total fall of so many feet, or
 - (iii) an artificial fall which can be made in a reach of, say 4 or 5 miles, in a river with a *steep* slope, by taking off the water and running it along the hill side at a *gentle* slope, or in a tunnel through the hill to another valley; and then, at a suitable place, running it down the hill sides back into the same or into another river bed.

For power purposes (i) and (ii) are merely superior to (iii) because the length of flume or open channel to the entrance of the pipeline is cheaper, and more convenient for regulation purposes.

(e) *Storage reservoirs* are natural or artificial collections of water situated above the fall, which are commonly called tanks or lakes. The water is collected during the monsoon periods or at other times when there is excess water, and is used for irrigation or power purposes, or for both. These reservoirs, which must be constructed above the fall, provide the necessary discharge in period of low supply in the river, and also collect the water which is running in the river when the water power plant is closed down, or when irrigation is not required.

(f) When it is found that a stream dries up or falls very low for a short period before the break of the rains, then in order to maintain a constant power, some storage must be provided.

(g) One cusec running constantly throughout the year is equivalent to 31.5 million cubic feet of storage, but allowance has to be made for evaporation and percolation losses, so that to obtain the equivalent of that constant discharge a storage of 35 million cubic feet should be provided. For one month the storage necessary may be assumed at 3 million cubic feet and for one day 100,000 cubic feet.

(h) The *Catchment area* of a stream at any point is the area draining into the stream at that point.

(i) *Watershed* is the boundary line between two catchment areas.

(j) The *Electrical Horse Power* that can be generated will be approximately $\frac{\text{Cusecs} \times \text{Head in feet}}{11}$, or $= \frac{\text{Cusecs} \times \text{Head in feet}}{15}$, when expressed in *Kilowatts* instead of Horse power.

3. *Sites suitable for producing power*.—Navigable or tidal rivers or waters are useless for water power purposes, because the cost of development is very great, and the power obtained is small. The power available depends on the product of the fall obtainable and the minimum discharge that can be relied on at the driest time of the year. A navigable river may have a large discharge but the slope of the river bed will be extremely small, and in a reach of 4 or 5 miles it will be impossible to produce more than a few feet of artificial fall. The product of the discharge multiplied by the fall will therefore be small while the cost of harnessing the river, and the cost of the other works will be very great. One thousand cusecs falling 5 feet will give the same power as 5 cusecs falling 1,000 feet, and it will be readily understood that the cost of developing the latter will be far less than that of the former. The best sites are therefore small discharges with big falls; say 50 to 200 cusecs falling 400 to 2,000 feet, but medium discharges of say 200 to 500 cusecs falling medium heights say 100 to 400 feet are also good, while large discharges (say anything above 1,000 cusecs) falling small heights of say 5 to 50 feet are expensive in construction, and therefore poor if anything better is available.

From this it follows that the best sites are generally those found in hilly country and on the tributaries of the large rivers, and that the power sites available in the large rivers themselves and on canals are seldom really favourable.

The ideal site is one where several small snow or spring fed streams collect in a high level valley above the fall, and then drop many hundred feet in a short length of the stream into a lower valley, where sound rock suitable for a dam is found at the exit of the upper valley; where the run off from the catchment area will be sufficient to provide the necessary storage; and where the valley is flat and uncultivated, which will enable additional storage to be collected by means of a low dam, without destroying cultivation.

All these conditions seldom exist in one place and one has generally to be content with a stream the discharge from which disappears for a couple of months before the rains, or with an indifferent storage site where the valley has a quick slope, and a high dam will be required to store much water, or where the rock is poor, or submergence will necessitate the removal of villages and the payment of heavy compensation for the loss of cultivation, and so on.

In the preliminary investigation however there is no necessity to give great consideration to all these points, it will be sufficient to find a perennial or nearly perennial stream where there is a good fall. The details of the storage site can best be left for expert survey work later on.

Any site is worth considering where the product of the minimum discharge in cubic feet per second multiplied by the height of the fall in feet is not less than 16,000. Anything less than this is too small for industrial purposes though it may be of use for town supply.

4. For preliminary reconnaissance an Aneroid Barometer to measure heights, a watch with seconds hand, and a tape measure or a 10 foot rod are all the instruments necessary.

The points to note are:—

- (a) Approximate discharge and Head available.
- (b) River and site on river, by reference to the 1" maps or by latitude and longitude.
- (c) Accessibility, *i.e.*, how to get to the site, and nearest road, rail or river communications.
- (d) General remarks (when known) on the height that the high flood water rises, whether a storage reservoir appears possible, nature of the country, geological formation, difficulties, market for power and any other points of interest which may affect the cost, construction, or upkeep of the works.

Where it is impossible to observe an accurate discharge, or where the correct methods and co-efficients to be employed are unknown, the following very approximate method may be adopted:—

Select a straight reach of the stream where the flow is uniform and where there are no marked pools, and mark off with pegs any convenient length of fairly uniform width. Then measure as accurately as possible the width of the stream, and find the *average* depth by soundings at intervals across the stream. Then throw into the centre of the stream a small stick and note the time it takes to pass along the marked length; repeat this 4 or 5 times to eliminate errors. Then the run in length in feet divided by the average time in seconds gives the velocity on the surface. Then the cross-sectional area in square feet multiplied by the surface velocity in feet per second and *divided by two* will give the approximate discharge in cubic feet per second.

For instance, suppose the length marked off is 100 feet and the floats take an average time of 50 seconds in passing along this length in a stream having a width of 40 feet and an average depth of $1\frac{1}{2}$ feet. This gives a cross-sectional area of 60 square feet. The surface velocity will then be 2 feet a second and the discharge $\frac{2 \text{ feet a second} \times 60 \text{ square feet}}{2} = 60 \text{ cusecs.}$

5. A careful study of the largest maps which are available will be found of great assistance in all reconnaissance work. In dense jungle or rough country it is frequently impossible to follow up the course of a stream, and unless the maps are carefully studied it may easily happen that a useful fall or a promising reservoir site is missed. The 1"=1 mile contoured maps are excellent and the 4"=1 mile Forest surveys are even better.

A few examples are given below to indicate the kind of information which can be obtained from maps:—

- (a) A flat or a steep valley or hill side is shown by the distance between the contour lines. The closer the lines are the steeper the country will be found.
- (b) The distance between any two contour lines which cross a stream will give the fall in that reach.
- (c) Absence of village sites and roads or pathways denotes wild or uncultivated country.
- (d) Numerous habitations on the hill slopes or in a valley in hilly country denote cultivation, and generally springs or perennial water in the streams.
- (e) When the discharge of a stream is known at a certain point, an idea of the discharge at another site can generally be guessed by a comparison of the catchment areas at the two places.
- (f) By a study of the nature of the valleys and the hill sides, a fair idea can be obtained of the general nature of the country, and its possibilities with reference to reservoir sites, slopes of the stream, and places where an artificial fall for power purposes can be found.
- (g) When a stream makes a long hair-pin bend, it is frequently possible to obtain a good fall by diverting the water in a tunnel across the neck of the bend. Several miles of a river can sometimes in this manner be replaced by a short cut diversion of a few furlongs.
- (h) Sometimes the slopes on one side of a water-shed are very steep, while on the far side they are gentle; when this happens it may be possible to form a reservoir and divert the water through the hill, and by this means obtain a most useful artificial fall.

Addendum to elementary note.

Useful Hydraulic Data (in round numbers generally). *Flow.*

1 cusec flow = 1 cubic foot per second = 62.4 lbs. per second,
 = 60 cubic feet per minute = 3,744 lbs. per minute,
 = 374 gallons per minute,
 = 3,600 cubic feet per hour,
 = 86,400 cubic feet per day,
 = 2.6 million cubic feet per month,
 = 31½ million cubic feet per year.

Regulating storage.

100,000 cubic feet stored will give 1.16 cusecs for 24 hours.

"	"	"	"	2½	"	"	12	"
"	"	"	"	4½	"	"	6	"
"	"	"	"	9½	"	"	3	"
"	"	"	"	27½	"	"	1	"

Main storage.

31½ million cubic feet stored is equivalent to 1 cusec for a year; but owing to evaporation and percolation more storage would actually be required. In round figures:—

1,000 million cubic feet stored will give 30 cusecs continuously for a year.

"	"	"	"	40	"	"	"	9 months.
"	"	"	"	60	"	"	"	6 "
"	"	"	"	120	"	"	"	3 "

Reservoirs.

1 acre = 43,560 square feet,

1 acre of water 1 foot deep = 43,560 cubic feet,

1 square mile = 640 acres = 27.88 million square feet,

1 square mile of water 1 foot deep = 27.88 million cubic feet, which will (in practice) give a flow of about ¾ cusec for 12 months, or a little over 3 cusecs for 3 months.

Catchments.

1 inch of rain = 100 tons or 3,640 cubic feet per acre. = 64,000 tons or 2.33 million cubic feet per square mile.

In practice, however, only a percentage, and often a small percentage will reach the reservoir ; see paragraph 9.

Power from flow.

On the practical basis assumed throughout this report $\frac{\text{Cubic feet flow} \times \text{head in feet}}{11}$
= electrical horse power.

If 15 is the divisor, the result is in kilowatts.

Power from storage.

(i) Regulating. $\frac{\text{Thousands cubic feet stored} \times \text{head in feet}}{42} = \text{e. h. p. hours.}$

If the divisor is 56, the result is in kw. hours or B. O. T. units.

(ii) Main. $\frac{\text{Millions cubic feet stored} \times \text{head in feet}}{370} = \text{e. h. p. years.}$

If the divisor is 500, the result is in k. w. years.

APPENDIX II.

Coefficients for ascertaining mean velocity from greatest surface velocity in channels.

Hydraulic mean depth.	Very smooth channels- cement.	Smooth Ashlar or brickwork.	Rough chan- nels. Rubble masonry.	Very rough channels earth.	Channels with detritus.
Feet. ·25	·83	·79	·69	·51	·42
·5	·84	·81	·74	·58	·50
·75	·84	·82	·76	·63	·55
1	·85	...	·77	·65	·58
2		·83	·79	·71	·64
3 . . . . .		...	·80	·73	·67
4 . . . . .		...	·81	·75	·70
5 . . . . .		...	...	·76	·71
6		·84	...	·77	·72
7 . . . . .			...	·78	·73
8 . . . . .			...		...
9			·82		·74
10 . . . . .					...
15					·75
20					·76
30					·77

The hydraulic mean depth is found by dividing the cross-sectional area in square feet by the wetted perimeter in feet. The mean values of several cross-sections along the chosen length of channel are used. For most streams and rivers in the hills the coefficients in the last column will be used. It will be observed that with a hydraulic mean depth less than 0·5 foot the coefficient is slightly below the figure suggested in Mr. Barlow's note (Appendix I); this however will almost always give conservative results.

APPENDIX III.

Part of an aneroid survey—see paragraph 13.

The entries in the field note book were as follows :—

Date.	Time.	Station.	Temp. F.	Reading of aneroid.	
April 4	6-0	I	72	1870	Outward journey.
"	8-45	II	83	1853	
"	10-0	III	92	2055	
"	12-0	IV	96	2850	
"	12-10	VI	91	2972	
April 6	5-30	VI	66	3002	Return journey.
"	7-0	V	69	2150	
"	7-30	II	74	1900	
"	8-30	I	80	1795	

Reduction by Molesworth's curve for diurnal variation in Calcutta and for air temperature by means of curves given in Molesworth and Deschanel, as follows :—

Outward journey.

Station.	Diff. by aneroid feet.	Correction for diurnal.	Result feet.	K	Final difference, feet.	
I } II }	Fall 18	+40	Rise 22	1-096	Rise 24	24
II } III }	Rise 202	+3	Rise 205	1-115	Rise 230	
III } IV }	Rise 796	-3	Rise 792	1-130	Rise 896	1,264
IV } VI }	Rise 122	<i>Nil</i>	Rise 122	1-180	Rise 138	
					TOTAL RISE .	1,288

Return journey.

VI } V }	Fall 852	-23	Fall 829	1-075	Fall 891	1,157
V } II }	Fall 250	-5	Fall 245	1-084	Fall 266	
II } I }	Fall 105	-5	Fall 100	1-095	Fall 110	110
					TOTAL FALL .	1,267

It will be seen that while the reduced results between the terminal stations agree very well, giving a mean difference between them of $\frac{1,288+1,267}{2} = 1,278$ feet, the two common intermediate readings do not agree; between stations 1 and 2 the outward journey gives a difference of 24 feet and the homeward 110 feet, while the discrepancy is balanced between stations 2 and 6, traversed by a different route. Unless the instruments can be carried in special lagged cases, so that the metal work cannot get heated up differently at various parts, these discrepancies will occur. A second instrument carried at this time showed equally discordant results at intermediate stations, and the two did not agree any better *inter se*. No doubt if a long halt could have been made at each station, to enable the instruments to settle down thoroughly, the results would have been more even; but this is generally impossible.

Station I was found by a 4" Forest map to be at *about* reduced level 990 feet. Adding the mean rise between 1 and 2' *i.e.*, $\frac{24+110}{2} = 67$ feet, Station 2 will probably be within 50 feet of R. L. 1,057. Station 3, with only a single reading, is 230 feet higher and the result, 1,287 feet, may be 100 feet out. Station 4 similarly may be taken as about 2,183 feet, with a similar margin. The terminal station 6 is probably within 15 feet of $990+1,278$ mean or 2,268 feet, as the results accord well and the Bengal weather reports showed that no considerable change of pressure occurred in the interval; station 5 is about 891 feet, below this, or say 1,377 feet within 100 feet. The reductions made from the second instrument confirm these probabilities.

A subsequent test of the two "compensated" aneroids, one kept in the shade as a control and other placed in the sun, showed that the latter in both experiments rose very rapidly; the relative change due to the temperature changes of the instrument itself were 60 feet and 84 feet respectively in the course of an hour or so. This no doubt accounts for the discrepancies at intermediate stations.

APPENDIX IV.

Mechanical and Electrical Power.

The British, and practically International, horse-power is the power obtained when energy is being expended at the rate of 550 foot-pounds a second or 33,000 foot-pounds a minute. Applied to water power, if 330 lbs. of water (5.28 cubic feet) are discharged per minute under a head of 100 feet (giving a static pressure of 43.3 lbs. per square inch) the energy expended will be at the rate of 1 horse-power. This, however, is theoretical, or water horse-power, w.h.p. If a turbine and pipe system having an efficiency of 90 per cent. are employed to utilize this flow and fall, the mechanical or brake horse-power obtained on the shaft will be 0.9 b.h.p. If this mechanical power is used to drive an electric generator, the efficiency of conversion being 95 per cent. under the particular conditions, the electrical horse-power obtained will be $0.9 \times 0.95 = 0.855$ e.h.p. The value of the horse-power in foot lbs. per minute is in each case the same, but the fraction available diminishes. The output of the generator, 0.855 e.h.p. \times .746 gives the exact electrical equivalent, viz., 0.636 kilowatt, as 1 e.h.p. = 746 watts or .746 kilowatts. To round up the example, if this .636 of a Kilowatt is converted to heat (where the efficiency is necessarily 100 per cent.) it will give out .636 of 57.3 or 36.4 British Thermal units per minute, which is equivalent to 28,200 foot-lbs. per minute, out of the 33,000 with which the example started. Thus horse-power is a *rate*, not an *amount*, so "500 h.p. per minute" is meaningless; the total amount of electrical power generated in any particular time is expressed in e.h.p.-hours or kilowatt-hours. If 500 h.p. (373 k. w.) is exerted for one minute the resultant energy is 500/60 or 8.33 h. p. hours or 6.21 k. w. hours. These elementary explanations are only given because the letters received from engineers show that they are required.

No mention has so far been made of "indicated horse-power" and "nominal horse-power." The former represents the power developed *in the cylinders* of a steam or oil engine, as calculated from the indicator diagram, and will generally be from 7 to 18 per cent. higher than the effective b.h.p. developed on the crank shaft. Nominal horse-power is a term surviving from the earliest days of the steam engine, and is practically meaningless now. The b.h.p. of an engine may be two or three times the n.h.p. as the term related to the size of the cylinders and length of stroke without regard to the steam pressure actually used. Where returns for the census of power are submitted in n.h.p. an endeavour should be made to ascertain the b.h.p. developed by comparison with other cases. Otherwise the n.h.p. should be multiplied by 3.

APPENDIX V.

List of sites in Assam.

Bhugai River (Garo Hills).—Unsurveyed in detail, but has a rainfall of 100 inches of which 91 per cent. falls between April and October. Appears unlikely to afford any good site judging by the $\frac{1}{4}$ -inch map. The catchment area however is some 85 square miles at Selhat Haut, where the Naranga tributary flows in. (Map 78 K. 7).

Bogopani River.—see Shella River.

Cherrapungi.—see Shella River.

Damring River.—see Krishnai River.

Didram River.—see Jinari River.

Digru River.—see Um Tru.

Dudhnai River (Garo Hills).—Nothing is known regarding this stream, or its tributaries, the Manda and Chichura but it is probably worth reconnaissance as the rainfall is high and the slope rapid. At the junction of the above tributaries the Manda has a catchment of about 40 square miles and the Chichura about 70 square miles. About 105 out of 115 inches of rain falls between April and October. (Map 78 K 13).

Jadukata or Kynshiang River and tributaries (Khasia Hills).—Appears to have considerable possibilities, the rainfall being between 100 and 150 inches of which 94 per cent. falls between April and October. There are many falls, and reservoir sites may be found in the Nongstoin area. The catchment area above the falls of 70 feet, with others near by, in latitude $25^{\circ} 26'$, longitude $91^{\circ} 8'$ is about $2\frac{1}{2}$ square miles. (Map 78 O ; 3, 7, 10).

Jatinga River.—The possibility of using this river for the electrification of the hill section of the Assam Bengal Railway has been considered by the Agent. The proposal is to dam the river just below the junction with the Ka Yeng (q. v.) near mile 277, up stream of the hair-pin bend near the railway tunnel. (There are no detailed maps of the river area available at present). The area flooded would be about $2\frac{1}{2}$ sq. miles, and with a 90 foot dam and mean depth of water of 45 feet the storage would be some 3,000 million cu. ft. The rainfall is said to vary between 144 and 250 inches in the catchment, mostly falling between March and October. It averages 84 at Haflong and 174 in the Jatinga Valley. The above storage would give about 380 cusecs for the 6 dry months and 12 hours a day. The catchment area of the combined streams is about 96 sq. miles above here. The power station would be near Damchara Station, where a head of about 200 feet could be obtained, with a long canal on difficult ground and perhaps a long pipe line so far as is at present known. The site may be good for 7,000 e. h. p. or more. It seems probable that a higher dam than 90 feet would be required to give the storage indicated, and this might involve the submergence and re-alignment of several miles of the railway in difficult country. The dam site requires further examination. Rock outcrops in several places on both banks, and is hard and compact, with the strata often vertical, sometimes twisted, and frequently broken. It is sound enough for a weir to stand on, but not for water to fall on unless heavily protected. It is probable that the river bed was once 100 feet deeper or more, and the present flat valley has been formed by the hills slipping down on the left bank and blocking the river. A lake was formed and in course of time its overflow has scoured out a new channel, but this is still much above the old level. There is a possible flank escape (not examined) on the left bank some little way back, where rock should be found, as evidently the river at one time escaped by this route. The dam would probably run across the river at a sharp angle, but the line would have to be trenched for examination and this would be most difficult. Further examination in detail is required before a verdict can be expressed on the scheme. See also Ka Yeng River and Maibang. (Map 83 G 4).

Jiwari, Jinjaram or Didram River (Garo Hills).—This has not been prospected; it has a catchment area of about 100 sq. miles at Roksaun, with about 100 inches of rainfall, and the slope is rapid. The stream is unsurveyed

on a large scale, but looks unpromising on the $\frac{1}{4}$ inch map. 91 % of the rain falls between April and October. (Map 78 K 5, 9).

Ka Yeng River.—This from the layered maps looks more favourable than the Jatinga river (q. v.), into which it flows just above the site mentioned on the latter. There is apparently a good reservoir flat some 2 or 3 miles from the Railway bridge, but it proved inaccessible in the time available.* The dam here would be well above the railway. The flow was found to be about 5 cusecs only in December, but the rainfall is about 150 inches here over a catchment of 30 sq. miles, mostly falling in 6 months. (Map 83 G 2, 3; unsurveyed).

Kulsi River (Khasia Hills).—This appears promising on the map, but has not been examined. It is a perennial stream and has good falls. Rainfall is 100 inches, mostly between April and October. There are large lakes in the reserved forest area, which could probably be dammed at the exit; but the fall would be that due to the dam only. The catchment area to the lake exit is over 100 sq. miles. (Map 78 O 5).

Krishnai or Damring River (Garo Hills).—Near the Jinari (q. v.) and the same comments apply. Catchment area at Chelteret about 200 sq. miles. (Map 78 K 9).

Maibang, Assam-Bengal Railway, hill section.—The railway station here is in the middle of a large flat valley, several miles long, with steep cliffs on the east side where good rock appears to outcrop. This valley is near the highest point of the line, and it falls steeply away towards Lumding. The valley is cultivated, but the railway could be cheaply diverted. The discharge of the river (name unknown) in December was only a few cusecs, but rainfall is high—about 100 inches. The site is most suitable for a large reservoir, as the valley is flat, the rock apparently good, and an excellent saddle escape exists on the east. This site is considered well worth examination. From the Atlas sheets the catchment area is about 80 sq. miles. (No maps available, but on 78 G 2 or 3).

Monas River.—This flows into the Brahmaputra from Bhutan, and has a large perennial flow. The fall after it enters British territory appears considerable. (Map 78 J 13).

Shella River (Bogopani River in Atlas; Khasia Hills).—This is within the belt of 200 to 440 inches of rain and consists of steep sided gorges, already cut down almost to plains level. Unless reservoir sites are found on the upper reaches in the Cherrapunji district (see General Remarks on Assam; para. 26) it is doubtful if the stream is of any use. If storage exists the catchment areas at almost any point are far larger than is necessary; excess water, not deficiency, will be the difficult problem. The months of December and January are almost dry; November and February receive an average of $2\frac{1}{2}$ inches; March averages 8 and October 15; so the distribution is unusually good. As the country is mostly steep and rocky the run-off will be very high, as all falls are heavy. By way of an index to the dry weather discharges 27 very small feeders of the Shella River were gauged in the area immediately west of Cherrapunji. All these flow into the Um Long and Um Pynjgithuli, which meet at R. L. 1,700 feet, $3\frac{1}{2}$ miles due west of the Dak Bungalow, and attention is called to possible reservoir sites above here in para. 26. January 1919 had only one measurable fall of rain, 0.63 inch on the 20th, and the combined discharges of the streams amounted to only 3 cusecs early in February. That month was quite dry. March had 0.92 inch on the 3rd and 4th only, and the combined discharges later in that month were under $2\frac{1}{2}$ cusecs. April had 13 inches of which half fell between the 17th and 23rd, the remainder being distributed in small falls. The combined discharges taken just after these heavier falls amounted to only 8 cusecs. The Umsophi reservoir site at the 100 feet contour is just over 1.1 square mile in area by the map. (Map 78 O 11, 16).

Shillong.—A small scheme was drawn up for lighting this hill station from the neighbouring falls on the Um Kra and Um Shirpi, but it offered no facilities for extension beyond about 150 e. h. p. A printed report on the site is in existence. Gaugings of the Um Kra taken at Mawlai Bridge gave from $11\frac{1}{4}$ cusecs at the end of December 1918, dropping very steadily to a minimum of 6.3 cusecs early in April 1919. The decrease is about 1 cusec per mensem in winter. Above Bishop's falls the Um Shirpi dropped steadily from 10 cusecs

* Since examined and found unpromising.

at the end of December 1918 to a minimum of 6.3 cusecs early in April 1919, with the same decrement. (Map 78 O 14).

Umian River, Khasia Hills.—This crosses the main road at Barapani, where a reservoir site may exist. There is however little information as to the fall available below, as the river soon passes to parts of which no detailed maps exist. The catchment at Barapani is about 20 sq. miles. Rainfall about 100 inches, mostly falling in 7 months, *viz.*, about 94%. (Map 78 O 14 and 83 C 1,2).

Um Kra; see Shillong *supra*.

Um Rai River, tributary of the Um Tru (q.v.). This has been gauged where it passes near the Gauhati-Shillong road, and where it is perennial. At mile 41 the discharge fell gradually, with large variations, from an average of 20 cusecs in January 1919, and 10 cusecs in February, to 6½ in March and 5 in the early part of April. The lowest record was 1 cusec. At the Laroh rapids (not identified) the discharge fell from 38 cusecs average in January and 28 in February down to 22 in March; the lowest record being 15 cusecs. Rainfall about 100 inches. (Map 78 O 13).

Um Shirpi.—See Shillong *supra*.

Um Tru or Digru River.—(Khasia Hills). This and its branches, which pass the Gauhati Shillong road, may offer some power, but not much information is available except that the river is perennial and has some good falls. Detailed examination of the maps has not yet been made. The catchment area above the junction with the Um Rai appears to be about 60 square miles, but it is difficult to trace out exactly. Rainfall about 100 inches, of which about 94 per cent. falls between April and October. (Map 78 O 9,13).

Someswart River.—(Garo Hills). Unsurveyed in detail, but looks promising on the layered and ¼ inch maps. At the junction where the Ramthang and Semthang from the west join the Rangdi from the east the catchment areas are about 300 and 170 square miles, or 470 in all. Rainfall over 100 inches, of which 90 per cent. falls between April and October. (Map 78 K 10, 11, 14, 15).

APPENDIX VI.

Bengal and neighbourhood.

Chittagong.—A small scheme was drawn up for utilizing the Karnaphuli River near this town, but no details are available. Rainfall about 100 inches. (Map 84-B, unsurveyed).

Damuda River.—There appear to be some possibilities in this river in connection with an irrigation project, but they have not been investigated from the power point of view. The development would, it is believed, be expensive. The rainfall averages 50 inches in the area. The Port Commissioners of Calcutta are interested in the reservoir project, as the monsoon flush is required to keep the River Hooghly clear. Several reservoirs were proposed, one of the upper ones creating a fall of 100 feet, some of which could be utilized. The lower reservoir, into which the tail waters would discharge, was designed for a capacity of 20,000 million cubic feet; and the river bed below this has a slope of about 10 feet per mile. The prospects are not alluring, owing to the proximity of the coal fields and the high cost of any development. (Map 73-M).

Darjeeling District.—The present plant (See Table 2) is incapable of supplying the whole district and various schemes (Table 5) have been drawn up for further power. None of these are particularly comprehensive and detailed examination should improve on them. The Great Rungeet River is mostly out of British territory; the Little Rungeet River with its tributary hill nalas is in all cases suggested, and these are certainly capable of development. They have a catchment area of about 200 square miles. It is probable that at least 1,000 feet head can be obtained with a minimum discharge, from the Little Rungeet and the Kahill Nala alone, of 40 cusecs. The 2,000 foot contour offers a favourable channel line, and the drop would be made to the Great Rungeet where these streams meet it, at about R. L. 1,000 feet. No storage sites (other than for regulation) are probable, but power to the extent of 3,000 e.h.p. may be obtainable. Rainfall 120 inches well distributed from April to October. The following gaugings were made on the 4th April 1919, when the flow was exceptionally low, at points selected as likely to be reliable, and capable of being combined into a single scheme. The coefficient locally adopted has been changed from 0.66 to 0.5, as the hydraulic mean depth is extremely small and the beds are full of boulders and no really good cross sections are possible; the readings however were carefully made, and the reduced results are dependable.

Raman 48 cusecs; Lodhoma 17 cusecs; Rungriate $4\frac{1}{2}$ cusecs; Rilling 7 cusecs; Little Rungeet 22 cusecs; Kahil 7 cusecs; total 105.

(Map 78 A 7 and 8, survey incomplete towards Sikkim).

Duars District.—In addition to the Jaldaka (q. v.) on the border there are to the East some half dozen much larger rivers, mostly snow fed, falling into the Duars and Goalpara from Bhutan. The Amo Chu or Torsa, Chin Chu or Raidak, Sankosh, Saralbhanga, Manas, as well as smaller streams, all come from very high ground and must have great possibilities; but no maps are available, and no prospecting has been done. Probably the power sites will be outside British India entirely.

Jaldaka River.—(or Hidden Stream). This lies on the border line between Kalimpong (Darjeeling) and Bhutan and flows into the Duars; its upper reaches are in Tibet and Sikkim; the road up from Kumani Forest Bungalow is negotiable by elephants for some distance; it crosses and recrosses the boundary, over the river, which is barely fordable to men at the lowest water in April before the snows melt. The main river is apparently fed from the snows of the Jelep La, north of Gnatong in Sikkim; a considerable tributary, the Ne Chu, joins the main river where Sikkim and Bhutan meet the Kalimpong boundary and a fair one on the left bank $\frac{1}{2}$ a mile below. The catchment area here is about 130 square miles. The streams were gauged in the first week of April 1919, when the discharge was believed to be the lowest ever known; it was about 130 cusecs at the junction, where the elevation was found to be about 2,000 feet. The tributaries lower down were nearly dry in March 1919. The rainfall is not less than 150 inches, and the flood discharges are vast, probably over 40,000 cusecs at times. The slope of the bed is fairly

steep throughout, down to the plains near Sipchu Ghat (some 12 miles) where the elevation is about 680 feet. The upper part of the area has not been surveyed, but it is probable that a channel could be taken along the right bank, in British territory, at about contour 2,000, to a point near Kumai Tea Estate, where a drop of 1,000 feet or more may be obtainable—but the lower part of this again has not been contoured. Neither the stream beds nor the hills along the route appear to afford good facilities for even regulating storage, but further investigation is required. If this development is impracticable other sites lower down may not prove so; there are several places where a dam might (with difficulty) be built to impound a fair lake, and the river does not carry much silt normally, but the escape would have to be over the dam. The river appears likely to afford at least 12,000 e.h.p. continuously without any storage. Its possibilities are, however, vastly greater, as if harnessed it would be required for the tea districts of the Duars; Mr. A. H. Abbott of Octavius Steel and Company, who are managing Agents of many of these gardens, first drew attention to the potentialities of the river. Tea plucking does not begin until the first rains produce new leaf; and as soon as the early rains begin the discharge rises. Furthermore, before the tea season is in full swing, the snows begin to melt and supplement the cold weather flow. It is very probable therefore that by the time the power would be wanted there would be from 50,000 e.h.p. upwards available; but whether this could be developed at a single site is somewhat doubtful. An artificial channel or flume of large capacity (several hundred cusecs) would have to be carried for many miles along the hill side, across several large tributary nalas, and possibly along precipitous or treacherous ground. As, however, the industry awaits the power the scheme is well worth detailed examination. The submontane tea area of the Duars covers about 1,000 square miles, all within easy transmission reach of the site. Some 90 million pounds of tea are prepared in a season, requiring the equivalent of some 85,000 tons of coal, costing at pre-war rates over 13 lakhs of rupees. The greater part of this fuel, about 60 per cent, is used for drying purposes, to heat air which is driven by fans through the leaf at a temperature of about 220° F. The volume of air required is considerable, but the heating of it electrically, by means of resistance coils, is a simple matter, already done on as large a scale in other industrial drying operations. The power required for this purpose is large, but susceptible of exact calculation. The district is probably able to absorb the whole of the power that can be economically developed from the Jaldaka River, during the season from April to December. (Map 78 A. 12, 16. Partly available on 4" scale; part unsurveyed on border of Sikkim and Bhutan.)

Sikkim.—Messrs. Burn & Co., Ltd., of Howrah have obtained various forest and mineral concessions in Sikkim, including the right to develop electrical energy from water power. After investigating a scheme to utilize the Tahung Chu and Zenn Chu at their junction they finally decided to develop power at the Lagyap Pass site, east of Gangtok. The source of power is a perennial stream flowing from a snow-fed lake at a high altitude and eventually finding its way to the Tista River. The site is near a gap on the watershed, through which the stream will be diverted to the west, without a tunnel. It will then be carried along the hill side to where there is a steep drop of 2,000 feet into the Roro Chu or Tahsourche nala. Communications are difficult. The site is estimated to yield some 6,500 e.h.p. continuously at an overall cost of about one-tenth of an anna per unit. (No maps available.)

* *Tista River.*—This is a snow-fed river with a minimum discharge of 10,000 cusecs. The slope of the bed where it enters the plains is about 10 feet a mile for 20 miles; and until well into Sikkim, above the junction with the Great Rungeet, the slope does not materially rise. The river is subject to enormous floods from its 3,000 or more square miles of catchment, and although capable of yielding much power the development would be an expensive one. There is little doubt that a dam would be the only method of controlling the floods and concentrating a fall (*i.e.*, its storage would not be drawn on); and to construct this would offer engineering great difficulties owing to the high minimum discharge. Assuming that a 50 foot head could be obtained by this means, as is probable, this would give some 45,000 e.h.p. continuously; and more than one such place could in all probability be found. The river in its lower hill reaches may be estimated as good for at least 150,000 e.h.p. at a price (Map 78-A).

APPENDIX VII.

List of Sites in Bihar and Orissa.

Barakar River : see Usri River.

Burhabalong River (Mayurbhang). Mr. (now Major) C. H. Douglas, late of the British Westinghouse Co., investigated a power site on the upper reaches of this river many years ago, having a fall of some 900 feet, and he expressed the opinion that 40,000 e.h.p. or more could be developed with the aid of storage. It is probable, however, that only a single gauging of the discharge was made, which may have been by no means at the lowest time or in a dry year. The reservoir site at that time was unbroken jungle, and not surveyed in detail. The rainfall in the surrounding plains is 60 inches, of which 90 per cent. falls between May and October; it is certainly much higher in the Mayurbhang hills, which rise to over 3,000 feet. The site has now been re-examined under the orders of the Chief Engineer, Public Works Department, Bihar and Orissa. It is reported that there are two main reservoir sites which will cover over a square mile each and store some 1,200 and 1,000 million cubic feet respectively; while the first of these, situated below the junction with the Bukwa stream below Simlipalgarh, can be increased greatly by raising the proposed dam higher than the 120 feet originally proposed. These sites are 2 and 5 miles above the fall, and smaller regulating dams can be built close to the fall with a capacity of 400 million cubic feet more. The fall itself is 795 feet high but can be raised to 950 feet by carrying a channel along the eastern side for a length of 2,500 feet, thus confirming Mr. Douglas' opinion. It is probable that the site is capable of a development of 10,000 e.h.p. at least, and Mr. Douglas' estimate has not been disproved. (Map. 73 J. 8 and K. 5.)

Durgaoti River, tributary of Karamnasa, Shahabad District. At Kadbar Khoh, 9 miles from the river's source, there were reported to be storage possibilities, but the Chief Engineer finds the valley unsuitable owing to the rocks being much fissured vertically and horizontally. Rainfall 40 to 50 inches nearly all between June and September; catchment area about 27 square miles only. The site is reported by the Chief Engineer to be useless, as the minimum discharge in 1918-19 was only $\frac{3}{4}$ cusec. The Bichli (Mojhli) site, close to the former, is equally useless and dries up entirely. (Map. 63 P. 14.)

Garrha Nadi, Singhbhum District, at Dutaura, 4 miles north of Dhirol Public Works Department bungalow on Chaibasa-Moholia Road, has been examined. There are good storage possibilities (at heavy cost) and the catchment is large, but the fall is probably not more than 50 feet. The flow was 7 cusecs in February 1919 at this site, where the stream breaks through the hills. It is 4 miles north of the Haldopokhar Road. (Map 73 J. 6.)

Kakolat Fall, Gaya District. This is 10 or 12 miles south of Nawada in the hills running east from the Job Nadi. An article in "Indian Industries and Power" says "At the very minimum this may be expected to yield 25,000 horse power" but it is, on the other hand, reported by the Commissioner, Patna Division, to run quite dry in the hot weather. The discharge was 2 cusecs in February, 1919. Large storage is therefore essential. The catchment area is extremely small and the available fall is only 160 feet. The site is reported as quite useless by the Chief Engineer. Rainfall about 50 inches nearly all falling between June and September. (Map 72 H. 10.)

Kanchi River.—The Raota (or Dasan Ghag) fall, 6 miles south of Taimara, in the 19th mile of the Ranchi-Bandu Road, is about 150 feet. The catchment area is about 260 square miles and the rainfall 50 to 60 inches, of which that falling in June to September is alone of real value. The minimum discharge in 1918-19 was $4\frac{1}{2}$ cusecs. No reservoir can be formed at the fall, but without storage no great power can be expected. A site for a reservoir exists 20 miles above the fall and others may exist. Possibly the fall can be increased also. (Map 73 E. 8, 12.)

Kao River, Shahabad District. Above junction with Kudra, at Tara-chandi. Has been examined and site reported by the Chief Engineer as useless. (Map 72 D. 1.)

Karo River, Ranchi District. At Perua Ghag, 6 miles south of Topkara, which is 6 miles from Torpa on the Khunti-Kamdera Road, there is a fall of 100 feet. The catchment area is over 500 square miles, and the minimum discharge in 1918-19 was 1 cusec. Storage is probably available 3 or 4 miles above the fall, which can also be increased by a suitable take-off. Rainfall about 50 inches, mostly between June and September. (Map 73 F. 1.)

Mohana River.—Tributary of Phalgu river, Hazaribagh District, 10 miles south of Grand Trunk Road. The Tamasin and Harikhal falls have been examined, and there appear to be storage possibilities 10 miles above Itkhori and possibly elsewhere. The falls are 50 and 60 feet respectively, and extra head can be obtained by taking off at Itkhori. The catchment area will be about 200 square miles at this site. The minimum flow is negligible. Rainfall 50 inches, of which only that between June and October, amounting to 92 per cent. will be of any real use. (Map 72 H. 3, 4, 8.)

Nindi River.—There is a 200 foot water fall at Mauzah Nindi, Thana Bishunpur, 4 miles north of Serandag and 10 miles east of Bishunpur. The catchment area is about 12 square miles only, but the monsoon rainfall is 50 to 60 inches by the map and probably more on the crest of the hills. Storage will be essential and the site will probably not allow of sufficient to be of any use. (Map 73 A 7.)

Papaharan River, Padampur Zemindari, Sambulpur District. The Narsinghnath or Kapildhar fall, 97 miles south-west of Sambalpur, and 20 miles south of Padampur is about 900 feet all told, but the catchment area is only 2 square miles with a minimum discharge of about 4 cusecs. It had previously been reported that the fall came from "a vast sheet of water at the top of the hill"! The stream, however, is sacred, and the Narsinghnath temple is below the main fall, so it is impossible to utilize the site. (Map 64 P. 1.)

Phulwaria River, Shahabad. Has been examined at Zibhar Khund, where there is a fall of 450 to 500 feet, but the discharge is very small and storage impossible. The site is useless. (Map 63 P. 9.)

Sankh River.—There is a site under examination 3 miles from Rajdera, on the southern end of the Pakripat-Natarhat Plateau. The catchment area is only 32 square miles with a rainfall of 60 inches, confined almost entirely to June to October. The Rajdera fall is 175 feet and it is believed that a reservoir can be formed above it, increasing the practicable head by tunnelling through to the river. There are mines near. The power is unlikely to be sufficient for alumina reduction, but bauxite is found within reach. The minimum discharge in 1918-19 was only $\frac{3}{4}$ cusec. (Map 73 A. 3.)

Ibid.—The Perua Ghag fall lower down the Sankh River, 12 miles north of Kochdega and 4 miles east of Kundra on the Gumla road, is about 23 feet, and the catchment area here is over 900 square miles. The bed some miles above the fall is wide and a reservoir site may exist, but storage would be costly. The fall is dry except in the rains, being on a loop of the river, but the main discharge is reported as having been not less than 144 cusecs in 1918-19. (Map 73 B. 5.)

Son River.—It is stated by the Chief Engineer that any storage scheme on any tributary of this river might be of value for irrigation for the Son Canals.

Subarnarika River.—The Hundrughagh fall, of about 312 feet, is 13 miles north of Angara at the 61st mile of the Ranchi-Purulia Road and 20 miles from Ranchi. Extra fall can be obtained by taking off 4 or 5 miles higher up stream. The catchment area is roughly 500 square miles with rainfall between 50 and 60 inches, nearly all falling between June and September; and the cold weather discharge is about 60 cusecs, falling to a minimum of 12 in 1918-19. There is no suitable reservoir site at the fall, but many higher up, all expensive however in arranging for surplus flood water. Probably the site is capable of giving 1,600 e. h. p. or more. (Map 73 E 7, 11, 15.)

Another site has also been examined 4 miles west of Chandil Village, where a storage site exists requiring a dam 600 to 1,000 feet long, to store an enormous volume of water up to 100 feet above bed without flooding the railway. Here the catchment area is over 2,000 square miles. There is a subsidiary site lower down, which might serve as a permanent dam to give the necessary head and two possible additional storage sites further up stream. The cold weather discharge is fair, but the stream must occasionally run dry in the hot weather,

as the dam at Sakchi has no flow at times. Rainfall 50 to 60 inches, mainly confined to June to September. The site will be very expensive to develop, and the power could not compete with waste gas from the Sakchi furnaces. (Map 73 J 1 and 5).

Usri River.—Hazaribagh District. At Usri, about 7 miles from Giridih, just below the crossing of the Gobindpur road, a fall of about 180 feet is obtainable where the junction with the Barakar river is. A good storage site exists above and has been surveyed by the Bengal Irrigation Department in connection with the Damodar flood regulation. Believed to be worth some 1,200 e. h. p. which would be useful for the construction of the neighbouring dam on the Barakar River. Of the total rainfall of 50 inches 86 per cent. is due to the June-September monsoon. The proximity of the coal fields renders it unlikely that the fall will be used. (Map 72 L 8.)

APPENDIX VIII.

List of Sites, Bombay.

Bhatsa River.—There are said to be falls in this river at the site indicated near Shahapur, but no details are known except that the rainfall in the catchment of nearly 400 square miles is very high, probably 200 inches or more in the Ghat area, from local information, though there are no records of the Meteorological Department there. It practically all falls between June and September. (Map 47 E 7.)

Gangavali River.—The Magod falls on this river are said to be 800 feet high and have a catchment of about 280 square miles with good rainfall of from 30 to 75 or possibly 100 inches. No details as to minimum discharge. The rainfall is heavy during June, July and August, but there is generally a fair fall in May, September and October also. (Map 48 J 9, 13.)

Igatpuri.—Western Ghats. There are possibilities of a further storage project here (site not identified), but it is unlikely to be developed until the present Tata schemes have all materialized (See Andhra Valley; Nila Mula; Koyna). Rainfall 75 inches or more, and over 100 in parts, nearly all falling between June and September. (Map 47 E.)

Indus River.—If the proposed barrage at Sukkur is built there may be considerable power available and high level irrigation may afford an outlet for it. It is too early to discuss this.

Kalinadi River.—The Borkund falls are said to be worth examination; also the Vincholi falls, and lower still, the Lalguli falls of 500 to 850 feet according to length of canal. The catchment is in the high rainfall district of the Western Ghats, *viz.*, 100 inches or more, and is about 280 square miles in area at the junction with the Dogi, near the lowest fall; but the minimum discharge is not known; it was 200 cusecs at Lalguli in the summer of 1905, date not given. A fall higher up the river, near Londa, is also believed to exist; probably this refers to the rapids at Supa, which have been surveyed for power required at Dandeli, as proposed by the Conservator of Forests, Southern Circle. The area has considerable industries, and the tail waters could be used for irrigation. The Executive Engineer, Kanara, estimated (in 1905) that with storage the Lalguli falls were able to give 60,000 e. h. p. but further investigation is required. (Map 48 I, 7, 11, 12.)

Koyna River Project.—This is already entered in Table 5 as having been investigated by Mr. A. T. Arnall. The catchment area is 346 square miles in the Western Ghats. The proposed Helwak Lake will have a draw-off capacity of 120,000 million cubic feet, giving 300,000 e. h. p. continuously. The water will be tunnelled through the watershed and the head is 1,600 feet. Rainfall said to be 150 inches, though shown on the 75 inch contour in the rainfall chart; but the precipitation at the edge of the Ghats is extremely high all along. (Map 47 G 10, 11, 14, 15.)—

Malaprabha River.—Belgaum District. There are falls in this river at the point indicated, but no details are known at present. The catchment area is about 250 square miles and extends through the zones of 30 to 100 inches rainfall, which mostly falls between May or June and September. (Map 48, M, 1.)

Mula River.—There are two rivers of this name. One is dealt with under the Nila Mula Project below. The other rises in the Trimbak hills, which have a rapid drop from about 5,000 feet elevation down to 2,000 feet. The catchment area at the site indicated appears to be about 180 square miles, with a monsoon rainfall averaging 30 to 40 inches but probably far higher in the upper reaches; it is confined however to the monsoon period. (Map 47 E 11, 15.)

Nila Mula Project.—This is already entered in Table 5 as having been investigated by Mr. H. P. Gibbs. The catchment area is 111 square miles in the Western Ghats, and the proposed Nila Mula Lake is estimated to have a draw-off capacity of 18,000 million cubic feet, giving 150,000 e. h. p. for 3,600 hours per annum, so that for tabular purposes the power may be given as 75,000 e. h. p. continuously. The water will be taken through the watershed in a tunnel and the head is 1,700 feet. Rainfall about 150 inches, though on the contoured map it is in the area of 75 inches. (Map 47 F 6, 7, 10, 11.)

Nira Canal Project.—Poona. See Table 5. After the new Bhatgar Dam is built much more power will be available, especially if the Vir Tank is enlarged to pick up the tail waters and store them for irrigation. The Ing falls or rapids also appear to offer some power for 8 months; some 1,700 e. h. p.

Pravara River.—Rises in Trimbak hills near the Mula River (q. v.) and has the same characteristics. The Randa falls have about 200 feet drop and are said to be able to give 3,500 e. h. p. continuously. The site appears promising from the maps, and the monsoon rainfall is said to be very high, from 150 to 200 inches. The catchment at the point indicated appears to be about 80 square miles. (Map 47 E 10 and 14.)

Sharavati River.—District Canara. The Gersoppa falls on this river have a drop of some 800 feet, and it is believed they have been examined for power, though no details have been received. The falls are within 20 miles of the sea and near Bhatkal Harbour, which is under investigation as a port. The monsoon rainfall is from 75 to 100 inches during June to September in the catchment of about 150 square miles, and reaches 150 inches over part of the Ghat area. (Map 48 J 12.)

Tadri River.—The Lushington falls are said to be 300 feet high, and are worth investigation as no discharges are known to have been taken. Monsoon rainfall between 100 and 120 inches over a catchment of perhaps 250 square miles; reservoir sites may be found. (Map 48 J 11 and 15.)

Vaitarna River.—There are waterfalls in this river at the site indicated by the map, north of Tansa Lake, but no details are available. The rainfall (mostly between June and September) is upwards of 75 inches and the catchment of the order of 200 square miles. (Map 47 E 2, 6).

Canal Falls, Bombay.

Canal.	Position.	Fall in feet.	Minimum flow except at closure cusecs.	Working period in days.
<i>Gokak Canal.</i>				
Wadarhatti Branch	Mile 5/7	4	10	240
” ”	” 6/5	5	10	”
” ”	” 6/6	3½	10	”

It is possible that these falls might be combined, no information is available.

Pravara Left Bank Canal.

Fall No. 1	Mile 34	4½	114	325 (4 closures of 10 days).
” 2	” 35	12½	114	”
” 3	” 36	9	114	”
” 4	” 36	4½	114	”
” 5	” 43	9½	58	”
” 6	” 43	14½	58	”
” 7	” 44	10	58	”
” 8	” 45	7	50½	”

Combinations of falls are apparently possible here also.

APPENDIX IX.

List of Sites in Burma.

Anisakan River, Maymyo, tributary of Myitnge. The Deitdawgyi falls on this river have a drop of about 1,000 feet, almost sheer down, and the minimum discharge is said to be about 2 cusecs in May. The catchment area is quite small, of the order of 20 square miles. There are possible reservoir sites, though these have not been surveyed, close to the falls. One appears to be 30 to 40 acres in area. It is possible that other small streams can be diverted into the catchment. No canal is required and a short pipe line only. There is little doubt that such power as is required in Maymyo can be obtained at reasonable cost from this project, 200 to perhaps 500 e.h.p. The rainfall is about 50 inches; 96 per cent. of this falls between April and November, and a considerable carry-over will be required from storage, especially as crops probably absorb most of the small flow in the dry months. The stream is also called Nadaungya Chaung. Minimum discharge in 1919 was 2 cusecs at Htonbo near Sedaw. (Map 93 C, 5.)

Balu Chaung; See Laimaw River.

Ban Chaung.—See Tavoy.

Bean River.—Tavoy. Mr. Crossley of the Southern and Boundary Burmese Wolfram Co., has located an 1,100 foot fall on this river, but no gaugings are available. (Map 95 J. 12, K. 9.)

Bernard Myo River.—This river, 9 miles north of Mogok, is said to have a minimum discharge (due to springs) of 20 to 40 cusecs, and a good drop, stated to be several thousand feet in a short distance. It runs into the Kin Chaung, a tributary of the Sweli, and is probably capable of 8,000 e.h.p. or more. Rock is gneiss and limestone. Rainfall between 100 and 50 inches, of which 96 per cent. falls between May and November. The catchment area is about 120 square miles. (Map 93 A 8.)

Bilin River.—South west of, and on road to, Papun; said to be worth examination. An isolated river, with seven months' rainfall of 100 to 150 inches over its catchment and 5 dry months. The drainage area above Yinon, (which may however be near sea level) is about 600 square miles. It runs nearly dry for 3 months, so storage would be essential. (Map 94 G, but mostly unsurveyed.)

Chaungmagyi. See Madaya R.

Che Chaung.—Yaw district. A promising gorge with a good perennial discharge is found 4 miles above Yeshin village, 45 miles from Pauk.

Chindwin River.—Tributary of Irrawaddy. Kanti Fall (presumably at the place of that name, latitude $25^{\circ} 58'$, longitude $95^{\circ} 45'$) is said to have a discharge of about 3,000 cusecs in March and a fall of 30 feet. It is in wild country, with rock soil, but is said to be the most promising site on the river. May be valued at a probable 10,000 e.h.p., but has not been examined. Mr. Barlow considered it well worth investigation. The catchment is very great, probably 5,000 square miles, with rainfall about 75 inches. (Map 83 O, but unsurveyed.)

Heho River.—Beyond Kalaw on the road to Yawngnwe. There is here a very large and almost flat valley, mostly cultivated, evidently an old lake bed, spongy peat like soil, with outcrops of inferior peat. The area of this flat valley (a small part only of the catchment) may be about 20 square miles, but at its lower end, where the drainage escapes, there is a smaller flat of about a square mile (dimensions not determined) partly enclosed by spurs coming in from either side. At the south west end of the large valley a big spring comes through the limestone and feeds the nala that drains the area. The discharge was estimated to be 150 cusecs early in February, 1919, and was gauged at 103 cusecs on the 28th of that month. It was again gauged on 28th April and found to be 64 cusecs, which may safely be taken as near the absolute minimum. At the exit through the hills into Yawngnwe, from the smaller flat referred to above, there is a rapid series of cascades giving a drop of 672 feet in a horizontal distance of 4,000 feet, but it is believed that there is a further fall of 100 feet or more within easy distance, the survey having terminated at the foot of the fall. The nala flows into Imle Lake. The ground on either side of the fall is fairly

good and is suitable for a duct, and the pipe line would be reasonably short. A small regulating tank could be made at the head of the fall and a reservoir of large size above this could be scoured out hydraulically when power is available. Possibly levels may prove that a dam at the head of the fall would impound a considerable volume of water in the small flat valley without flooding the larger valley. The cross-section at the dam site is very favourable so far as it has been taken, showing that a height of 28 feet above water level could be obtained with a crest length of only 240 feet (much greater height is practicable), with rock on one bank and, almost certainly, near the surface on the other. As however there is a drop in this valley of only 14 feet in the 6,000 feet above the fall it is fairly certain that a dam of any size would flood valuable land in the larger valley. If however a power scheme were developed at this excellent waterfall the problem of large storage could be solved quite simply by utilizing a small proportion of the total power in driving large low-lift centrifugal pumps, to keep the upper valley clear, an earthen embankment being constructed at the neck across the smaller valley. Thus, suppose the main dam to be 30 feet high, giving a water level at the neck 16 feet above the stream level. Then the pumping through the embankment at this point would only require about one-thirtieth of the total power available, based on the relative main and pumping "heads." If the nala were liable to violent floods such a scheme might prove impracticable, but this is not the case. The total catchment area is perhaps 150 miles, with an annual rainfall of about 40 inches, of which 97 per cent. falls between April and November. The great flat spongy valley involves a very slow run-off, and considerable evaporation from its swamps, so that the stream (and examination confirms this) is comparatively even in its discharge. It may be hazarded to average not less than about 150 cusecs throughout the year. Before the amount of storage which can be obtained, and the steady flow which can thus be depended on, can be determined, further information is required regarding the actual rainfall and run-off and the capacity of dams of different height with their corresponding embankments. It is also necessary to survey both banks for the best location for a channel from the head of the fall to the point where the pipes would be carried down to the power station; to survey the most practicable pipe line in each case; and to determine from these which bank should be used and where the power station will be located.

The minimum flow will give some 3,800 e. h. p. continuously, which would allow a plant of about 8,000 e. h. p. on ordinary 12 hour working. At the lowest estimate storage coupled with the much greater normal discharge would give at least half as much again. The scheme appears to be a first class one of about 10,000 e. h. p., which would not be expensive to construct, and it should be fully investigated. There is, however, no likelihood of the power being required in the district unless an industry is founded on the power. The Kalaw railway will soon be extended up to the site, and there is considerable traffic awaiting it. The site was examined by Messrs. Barlow and Meares and subsequently discharges and a preliminary survey were carried out by Mr. F. A. Clift, Executive Engineer, Taungyi. (Map 93 D. 10,14.)

Heinza Chaung.—Tavoy. There are falls "of great height and volume" north-east of Yebyu.

Indawgyi Lake.—This has an area of some 40 square miles, and a low dam would impound an immense volume of water. There is a perennial flow from it down the Indaw Chaung, and regulation would be easy. The available fall is not known; nor is the catchment area and rainfall. (Map 92 C. 7,8.)

Irrawaddy River.—Reference has already been made to the British Water Power Committee's remarks on this catchment. Having seen their figures Mr. T. Hare, Executive Engineer, Public Works Department, drew up a scheme for harnessing the river at the defile by damming it below Sinbu. He proposed to divert the river by a channel to the east, *via* the Nainsang and Mole Rivers, a distance of 45 miles. The scheme would be both expensive and difficult to construct, with this diversion, a large flooded area with the submergence of many villages, new roads required, etc. The floods rise 60 to 90 feet in the defile so that it is improbable that with any reasonable dam a head of more than 50 feet could be obtained. The minimum discharge is not known. Above Myiti-

kina there is doubtless great power available, at a cost which is likely to be prohibitive.

Kaingyi Ye Ta Gon in the Tawnglet circle of Monglong sub-State, Hsipaw has been mentioned. (Map 93, B, 7)

Kaladan River.—Akyab. The upper reaches stated to have possibilities. The catchment area is over 3,000 square miles at Kaladan, where the Mi comes in, but the elevation there is unknown. Rainfall 100 inches, 97 per cent. falling in 8 months. (Map 84 B. C, and G. unsurveyed.)

Kalonta Gorge.—See Tavoy.

Kelaung River.—Mandalay district. Said to be worth reconnaissance near Wetwun.

Kin Chaung River, tributary of Shweli, near Mogok. Above the junction with Bernard Myo (q. v.) this has a good catchment of about 1,200 square miles, including the Bernard Myo and Konwet, and a good perennial discharge, with several places said to have a good drop also. Below the junction there is also a likely site. Where the Kin Chaung crosses the road the R. L. is about 500 feet whereas 3 miles further up it appears to be about 1,100 feet. Rainfall about 100 inches, 96 per cent. falling between May and November. (Map 93 B. 5.)

Konwet River (near Mogok) is believed to have a perennial flow of 20 cusecs and a drop of 2,000 feet in a few miles. From the map the site appears good, but the catchment is not known. If the streams at Mongmit make it up it is about 400 square miles, but this has already been included (rightly or wrongly) in the Kin Chaung. The river joins the Muik, (?) a tributary of the Shweli. Probably good for 3,000 e.h.p. Rainfall about 100 inches, of which 96 per cent. falls between May and November. (Map 93 A. near square 12.)

Kun Chaung, Toungoo. Said to have possibilities. Its tributary, the Sinmakadin has falls which are believed to be promising.

Kyan kpyu Chaung.—See Tavoy.

Laimaw River.—Or Balu Chaung enters Imle Lake near Indemze and is said to have a good discharge and many rapids about 7 to 10 miles from the south-west end of the Lake. Considered capable of 2,000 e.h.p. Rainfall 40 to 50 inches of which 97 per cent. falls between April and November. The catchment area appears to be about 370 square miles up to the valley, but the Atlas sheets show some of the streams apparently flowing both ways! For this reason many of the catchments may have been wrongly estimated. They can be checked by larger scale maps later on. (Map 93 D. 14, 15.)

Lampar River.—Said to be perennial with a large fall.

Lenge Chaung, Meiktila, Div. Minimum discharge at Pweya Se was 2.75 cusecs on 29th April 1919.

Lenya River, below Mergui; said to have power sites. Rainfall about 160 inches, lasting from April to November, with a catchment at Lenya of some 700 square miles. (Map 96 I 15, 16.)

Madaya River, or Nam Pai, tributary of Irrawaddy. This has a minimum discharge in the hot weather of about 400 cusecs near Mandalay. Higher up, some 10 miles, the river is said to have a good slope, so power should be found. Near Mogok it is also said to have a good discharge and rapid fall. Rainfall between zones 40 and 100 inches, practically all falling between May and November. The catchment area at Gwe Kyaung is about 1,200 square miles, but the altitude there is not known. The minimum discharge in 1919 was 350 cusecs on the 19th May at the headworks of the Mandalay Canal. (Map 93 B.)

Magyi Chaung.—Tributary of Madaya, 45 miles from Mandalay; this and other similar streams near had a fair discharge (about 50 cusecs) in March and possibly several could be run together for a fall. No details. Site not identified. Elsewhere the Chaung Magyi is identified with the Madaya (q. v.)

Man River, tributary of Irrawaddy. This is said to have some possibilities below Ngape but is very little known. It is near the Mon River and has less discharge; and may even dry up at times. A discharge taken near Payagyi village, 12 miles above Aingma weir, showed 40 cusecs on April 7th 1919. A fall may be got by tunnelling through the watershed, it is believed. Very unhealthy till January and of doubtful value. Rainfall 50 inches or more over a catchment at Ngape of about 250 square miles, (Map 84 L 8 and 12.)

Mandalay District (see also Anisakan River). From the headworks of the Mandalay canal the Yetagon waterfall, flowing into the Madaya, can be seen some 6 miles off to the N. N. W.; 40 miles from Mandalay and 35 from Maymyo. There is a drop of 1,700 feet, and Mr. Scott, Executive Engineer, found a discharge on the 9th March 1919 of $14\frac{1}{2}$ cusecs. The minimum, on 12th May, was 5 cusecs. The catchment is only about 8 square miles. Reservoir possibilities are poor, as the limestone is very fissured, but a site north of Yonbin village might carry 100 million cubic feet. The site appears good for 2,000 e.h.p. Rainfall about 40 inches, of which 97 per cent. falls between April and November. (Map 93-B 2, 3, 6, 7.)

Mandalay District.—There is said to be a perennial stream with a large fall some 35 miles north east of the town, not far from Mogok. No details, but probably refers to Madaya or Magyi Ch. (q. v.).

Manipur River, tributary of Myittha. Subject to high floods, and has a quick slope, but in very wild country and unlikely to offer much steady power, though stated to be worth 4,000 e.h.p. Rainfall 50 to 100 inches, over a catchment of some 4,000 square miles, including the considerable Loktak Lake, near Imphal. (Map 84 E. & F., unsurveyed.)

Menyan River.—This has not been identified, but is said to have a perennial discharge and a good fall 20 miles from the Irrawaddy.

Mindon Chaung (or Mu) River.—Tributary of Irrawaddy, Thayetmayo District. The upper reaches of this river are stated to be worth examination, and good for 2,000 e.h.p. The lower parts are navigable and useless for power. The rainfall varies from 40 inches up to 100 near the watershed, of which 95 per cent. falls between May and November. The catchment area above Mindon is about 600 square miles. Discharges are available from 1893. The minimum on record is 95 cusecs at the Shwebo Canal. (Map 85 I.)

Minpaw.—A 30,000 horse power scheme was mentioned, working on a 280 foot fall, but it has not been identified so far.

Mon River.—Tributary of Irrawaddy, said to be perhaps worth prospecting as discharge is generally good (seldom below 500 cusecs) and slope quick in upper reaches. Very little information available, as the region is inaccessible and unhealthy until January, but a possible 6,000 e.h.p. was suggested. From Kyion downwards, above the canal headworks, it is believed that excellent reservoir sites can be found to carry over the low water period, and from 2,000 to 10,000 e.h.p. can be obtained. A discharge taken at the end of April 1919, gave 279 cusecs above the Dwe junction and on the 5th May 450 cusecs at the canal headworks, Mezali, 40 miles lower down. Regular readings are taken here. Some of the tributary streams look favourable on the map, especially one which joins near Dwe. This tributary joins the river above Paiksok, and carried 48 cusecs at the end of April 1919. The total catchment here is about 800 square miles. Rainfall in upper reaches 50 to 75 inches. (Map 84 L 2, 3, 7).

Monghang River.—Southern Shan States. A natural limestone tunnel exists here with a fall of several hundred feet. It is about 150 miles south east of Taungyi, a cart road existing as far as Mongnai. River not identified, but probably on map 94 I.

Moulmein to Pegu.—The hills near the railway are said to offer possibilities by running through the watershed from reservoirs on the east to the coast side. The rock is good. Rainfall probably over 150 inches, mostly falling in May to October. Detailed examination of maps will be necessary. (Map 94 C G. H.)

Mu River.—See Mindon Chaung.

Myittha River.—Tributary of Chindwin. Near its junction with the Chindwin River this (which includes the Manipur River) is said to have a series of rapids and a large discharge, but it is of doubtful value except in upper reaches. Probably 3,000 e.h.p. could be obtained. The lower reaches are at times navigable. Rainfall 40 to 75 over very large catchment (of the order of 10,000 square miles), but concentrated into about 6 months (Map 84 I, mostly unsurveyed.)

Myitnge River.—Tributary of Irrawaddy. There are falls above Theebaw which could be increased, coupled with good perennial flow. This river is said to be "full of power sites." The discharge in March was about 10,000 cusecs

in the reaches near the Mandalay-Maymyo Road. Some 25 miles further up there is said to be a promising "hair-pin" bend. The floods rise about 30 feet and a dam would be most difficult to construct, but a tunnel across the bend appears simple. (This is similar to the Sutlej Scheme.) The tributaries of this river are worth gauging and examining, (See Nam Tu, Namma and Nam Laung below.) The rainfall over the whole catchment of some 8,000 square miles at the junction of the tributaries named is probably about 40 inches. Minimum discharge in 1919 was 6,360 cusecs on 16th May at Kimbet. (Map 93 B and F.)

Nandaungya Chaung; see Anisakan falls.

Nam Et River.—Tributary of the Nam Laung and the Myitnge, 60 miles east of Kyaukse, said to have 1,000 feet fall and a large discharge. By making a dam or tunnel the river, it is said, could be diverted across to the Zawgyi, through a hill, to give some 6,000 e. h. p. Rainfall about 40 inches of which 94% falls between May and November. The catchment area at latitude 21° 35', which is probably near the place referred to, is about 1,000 sq. miles. (Map 93 C 10, 14 with G 1, 2).

Nam Kaw, falling into the Salween below Na Hang. (Map 93 J, 11.)

Namkwe Lake, north of Yamethin. There is a project here but no details are known. The Executive Engineer, Meiktila Division, proposes to examine it.

Nam Lan River.—Northern Shan States. Said to be worth reconnaissance between Namtu and Mongtung.

Nam Laung River.—Tributary of Myitnge. There is said to be a natural bridge and a 15-foot drop about 12 miles above the junction with the Nam Tu, but the prospects of power do not seem good. The Nam Et flows in above this (q. v.). Rainfall about 40 inches. The catchment at the junction mentioned is however about 3,000 sq. miles. (Map 93 F 4 and 8).

Namma River.—This joins the Namtu (q. v.) below Mansan Falls, and some 12 miles from the junction there is said to be a site with a fall of 200 feet and a minimum flow of about 600 cusecs, equivalent to 11,000 e. h. p. There is also a possibility of making a large reservoir a little distance above the natural bridge that gives the drop in this river. The rock however is limestone and may be fissured. A further site 20 miles due west of Hsipaw was mentioned. Coal (poor quality) is found near this river and there is also iron ore. Rainfall probably 40 inches. The catchment area at Namma is about 400 sq. miles. (Map 93 F 10 and 14 and J 2.) The Nam Hawm or Namhsawn tributary on map 93 J, 5, above the junction with the Namma, is also mentioned.

Nampai River.—See Madaya River.

Namparga River.—(Tributary of Chindwin River). Said to have a fair discharge with quick slopes. The rock is largely sandstone with some shale. Not identified but stated to be good for 2,000 e. h. p.

Nam Pawn River.—Tributary of Salween. Navigable up to latitude 19°, but has a large perennial discharge and probably has rapids in upper reaches. There are falls between Hsataung and Karenni, but not of great height. Rainfall 40 to 50 inches. The catchment area above latitude 20° is some 1,600 sq. miles. (Map 93 G. H.)

Nam Tang (or Teng) River.—This is a tributary of the Salween and 70 miles east or north-east of Taungyi it is said to have large falls at about 97° 45' by 20° 20' to 20° 55'. There is a "good discharge" and the road from Taungyi passes near by. Rainfall 40 to 50 inches of which 97% falls between April and November. The catchment area above latitude 20° is about 2,500 sq. miles. (Map 93 H 11, 15).

Nam Tay River.—Tributary of Salween. Said to have good discharge and high falls. No details. Site not identified. Possibly the Nam Tang (q. v.).

Nam Tu River.—Tributary of Myitngye. Already being developed at the Man San Falls (see Table 4). There are many rapids all along this river, which has a large perennial discharge, but it is unlikely that any other equally favourable site exists. Immediately below Nam Tu the low water discharge is estimated as 15,000 cusecs and a fair head may be obtainable. There is also a possible site 12 or 15 miles above the railway bridge over the river, accessible from Hsipaw. Near Hsipaw where the Nampu (?) Chaung joins the Namtu there are said to be good possibilities and power may be wanted. At Makyeng some 8½ miles above Namtu town, it is said that 1,500 h. p. can

be developed, but the falls are mostly small and would be expensive to combine. Rainfall about 40 inches with a catchment area, at the junction with the Namtu, of about 5,000 sq. miles. (Map 93 B, E and F).

Nyaunggho Stream.—Thaledan Forest Reserve. Said to have possibilities 28 miles from Padaung or 40 from the Irrawaddy west bank, opposite Prome. Discharge not great in the hot weather, but a drop of 1,000 feet or more available.

Pang River.—Tributary of Salween, Southern Shan States. In about 6 miles, at a point 2 miles south of the Taungyi-Kengtung road, there is a fall of some 600 feet in a series of cascades. The stream is of considerable volume. (Map 93 H).

Panlaung River.—Tributary of Myitnge, above Myittha, Kyaukse, is said to be well worth prospecting, as there is a natural reservoir site of some 5 acres extent; the rock however is mostly limestone, and fissured. Discharges of 400 cusecs and a 900-foot fall were mentioned. Position not identified, but probably good for 5,000 e. h. p. or more. It is believed to have been surveyed already either by Government or the Burma Railways, Limited. The catchment cannot be traced on the Atlas sheets, but includes that of the Zawgyi (q. v.) and is probably over 4,000 sq. miles at Kyaukse. Rainfall 30 to 40 inches. Discharges have been taken from 1909 onwards. The average flow between December and May varied fairly evenly between 1,100 and 400 cusecs. A flow of 500 cusecs can generally be depended upon. (Map 93 C).

Panlang River.—Tributary of Sittang; also said to be worth examination. It is apparently near the previous entry, but the site has not been identified as yet. (Map 93 C?).

Papun-Dagwin road.—Near Yedagon hill stream has a discharge of about 20 cusecs in February, and may have a site giving 1,000 feet head.

Pathechaung River.—Near Toungoo. May have a little power, sufficient for local needs (200 e. h. p.?) But there are no reservoir sites and dry weather discharge is small. The river however is constantly mentioned as worth investigation. Thandaung beyond here has a rainfall of 200 to 250 inches, between May and November, but practically none in other months, and the catchment is quite small. (Map 94 A 12).

Paungdaw Chaung.—See Tavoy.

Payagale Ch. Pegu Division. Minimum discharge at mile 12-6 was $\frac{1}{2}$ cusec on 3rd April 1919.

Pin River.—Tributary of Irrawaddy, flowing from Popa Mount, an old and isolated volcano (4,980 feet) seen from the Irrawaddy from Pakokko to Yenangyaung. The catchment area at Magyigon is about 40 sq. miles only; elevation here unknown. There are numerous springs on the hill side which it is believed could be collected to give a good discharge at a fair altitude above the flat plain. Rainfall 30 to 50 inches of which 96% falls between May and November. (Map 84 O 4, 8; P 2, 6).

Pinkan River.—This is perhaps the same as the Pin; it has "a perennial discharge and a good fall 20 miles by cart from the Irrawaddy."

Pyu River.—Toungoo. Said to have possibilities.

Pyinpongyi Ch. Pegu Division. Minimum discharge 0.6 cusec on 3rd April 1919, at mile 18-4.

Salin River.—Tributary of Irrawaddy. This is said to be of no use except for the tributary which runs from Kodakham towards Laungshe, which is worth reconnaissance. There is no definite information, but it is stated to be worth 1,000 e. h. p. Mount Victoria (10,085 feet) appears to feed this and the rainfall is in the 50 to 100 inches zones. The catchment area of the tributary in question is about 400 sq. miles. A discharge taken in the main stream near Minyin village, 20 miles above the headworks of the Myaungmadaw Canal, in the dry season of 1919, showed 4 cusecs only, with an additional $\frac{1}{2}$ cusec from the Mwe. (Map 84 K 4 and L 5).

Saingdin Creek.—Akyab District. There is a mainfall of 47 feet and others making up 66 feet below Buthidaung and 8 miles from the Mayu River, all in a length of 1,000 feet. Minimum discharge about 1,000 cusecs and maximum 100,000.

Salween River.—The Hatgyi Rapids about 100 miles south east of Taungyi and 100 miles north of Moulmein, some 40 miles above entry of the Yunzalin

River, and below the mouth of the Thaungin R., are believed to be capable of great development; the possibility of locking the river and making it navigable for boats for several hundred miles further up was also raised. A fall of 70 to 300 feet is believed to be obtainable (reports are conflicting), and the minimum discharge is stated to be over 1,000 cusecs. Another report says there is a triple fall of 20 feet in 300 feet length, with a discharge generally of a million cusecs—presumably this is in the rains. The flood waters however rise about 90 feet. Lime is obtainable. There is a cart road to Mongnai, and pack transport must be employed beyond. May be considered worth at least 6,000 e. h. p., but would be very expensive to develop. The catchment area is enormous and covers the whole gamut of rainfall; and there are said to be more many rapids higher up. Above the mouth of the Yunzalin there are said to be many sites, especially 8 or 10 miles above Kammanaung, which is accessible by boat and elephant. Here a canal a few miles long, which the banks would allow to be constructed, would give a moderate head. (Map 94 G, square not known, but probably unsurveyed).

Sawchaung.—Yaw dist. The gorge 4 miles above Saw and 75 miles from Seikpyu can, it is said, be dammed to a height of 80 or 100 feet. There is a good flow in the dry weather.

Shweli River.—Tributary of Irrawaddy. Said to have a discharge of 4,000 cusecs in April, with a drop of 1,000 feet in 5 miles, (highest fall at one spot 34 feet) 20 miles below the large swamp or lake near Selan (R. L. 2,400 feet). The lake land is too richly cultivated and valuable to be dammed. There is granite rock in the district, and a good reservoir site exists higher up the river. May be worth from 300,000 e.h.p. upwards. Rainfall 50 to 60 inches, over a catchment at this place of 2,500 or more sq. miles. (Map 93 E 6, 9 and 13.)

The upper reaches below Namkhan and the Kyanktake rapids are also mentioned as well at the Nam Chit falls on a tributary, said to be 300 feet high.

Sin Bo Sin Ma falls; See Tavoy.

Sittang River.—There is said to be a good power site on the head waters (?) of this river north of Pyinmana near Yezin village and near Taungnyo. Further north, 20 miles due east of Yamethin, there is said to be a fall of about 1,200 feet, with a minimum discharge of about 50 cusecs, which can be supplemented by storage with considerable bunds. The possibility of tunnelling through to another catchment was mentioned at this site, in which case the water would be useful for irrigation. The formation is limestone, but high mud banks have been used successfully for storage in olden days. The site is probably worth 5,000 e. h. p. Rainfall 40 to 50 inches nearly all between May and November. Catchment area not determinable from Atlas sheets. (Map 94 A 1, 5; 93 D 3, 4).

The tributaries of this river on R. bank are also said to be worth examination, having good perennial discharges up to 100 cusecs in some cases. (Same maps).

Tabak Hla River.—Where the Lwema joins this stream, 2 miles east of Namlang, there is a rocky gorge with a drop of about 150 feet, a good perennial discharge, and a possible reservoir site. Rainfall and catchment area not known. (Map 92 G 12 ?).

Talaingya Chaung; see Tavoy.

Tandin Falls.—North Arakan. There is an ample discharge, used for timber flotation, and a fall of 60 feet. The passing down of the timber is not a matter of difficulty, and the river is believed well worth examination.

Taping River.—This joins the Nam Ti which runs into the left bank of Irrawaddy near Bhamo. About 31 miles up the river from the junction, near the road suspension bridge, where the catchment area is about 450 or 500 sq. miles, there is believed to be a cold weather discharge of 500 cusecs (minimum not known) and a drop of 500 feet in 5 miles. The site is worth examination, and may be worth 10,000 e. h. p. or more. The Tunhong Gorge beyond Kalechet has also been mentioned. Rainfall not known. (Map 92 H 11, 14; latter unsurveyed).

Taungdwin Chaung.—Mingin, Myittha Division. This is stated to be worth reconnaissance, though somewhat remote. Site not identified.

Tavoy District.—One power site has been developed, see Table 2. It is believed that many more, including good reservoir sites, are to be found; but the country has been little prospected for power. Rainfall 150 to 200 inches of which 96 % falls between May and October. Mr. Raikes reports that gaugings will be taken in the following;

Paungdaw Chaung, which has a fall of 600 feet at one point.

Ban Chaung (130 cusecs, 29th March 1919.)

Kalonta gorge (19 cusecs, 19th April 1919).

Kyankpyu Chaung falls.

Sin Bo Sin Ma falls.

Talaing-Ya Chaung.

No falls have been determined as yet, but the first on the list is said to be the most favourable. (Maps 95 J & K).

Teng River.—*Southern Shan States.* (*Nam Teng?*). Near the Pang (q. v.). This feeder of the Salween is said to have a large volume and a fall of 365 feet some 2 marches from the Tang falls (Map 93 H?).

Thaukyegat River. Tributary of Sittang, 11 miles from Toungoo. This river has a very large catchment area and before entering the plains is said to have a large discharge, while falls of about 250 feet in 7 miles can be obtained near here, where the catchment area is over 400 sq. miles. It probably falls very low in the driest seasons. On the northern or main branch a fair reservoir appears possible, holding perhaps 1,000 million cubic feet, from which a short channel would run to the power station. The run-off is said to be fair but not high. Most of the smaller streams have a trickle of water and there are many springs. The southern branch is not likely to be of use unless its discharge can be led round by a channel into the northern branch near the junction. The latter appears good for 6,000 to 12,000 e.h.p. from information received, but further examination is required. Rainfall between 75 and 100 inches, of which 96 % falls between May and October. (Map 94 A 11, 12, 16; B 9, 13).

Tonbo River.—Mandalay. Attention has been called to the upper reaches of this stream.

Ye River.—near Pagyi ($98^{\circ} \text{ X } 15^{\circ} 20'$) has about 150 to 200 inches of rain in the elevated catchment of over 400 sq. miles. (Map 95 I 3, 4).

Yezin Ch., Meiktila Division. Minimum discharge 3.3 cusecs near Yezin on 28th April 1919.

Yetagon Falls.—See Mandalay.

Yunzalin River.—This is said to have a rapid fall of over 3,000 feet to near Papun, but is very inaccessible. Where the road from Papun to Kawluck leaves the river the discharge is said to be about 10,000 cusecs and there is a fall of 1,000 feet in 3 or 4 miles. This site is accessible by elephant from Papun and appears very promising. There are others lower down also.

Zamayi River.—Pegu District. There is a waterfall in forest compartment 91 and the river is believed worth prospecting.

Zami River, running to Moulmein. The higher reaches are said to merit investigation as power may be required for pulping work, already proposed there. (Site not identified).

Zawgyi River.—Tributary of Panlaung and Myitnge. There is a small waterfall of about 10 feet some 4 miles north-east of Lawk Sawk, showing a good discharge in April, which is fairly maintained. There are said to be many other falls, but little is known. A possible site was also mentioned near Myitson, about 20 miles from Kyaukse. From the hills to the plains there is a fall of some 4,000 feet in 20 miles. The water of this river is said to be exceptionally fine for crops. Rainfall probably between 30 and 40 inches. The catchment above Kyaukse is about 2,500 sq. miles. Gaugings have been taken by the Irrigation Department from 1900 onwards, but until 1909 the low readings were unreliable. From 1910 to 1918 the average flow between December and April varied between 515 and 2,200 cusecs with a mean of about 900. Very heavy floods have occasionally occurred. The drop of the bed is generally said to be quite gradual. (Map 93 C 15, 16).

Zingyaik River.—Thaton district. The river is dry for many months, but the waterfall is believed to be worth investigation in case there are reservoir sites above. This is a mining and also a salt district, and power is wanted.

APPENDIX X.

List of Sites in the Central Provinces and Berar.

Aran River.—At Masni, in Magrul Taluk, there is said to be a good site for impounding 5,000 million cubic feet of water with a 90-foot bund 2,600 feet long, having 330 sq. miles of catchment. The submerged land is forest waste land mostly. There is "a good site for utilizing the water with a high fall," which is very indefinite as the layered map shows that the whole district indicated lies between 1,000 and 1,500 feet, so that not more than a 200 foot fall (low medium) is likely. The catchment area at Sangri, probably below the site referred to, is about 300 sq. miles. Investigation is required. Rainfall 30 to 35 inches, mostly concentrated in 5 months, and 85 % between June and September. (Map 55 H 7,11).

Baihar Plateau, Balaghat.—A reconnaissance was made in the hot weather of 1919 and none of the streams had more than a trickle, though villagers stated that the flow continued through the cold weather. Some of the streams appear in the list.

Ban River.—Tributary of Purna, near Wari on the border of the Jalgaon and Akot Taluks. This flows from the Gawilgarh hills, Satpura range, and is said to have a vertical fall of 60 to 70 feet which can be increased. The catchment area is 130 sq. miles, to the west of Narnalla. The stream is "practically" perennial and reservoir sites are said to exist. The rainfall, averaging about 30 inches, is said to be good in these hills even in a year when the monsoon fails in the plains below, but it falls to the extent of about 90 % in the 5 months June to October, and 85% in June to September, so very large storage would be required especially with a view to the necessary carry-over for bad years. (Map 55 C 12,16.)

Bearma River.—Tributary of Ken. A favourable reservoir site with a catchment area of 4,126 sq. miles is reported at Khumergar, Damoh, below the junction with the Sunai (Sonar?) where a flood discharge of 235,000 cusecs has been recorded. The site has not been identified at present. Rainfall about 45 inches, of which 43 inches fall in the monsoon between June and September. (Map 55 M.)

Bina River.—Near Rahatgarh (Saugor). The catchment area is 500 sq. miles and the slope is said to be fairly rapid; about 50 feet a mile (?). Reservoir sites have been located above and below here, and are worth investigation. Rainfall about 40 inches, of which 93 % falls between June and September. Estimated by Mr. Batchelor to be worth some 5,000 e.h.p. or more at each of two sites; but this requires further examination. (Map 55 I 5,6).

Chandra Bhaga.—Close to the Sarpia (q. v.) and the same remarks apply. (Map 55 G 7,11.)

Chargad River.—Tributary of Wardha. A large reservoir could, it is said, be constructed at Udkheir, 9 miles south-west of Morsi, with a catchment area of about 80 sq. miles. Rainfall 35 to 40 inches, nearly all in June to September. No information as to falls. (Map 55 G 15,16).

Chikalda Plateau.—(Melghat). Mr. Batchelor believes that some 2,000 e. h. p. can be obtained here from a reservoir commanding a head of 1,800 feet. The site should be examined further. Catchment not specified. Rainfall 35 to 60 inches; mean at Chikalda itself 67 inches of which 60 inches fall between June and September. (Map 55 G 7.)

Chornai River.—Uprora (Bilaspur). There is said to be a reservoir site with a catchment of 150 sq. miles, and some perennial flow, and a fall of 100 feet is indicated. Estimated by Mr. Batchelor to be worth 8,000 e. h. p. but has not been examined as yet. Rainfall 60 inches, of which 82 % falls between June and September.—(Map 64 J 10.)

Darekasa Waterfall.—Gondia Tehsil. Situated in hilly country near the station of that name on the main line of the Bengal Nagpur Railway. It dries up by the end of the cold weather, so will be useless unless storage can be found. (Map 64 C 11 or 12).

Deo River.—Balaghat district. This rises on the Baihar plateau and flows into the Waingunga, and is said to be worth investigation above Bhanpur,

where the catchment is 120 sq. miles or more. Being near the Naharā and Uskal rivers the conditions are likely to be similar. (Map 64 C 5,6,9.)

Erai River.—Tributary of Wardha, 12 miles north of Chanda. Reservoir sites are indicated, without details. The area does not look particularly promising, though the catchment is about 300 sq. miles, and the rainfall 40 to 50 inches between June and September. There is a known fall of 20 feet on the Mul hills. (Map 55 P. 4, 8.)

Ghisari River.—Near Dhansura, is stated to have a waterfall of several hundred feet, though the stream dwindles down to a few cusecs in the hot weather. Reservoir sites may however be found. (Site not identified.)

Hasdo River.—where it leaves the hills above Chhuri and Korba. Reservoir sites suggested; no details, but there is apparently a rapid fall where the plains are entered. The catchment area is about 2,800 sq. miles at Garaghat, where the 1,000 foot contour crosses, and the rainfall averages 60 inches of which 80 % falls between June and September. (Map 64 J 9, 10.)

Indrawati River.—Chatisgarh State. There is a waterfall of 90 to 100 feet at Chitrakot, and the flow is always substantial. In May 1906 760 cusecs were gauged. The rainfall over the large catchment of about 4,500 sq. miles at the falls is 60 to 75 inches, mostly falling between June and September. On the 29th May, 1919, the discharge was 443 cusecs. There is a possibility of constructing a very large reservoir immediately up stream of the fall, where the country is very flat. Reconnaissance indicated that this might carry 50,000 million cubic feet with a dam of reasonable cost, but the land acquisition would be expensive as much of the area is cultivated. The site appears worth 4,000 e.h.p. without storage and perhaps 12,000 to 15,000 e.h.p. if the storage turns out feasible to the extent named. It is worth full investigation. (Map 65 E 12,16.)

Kanhan River.—An irrigation scheme was prepared involving a reservoir on this river (which the Pench joins higher up) a few miles north of Nagpur, but it fell through. The site may be worth reconsideration for power purposes in combination with irrigation from the tail waters. No details are at present known, except that the site is near the junction with the Waingunga, above the village of Ambhora, and 8 miles south of Bhandara, where any large fall is unlikely. Rainfall over catchment 35 to 40 inches between June and September. (Map 55 O 12.) The catchment at the 2,000 foot contour is 178 sq. miles, increased, before the junction with the Pench, to about 1,200 sq. miles. Four other points on this river between Khapa and the above were also referred to. (Map 55 K 15; O 3,8.)

Mazu River.—Tributary of Wardha. It is stated that reservoirs (of unspecified size) can be constructed north of Destara, Morsi Taluq, having a catchment of 204 sq. miles, but no information is given as to falls. Site not identified but probably on map 55 G.15. Rainfall about 35 inches, mostly in June to September.

Melghat Area.—The possibilities are said to be promising in the Melghat area, where there would be a demand for power from the Tapti and Sipri Rivers and smaller streams mentioned in this list. The rainfall is from 35 to 40 inches up to 60 on the Gawilgarh Hills near Chikalda (q. v.), which fall rapidly from over 3,000 feet to about 1,500 feet. The McKenzie falls are said to be several hundred feet high with a perennial flow; but the site has not been identified.

Mhas River.—A site is named between Waigaon and Hingna, Nelgaon, Buldana, for a small tank of 10 million cubic feet, which is unlikely to be of much use over 9 dry months. It is stated however that the Mun and Panigunga rivers could also be diverted into this reservoir, thus increasing the catchment from 90 to 450 miles, with a rainfall of about 30 inches concentrated in 5 months, and almost in 3 months. The latter streams are "practically perennial." (Map 55 D, square not identified yet.)

Moga River. 12 miles north-east of Ellichpur. It is stated that a reservoir draining 88 square miles may be constructed north of Pala, with "a number of falls higher up." This reservoir is presumably intended to impound the tail waters, as it is useless for power; but without storage there will probably be a dry bed for many months. (Map 55-G 11.)

Munyari (?) north-west of Bilaspur. Information was received of an abandoned irrigation reservoir scheme here, which it was stated might be worth examination for power purposes. (Map 64-J 7 ?).

Marna or Morna River. At Shaikla, 16 miles south of Akola, a reservoir of 80 square miles can, it is said, be constructed by a bund one mile long and 70 feet high. Whether a rainfall averaging about 30 inches over a catchment area of about 110 square miles (taken from the millionth map only) will fill this reservoir and give nearly 7 months' dry weather supply is a matter for further consideration. The river is "practically perennial." (Map. 55-D 15 and H 3).

Nahara River.—Balaghat district. This comes down from the Ghat a few miles east of Charegaon Station, ending in a considerable waterfall (Jhang Gogra fall). A reservoir site was found near the village of Sale, but the 4 inch Forest maps may serve to locate others, as the upper reaches are not well known. With a 5 mile channel from the site mentioned a fall of some 500 feet would be obtainable. The catchment area is about 120 square miles there and the average yield about 12,000 million cubic feet. Rainfall 60 inches, mostly in June to September. The site, allowing for a large carry-over for bad years, is reckoned worth some 9,000 e. h. p. (Map 64-B 4, 8 and C 1).

Nawegaon Tank.—This is situated in a basin surrounded by hills in Sakoli Tehsil, Bhandara District, with a catchment of 23 square miles, and a water spread of 5 square miles. In June 1919 the discharge was about 5 cusecs. It is not known what fall is available. The site is a mile from Dewalgaon on the Gondia-Nagbhir branch of the Bengal Nagpur Railway. (Map 64 D 1).

Nerbudda River.—Discharges have been taken during the dry season of 1919, but have not come to hand as yet. The river is known to have possibilities but they have been little examined except at the falls at Marble Rocks near Jubbulpore; and no details of this scheme have come in. It was proposed however to manufacture cyanamide. (Map 55 M 16).

Ibid.—The Dharighat fall in Nimar District has also been put forward. The actual fall is 50 feet, but it can probably be increased to 100 feet or more, and the flow is "large". This site is in dense forest, 24 miles by road from Bir station on the Great Indian Peninsula Railway. The rock is hard Vindyan sandstone. (Map 55 B 7).

Ibid.—The Baroda Darbar also calls attention to the Khodiar Mati falls on the Nerbudda in Dhari Taluka, which may be the same as above: also to the Mokhadi falls, which have not been identified.

Pench River.—A definite site is indicated near Bhiwagarh, 22 miles directly north of Nagpur, where the catchment is about 1,700 square miles. Other sites are indicated on the river, which requires further examination. The catchment area is 527 square miles where the 2,000 foot contour is met. The discharge between Seoni and Chhindwara was practically nil in May 1919. (Map 55 O; 1, 2, 3, 4, 5, 8).

Mr. Batchelor's Silewani Ghat scheme also brings in this river.

Penganga River.—There is a fall on this perennial river, which forms the boundary between Yeotmal District and Hyderabad, known locally as the Susar Kund. No details are available. The site has not been identified, but is on Map 56, E or I.

Purna River.—The remarks on the Moga River apply here. The falls are above the reservoir.

Sarpin River.—At Wajar, 8 miles north of Ellichpur, Amraoti. A fall of 2,000 feet is said to exist in 10 miles; the catchment area however is given as 44 square miles only, and "with impounding reservoirs along the course of the stream very cheap energy can be obtained." The conditions appear to be the very reverse, but the site should be examined. Rainfall about 35 inches, mostly falling in 4 months. (Map 55 G 7, 11).

Shahmur River.—West of Ellichpur (Amraoti). A reservoir site is indicated by Mr. Batchelor between Tekra and Ambaparti, with a catchment of 12 square miles and a possible fall of 600 feet. A further site between Raipur and Moragarh has been mentioned. Rainfall about 35 inches, mostly between June and September. (Map 55-G 7 and 8).

Silewani Ghat. Mr. E. Batchelor, I.C.S., prepared and published a number of "paper" schemes—such as indeed are most of those in this section of the

present Report—dealing with the Chhindwara area. There is, in the pamphlets issued, a great volume of assumption and no very clear description of the schemes themselves but at the same time attention has been drawn to an area which is well worth technical investigation. Mr. Batchelor's estimate of an available 70,000 kW or say 94,000 e.h.p. must be taken with great reserve. One site of those mentioned was visited by Mr. Barlow who recorded his opinion, as follows:—

“The proposals for Umra Nala tanks are wrong; the catchment area is too small. Run-off will be poor, rainfall is not high, area flooded is A 1 land but probably cheap and the line of the canal from the reservoir to the edge of the ghat runs through undulating country where rock is near the surface. The site is certainly near the ghat, and the drop in the ghat is good; but it is not sudden and a long pipe would be necessary. The Nala is joined by another larger Nala a little way on the far side of the *pacca* road and the Railway, and a proper reconnaissance is required to find a suitable storage site near the Ghats, with a good drop. Nagpur already requires 5,000 h. p. and this will increase if power can be provided cheaply. The project (*i.e.* the whole series of projects) is therefore one of the first that should be investigated. “Again, Mr. Barlow notes “His ideas are good but his figures are unreliable and useless. Some of his proposals are undoubtedly worth further consideration, but no reliance must be placed on his details.” Examination of the maps of the district shows that possible reservoir sites certainly exist; the question of their employment and cost should be further examined.

Briefly the following is an outline of the chain of projects, which can only with difficulty be traced from the printed account. The main power station, one mile North of Khapa, elevation 1,200 feet, on the Kanhan River (Map 55 K 13, S. W. corner), is to be supplied by a long pipe line down the Ghat from Silewani Tola at 2,150 feet. The system is to be fed by a canal from a service reservoir on the Umra Nala, estimated to have a draw-off capacity of 600 million cubic feet, of which the dam is to be one mile North-East of Mau. A second dam immediately above this, up to the 2,200 feet contour, and an Upper Umra Nala reservoir one mile North-East of Palakher feed this. Yet another dam for the Chin Nala reservoir is placed one mile West of Umaria Dalel running up to the 2,200 feet contour, to feed the service reservoir by a canal. On the head of 950 feet gross Mr. Batchelor estimated this group to be capable of giving 1,400 e. h. p. at the high cost of Rs. 1,500 per e. h. p. (say Rs. 2,000 per k. w.), on his assumption of a 30 per cent load factor.

Further North is the Rohna reservoir site, one mile North of Rohna on Map 55 J 16, running up to 2,250 feet, and estimated to contain 3,000 million cubic feet. Mr. Batchelor proposes to canal this water to the Chin Nala reservoir, a distance of 16 miles, so after allowing for the slope of the canal a good deal of this water would not be of any use.

North of this again, a nine mile canal (including a three mile tunnel) would discharge the waters of the proposed Upper Pench reservoir *via* the Kulebehra Nala into the Royna reservoir. The site of the dam across the Pench River is two miles North of Chhinda, at the top of Map 55 J 16, and it is proposed to carry it up to R. L. 2,450 feet. The site is certainly very favourable on the map, and a short dam is estimated by Mr. Batchelor to impound 12,000 million cubic feet. Minor power stations are also proposed below this lake.

Further dams are proposed on the Pench River one mile West of Palatwara up to 2,250 feet (Map 55 J 16), and on the Gunor one mile North-East of Thesagora on the same Map up to 2,350 feet. These, however, though possibly of use for irrigation, would appear to be too low down for feeding the power system.

At first sight it would seem that if the Upper Pench site is good, and if its waters can be led at any reasonable cost to the edge of the Ghat, it would be better to concentrate on this and to omit all the smaller reservoirs except the regulating one, and all the minor power stations.

If Mr. Batchelor's estimates are at all near the truth, the cost of the Upper Pench reservoir and the regulating reservoirs at the Umra Nala, together with the necessary canals, would be in the region of 110 lakhs. The

storage, if correct, would on a 900 feet net head give some 22,500 kilowatt years, allowing of a plant of 45,000 kilowatts on a 50 per cent load factor, making a cost of some Rs. 250 per kilowatt for the hydraulic works, exclusive of the pipe line and power house. This, if attainable, would be a reasonable figure.

Son River.—North east of Langi, above Bijagarh: Indicated, but without details. Reconnaissance required. (Map 64-C 9, 10, 13, 14).

Tan River.—Pendra, Bilaspur. A reservoir site is indicated at an elevation of about 2,000 feet, with a rapid fall of 700 feet, where this river comes into the plains near Marai. The normal rainfall is 50 to 60 inches, concentrated into the months of June to September. The catchment area however is very small, some 15 square miles, and large carry-over would be required. The site may be worth 1,000 e.h.p. or more. (Map 64 F 9, 10, 13, 14).

Tapti River.—This rises in the Aravalli Hills, which it leaves some 25 miles east of Burhampur. The catchment area above here is about 2,000 sq. miles, with a rainfall of about 40 inches and there is a perennial flow. A site for a dam has been indicated but is apparently situated where there would be little or no further fall. The river at Betul was found dry early in June 1919, though it runs until the beginning of the hot weather. A possible site for storage was found, with a series of drops aggregating 100 feet. As the area is favourable further reconnaissance is desirable. (Map 55 C-7, 11, 14, and G 2).

Tawa River.—Said to be worth investigating where it enters the plains at Bagra, near Itarsi, Great Indian Peninsula Railway. The layered atlas sheets indicate that at the junction with the Denwa tributary there is a narrow neck between spurs. The rainfall is 50 to 70 inches in the upper parts of the catchment, mostly falling in June to September. (Map 55, F. 14).

Umra Nala; see Silewani Ghat *supra*. (Map 55 K 13).

Uskal River.—Balaghat District. This is stated to be perennial and to be capable of a fall of 1,000 feet or more, near the village of Udwa, Balaghat junction, presumably below the junction with the Nahara (q. v.) but not so far located on the 1 inch map. The locality has greatly mineral possibilities, and power is certainly likely to be wanted in future. It is stated that some 4,000 continuous e. h. p. at least can be got from the site, and by further raising the proposed dam 17 feet the capacity of the tank can be doubled. A local report on the site exists, and it is still under investigation. The catchment area above the junction with the Nahara is about 130 sq. miles. Rainfall normal about 60 inches during the June to September monsoon. (Map 64 B 4, 8).

Waingunga River.—Small falls are indicated, but no details of any value as yet. Judging from its tributaries the river should be worth further reconnaissance. The catchment area above the 2,000 foot contour is 275 sq. miles; at the 1,000-foot contour it is about 1,800 sq. miles. Rainfall 50 to 60 inches, mostly between June and September. See entry under the Kanhan River also. (Map 64 B. 3, 4 and C. 1).

Wardha River.—Small falls are said to exist near Pulgaon and Mr. Batchelor believes that 1,000 e. h. p. is available. No details are available, but the catchment area is over 2,000 miles here. Rainfall 35 to 40 inches, mostly between June and September. (Map 55 L. 5 and 6).

Canal Falls, Central Provinces.

The Chief Engineer, Irrigation Branch, considers that there is good scope for utilizing the canal falls for pumping to uncommanded areas, especially from the Mahanadi canal, where large areas of well drained *bhata* soils lie out of command. This soil is particularly suitable for growing long-stapled cotton, as recommended by the Cotton Committee. The canal falls are not likely to be of any use for general purposes as they only run a comparatively small number of days in the year. Most of the irrigation is done during the Kharif; rabi irrigation is purely subsidiary. There are 62 canal falls, running from 90 to 120 days.

APPENDIX XI.

List of Sites in Madras.

Aliyar River.—Anamalai Hills (q. v.). There is said to be 2,000 feet of fall, of which 500 feet could easily be utilized, in this river some 40 miles from Coimbatore and 16 from Pollachi. The discharge is believed to vary from about 800 down to 6 cusecs. Further observations will be made. The catchment area is small, but the rainfall varies from 40 to 75 inches over it, well distributed from April to November. Probably worth 2,000 e. h. p. or more. (Map 58 B. 15 and F. 3).

Anamalai Hills.—Messrs. Siemens are interested in the Kayanapardal Falls, Sholujar (Suruli ?) River, near Coimbatore. No details are available. See also Aliyar River. (Map 58 B. and F.).

Bhavani River.—The falls near Thondai, 13 miles above Metupalliam, and 22 miles from Coimbatore are said to be about 50 feet. The catchment above them is about 400 sq. miles. The discharge is believed to vary from over 3,000 down to 40 cusecs. Observations are being made of the dry weather discharge in 1919. The rainfall contours probably give too high a precipitation for this catchment, but there are no stations in it. It may be anywhere between 20 and 75 inches. December to March are dry months. (Map 58 A. 16).

Ibid.—Malabar District. A fall of 2,500 feet in 3 miles is shown on the upper Bhavani, 45 miles from Coimbatore and 21 from Ootacamund. A water level recorder will be installed as gauging cannot be undertaken at this out of the way spot. The catchment area must be very small here, but the above distances meet outside the Bhavani catchment altogether. (Map 58 A. 12).

Cauvery River.—Apart from the existing development (see Table 1) there have been proposals for utilizing the Goat's Leap Fall, the Mekadatu Falls (q. v.), and the Hogenkal Falls (q. v.). The Goat's Leap Fall is 26 miles below Sivasamundram, and no details are available.

Chalakuudi River.—Cochin. This has been investigated by Mr. Forbes, Chief Electrical Engineer, Mysore. He states that the minimum flow is 50 cusecs and storage of 1,000 million cubic feet is proposed. The site is estimated to be good for 25,000 e. h. p. on 577 feet head. (Map 58 B. 11).

Chandravanki River.—Guntur District. The Ettipotata waterfall is near Macherla, and 16 miles from Gurzala. No details are known and the site has not been identified as yet, but the river is presumably one of those flowing into the Kistna from the north. These all appear from the layered map to pass through fairly narrow gorges within 10 miles of the big river, and reservoir sites may exist above. The Superintending Engineer is examining the site and will take dry weather discharges. Rainfall about 30 inches, of which 92% falls between June and November. Catchment area not determined. (Map 56 P.).

Cochin State.—There are believed to be possibilities of considerable magnitude in this State, but no details have been made public. Some 24,000 e. h. p. can, it is understood, be developed, presumably from the Chalakuudi River (q. v.).

Coonoor and Karteri Rivers.—When the Coonoor-Ootacamund section of this hill railway was being built in 1905, the Electrical Adviser to the Government of India drew up a project, at the instance of the Railway Board, for its electrification. The site chosen for power development was on these two rivers, near Runymede, some 3 miles from Coonoor and 12 from Ootacamund. The project was limited to what was then required, and details are given in Table 4. A far greater head than the 1,000 feet proposed, probably up to 3,500 feet, could however be obtained. The minimum discharge in 1905 was 4.3 cusecs for the Coonoor branch and 12 cusecs for the combined streams. Large storage is possible. Further investigation is proceeding. The Karteri River is already employed in its upper reaches for the Government Cordite Factory; see Table 2. The rainfall over the catchment area of some 60 or 70 sq. miles is particularly well distributed. It averages about 60 inches, catching both the south-west and north-east monsoons, and from April to

November the monthly averages are reasonably constant. The worst months are January to March, but they receive about 10 per cent. of the total in average years, or some 2 inches per month. (Map 58 A. 15).

Gundar Valley.—Near Kodaikanal. Attention has been drawn to this valley. The catchment area is very small, about 8 square miles, but the rainfall of 60 inches is well distributed throughout the whole year; even January and February each receive an average of nearly 2 inches. The perennial flow is good and a fall of about 1,000 feet is said to exist. There are also said to be good reservoir sites. (Map 58 F. 7, 8, 11, 12).

Hogenkal Falls.—Cauvery River, Salem and Coimbatore. The utilization of these falls (also called Smoking Rocks Falls) on the River Cauvery, 66 miles above Erode, has long been discussed especially in connection with the Salem iron ore district 40 miles distant, where electrical reduction has been contemplated. Some survey work has been done at the dam site, where the rock is said to be a brittle granite. A head of 46 to 85 feet is available, according to whether Metur reservoir is or is not constructed. The flow of water depends on unsettled irrigation projects, but is likely to be of the order of 550 cusecs minimum, so that some 2,500 e. h. p. at least is available at the site. The maximum flow is about 250,000 cusecs. The power available would be increased to well over 3,500 e. h. p. if certain other projects materialize. The cost has been estimated as about Rs. 570 per h. p. installed or Rs. 760 per kW. The water rights of the river are somewhat complicated as between Madras and Mysore. A survey has been made and cross-sections of the river taken above and below the falls. A site for a low dam is being investigated. (Map 57 H. 12 or 58 E. 9).

Karteri River.—See Coonoor River; also table 2 "Cordite Factory."

Kolakambe water fall.—Nilgiris. This is a neighbour of the Karteri River and has a drop of about 600 feet, but by means of a short tunnel a fall of 1,000 feet could be obtained. The waters of the Karteri could probably be diverted into this stream below the existing power house of the Government Cordite Factory (table 1). The minimum flow is believed to be about 10 cusecs. With a short high dam it is believed that 3,000 e. h. p. might be obtained. (Map 58 A. 11, 12).

Kundah River.—A project for utilizing this most promising river in the Nilgiris, 9 miles from Ootacamund, was sketched out by the Hon'ble Mr. Murray, then Chief Engineer, P. W. D., Madras. It appears well worth further investigation. The catchment area at the Kundah bridge is 65 sq. miles and the minimum discharge recorded in 1918 was 31 cusecs, but by comparison with neighbouring catchment it is believed that the true minimum in a very dry year, such as 1914, would be about 20 cusecs; gaugings are proceeding. There are two good reservoir sites, one in the main river a mile above the junction with the Emerald Valley stream and one in that valley itself, where the minimum flow is estimated to be $4\frac{1}{2}$ cusecs. This latter site has not been fully examined. The mean rainfall is about 80 inches and is extremely well distributed; a run-off of 60 inches is estimated from known data, giving some 1,600 million cubic feet available for storage in the Kundah river site, with an estimated minimum flow of 5.6 cusecs at that point. The site allows some 828 million cubic feet to be stored with a dam of 120 feet. The fall in the neighbourhood is about 3,000 feet of which 2,000 feet are in 2 miles, but it has not been determined whether this could be utilized. The scheme however appears likely to yield some 20,000 e. h. p. or more and is worth thorough investigation. The minimum flow in 1917 was $30\frac{1}{2}$ cusecs and in 1919 24 cusecs; no readings were taken in 1918. (Map 58 A. 11, 12.)

Malabar District.—Said to have great possibilities, with high rainfall and jungle products, such as bamboo for pulp, which may require power. The average rainfall is about 120 inches and is fairly well distributed over April to November, though 70 per cent. of the total fall occurs during the 3 months June to August.

Machkund or Sileru River.—This appears from the Atlas sheets and the $\frac{1}{4}$ inch maps to have great possibilities if levels are favourable, but practically none are given. A fall of 540 feet with a discharge of 104 cusecs in the driest part of May, 1919, has since been reported. The site has not been identified but is on Map 65 J.

Mekadatu Rapids. Cauvery River.—These are 28 miles above Hogenkal falls (q.v.) and 21 miles below Sivasamundram (see Table 1, Cauvery falls). The distance to Salem is 67 miles. The flow is the same as that at Hogenkal falls and the drop is 175 feet. The frontier between British and Mysorean territory runs down the centre of the river, and negotiations are proceeding between Madras and Mysore as to the utilization of the fall. An estimate has been framed by the Chief Electrical Engineer, Mysore. At least 8,500 e.h.p. is continuously available on the 550 cusec minimum. (Map 57, H 8 or 12.)

Nurpurya River.—Nilgiris. This is stated to be worth examination at Cherambadi Village, in the Wynaad, reached *viâ* Gudalur, Devala and Pandalur. The Glenrock Tea Estate is near by. (Map 58 A 7).

Periyar Project.—The history of the proposal to utilize the water of the Great Periyar Lake in Travancore for power purposes would fill a volume and stretch back a generation, and it is sufficient to say that negotiations are still proceeding between Government and Mr. Garrett, a retired Chief Engineer of the Madras Irrigation Department. There is an available fall of about 1,000 feet and a minimum supply of 250 cusecs for 240 consecutive days has been the basis of negotiation. This is equivalent to some 54,000 e.h.p. (Table 4). There is little doubt that, as a rule, power of this order could be generated for a longer period in most years; but as matters stand, it cannot be guaranteed. The construction of a supplementary reservoir above the lake, in the Cardamon Hills, Travancore, would enable 150 cusecs to be given continuously, and this might indirectly benefit industrial India (including this progressive State) greatly, as the manufacture of fertilizers is proposed. For reasons which cannot be discussed here the supplementary project is held up, but it is highly important that a settlement should be arrived at. A suggestion may, however, be hazarded as to the project as it stands. The draw-off level is fixed by the location of the tunnel which carries the supply through the water-shed; and the lowering of this tunnel a few feet, so as to increase the possible draw-off, would be a costly matter. If, however, a power plant is put up, utilizing the full 1,000 feet head, it would be a comparatively simple matter to utilize a fraction of the power to pump additional water from the lake, below the present draw-off to the tunnel level, a suitable intake chamber being constructed for the purpose. Thus, if the total lift were 5 feet not much more than one two-hundredth of the power would be sacrificed and a much longer working period would be possible. (Map 58, G. 2, 3.)

Pykara River.—A project to utilize this river (See Table 4) for the supply of the Ootacamund District (15 miles from the town) was drawn up by Mr. H. P. Gibbs and has been the subject of negotiations between him and the Government of Madras. The lowest gauging recorded on the river at the power site was $9\frac{1}{2}$ cusecs in 1914; gaugings have been resumed since and have varied from $15\frac{1}{2}$ cusecs minimum in 1917 to 19 minimum in 1918. Two falls aggregating practically 900 feet could be combined, but it is believed that 3,000 feet could be obtained by tunnelling through the watershed to the catchment on the north. A storage site exists above the upper fall, but the capacity is not known. It is believed that the scheme is good for at least 2,000 e.h.p. or more continuously. The mean rainfall is about 76 inches and both monsoons affect the catchment area to some extent; from January to March however the average precipitation is very low. The catchment area has not yet been determined. (Map 58, A 10.)

Sandy Nullah.—Five miles from Ootacamund. This small scheme with a minimum flow of 1 cusec and a fall of 1,000 feet is being investigated for local employment; see Table 4.

Sileru River: see Machkand.

Silent Valley.—The District Forest Officer, South Malabar, states that a short dam 200 feet high would form a reservoir 6 miles long, though not of great width. The position is $1\frac{1}{2}$ miles up stream (name of river not given) from the point where the river crosses the forest boundary. The rainfall is at least 150 inches and the catchment "large." The fall available is not stated, but there is a "considerable drop" into the plains of Malabar, South of Mannaghat. The dry season lasts from the middle of January till the end of April. (Map 58 A 8).

Singamputti Scheme.—Madura District. This was mentioned, but the site has not been identified.

Siramalai Hills.—Mr. H. Perry has suggested that a power scheme for the Madura District can be formulated in these hills, situated 20 miles from the town in the Ammayanayakanur Zemindari. The rainfall map shows a mean between 30 and 35 inches in the surrounding plains, but the hills probably receive more; Mr. Perry's estimate, obtained from a Planter, is 65 inches; but there are no true records in the hills. The catchment area proposed is only 8 square miles, and a considerable number of artificial reservoirs is proposed; the fall available is stated to be 1,500 feet. The power available is estimated by Mr. Perry at "6,500 h. p. *per minute*," and the words italicized show that caution must be exercised in accepting his conclusions; see Appendix IV. The project requires to be examined by an expert, and may prove less expensive and more reliable than would appear at first sight; various enquiries were made as to its practicability by persons interested in local industries. (Map 58 J 4).

Siruvani River.—Tributary of Bhavani. A project, first mooted so long ago as 1879, has recently been investigated for utilizing this stream for combined water supply and power to Coimbatore, which is 25 miles distant. By damming up the valley so as to form a lake, and piercing the ridge with a tunnel, there would be an available fall of some 1,200 or 1,300 feet; some of the tail water would then be piped to the town for water supply. The minimum flow of the stream is small ($4\frac{1}{2}$ cusecs) as the catchment area is only $6\frac{3}{4}$ square miles, but as it receives both the south-east and north-west monsoons, with an annual rainfall of 75 inches or more, it is merely a question of storage. From December to March there is not much rain. The proposed dam would hold up from 280 to 450 million cubic feet according to height, from 120 to 140 feet; and with the fairly frequent rainfall replenishment it is believed that the site is good for about 2,500 to 5,000 e. h. p. continuously. (Table 5). The tail waters can be used for irrigation. Investigation is still proceeding. It is understood however that expert geological opinion condemns the dam foundation, and if this is so the scheme cannot materialize. The neighbouring Kundah River scheme is more promising, though the Siruvani can still be used for water supply. (Map 58 A 12, 16).

Suruli River.—See Anamalai Hills.

Tambrapani River.—The Paponasam falls, 22 miles from Tinnevely and 54 from Tuticorin, are 250 feet high. The river is already utilized by Messrs. Harvey Brothers for their mills at Ambasamundram. Gaugings have been made in connection with an irrigation reservoir above the falls and work will proceed. (Map 58 H 6, partly unsurveyed).

Canal Falls, Madras.

The following falls, of which the exact positions are recorded but not printed here, are capable of utilization for power on a small scale. Nos. 1 to 12 are on Map 94 and the rest on Map 95. It is proposed to use No. 17 for pumping from the Kistna River to irrigate 10,000 acres. The remainder are not required either for sub-soil pumping or for pumping to uncommanded areas. The power aggregates about 3,300 e.h.p.

Serial No.	Canal.	Position.	Fall in feet.	Minimum flow except at closure.	Working period.
<i>Godavari Eastern Delta.</i>					
1	Cocanada Canal . . .	Medapadu lock weir . . .	10.0	373	11 months.
2	" " . . .	Tossipudy Lock . . .	6.75	268	"
3	" " . . .	Chintapally Lock . . .	8.5	108	"
4	Bank " . . .	Kulla Lock . . .	8.5	101	"
5	Coringa " . . .	Vella Lock . . .	8.25	91	"
<i>Godavari Central Delta.</i>					
6	Gannavaram Canal . . .	Gopalpur Lock . . .	4.80	425	11 months.
7	" " . . .	Mondepulanka Lock . . .	5.58	287	"
8	Bank " . . .	Wadapalem Lock . . .	5.25	414	"
9	Amalapur " . . .	Palivela Lock . . .	4.16	407	"
<i>Godavari Western Delta.</i>					
10	Bank Canal . . .	Siddhantam Lock . . .	9 to 12 ft.	100	11 months.
<i>Kistna Eastern Delta.</i>					
11	Ryves Canal . . .	Komatigunta weir . . .	6.84	1350	9½ to 10 months.
12	Bandar " . . .	Kankipad Lock . . .	4.25	481	"
13	" " . . .	Veeranki Lock . . .	10.41	224	"
14	Bantumilli " . . .	Cowtaram Lock . . .	5.60	316	"
<i>Kistna Western Delta.</i>					
15	Bank Canal . . .	Kollur Lock . . .	5.54	330	9½ to 10 months.
16	Commanur " . . .	Kollimerla Lock . . .	5.60	324	"
17	Head of Commanur Canal	Duggirala Lock . . .	7	200	...

APPENDIX XII.

Sites in North-West Frontier Province.

Indus River.—This is not considered likely to be capable of development, at any rate economic development, in the Himalayan area; the proposed Sukkur barrage (Bombay Presidency) may or may not be able to supply power. It is early to speak of this until the project materializes, but the possibility of high level pumping to canals, should it be required, may be borne in mind.

Kunhar River.—This joins the Jhelum not far from the Abbottabad-Kashmir road and had many rapids with a large perennial flow. As however the district is within easy transmission reach of the Kashmir Darbar's power station at Mohora on the Jhelum (table 2), where much surplus power is already installed, it is unlikely that any other large scheme will be required for the present. (Map 43, F 7).

Sinan River, trib. of Indus.—This flows in from north of Mansehra, and at the time of the Boer War a small plant was erected on one of its tributaries to supply the prisoner's camp. It was subsequently dismantled. It is probable however that sites exist in the main stream, which has not been prospected. (Map 43, F 3).

Canal falls in N. W. F. P.

Upper Swat Canal.—Soon after leaving the headworks this runs through the Malakhand tunnel and then, on exit, down a steep river bed, which is pitched. At Dargai the right and left bank canals take off. The discharge of the canal is 2,200 down to 1,000 cusecs, and the drop available below the tunnel is about 230 feet, giving a minimum power of 20,000 e. h. p. Mr. Sangster, who was in charge of the works, and Mr. Walton, his assistant, read papers on the subject before the Simla Engineering Conference; and Captain (now Lt.-Colonel) Battye proposed the utilization of the falls for the manufacture of nitrates, in a paper read before the Punjab Engineering Congress. The district however is a wild one. Constant power could be obtained by tailing into the river below the power house instead of into the canal as proposed by Mr. Sangster. The canal has to be closed for 10 days every alternate year to provide local irrigation in the rains on the banks lower down the river. Riparian rights necessitate this. Otherwise the canal could probably be run constantly.

Upper Swat Canal.—Branches. By utilizing the existing falls these have considerable power available; there are frequently groups which will permit of 30 to 50 feet drop with a minimum discharge of several hundred cusecs during about 286 days in the year. Unless required for irrigation pumping however there is not likely to be much demand for power.

Lower Swat Canal.—There are no falls suitable for power here, but near the head works power is now generated for the works by dropping the water about 50 feet down into the river area, where there are small canals that require feeding. The site could be utilized later. There is also another small scheme near the tail of one of the distributaries, for developing power for pumping water for a new grass farm. Elsewhere no pumping is required in this district.

Cabul River Canal.—A scheme has been considered for running water from one branch to another, near Peshawar, giving a 50 foot drop.

APPENDIX XIII.

List of Sites, Punjab.

Baspa River, trib. of Sutlej. At Raturing gorge this pours over a series of cataracts below Sangla, with a drop of about 500 feet in half a mile. It is believed to be a good site, though remote. (Map 53 I, 7.)

Beas River.—This has not, so far as is known, been prospected for power. Between its rise at the Rohtang Pass in Kulu and the plains there are however continual rapids, during which the descent amounts to several thousand feet. Whether there is any concentration of falls sufficient to allow of economic development is not known. Several of the larger snow fed tributaries in Kulu, especially the Parbatti and the two rivers flowing in at Largi, have also great potential power; but they are used for extensive timber transport up till the monsoon, so it would perhaps be impossible to divert the water from the stream without interfering with forestry. The catchment area is 5,700 sq. miles and the average rainfall over it is 62.5 inches. The maximum flood at Naushera is 325,000 cusecs and the minimum recorded discharge 2,600. (Map 53 A 1, 5, 9, 13, 14 and B 2).

Chenab River. (Kashmir).—A project has been proposed for utilizing this river at Riasi, where 30,000 e. h. p. can, it is said, be developed. The catchment area is 12,000 sq. miles, of which half is in the exterior Himalayas, and the average rainfall is 41.7 and 28.7 in the exterior and interior divisions. The maximum observed flood carried some 600,000 cusecs and the minimum recorded discharge is 3,884 at Marala. (Map 43 K 16).

Giri River.—The upper reaches of this perennial river were prospected about 1900 for power for Simla, but the Nauti Khad was found preferable. There are probably good sites for power lower down, but they are not recorded. The rainfall is from 50 to 75 inches, and is well distributed except for October to December, which are dry months. Much of the winter rain falls as snow in the upper areas, thus tending to equalize the discharges. The catchment area is about 600 sq. miles at the junction a few miles from Solon. (Map 53 F 6, 10).

Haro River, near Hasan Abdul, Attock. Enquiries have been made regarding this river and the Jablat (or Chablat) in the same district, and discharges were asked for. There is said to be a fall of 50 feet and a good perennial discharge. Rainfall 25 to 40 inches. (Map 43 C. 5, 9, 13).

Indus River.—(See also entry under Bombay). The catchment areas above Kalabagh amount to 50,400 sq. miles in the exterior Himalayas and 63,000 in the interior range, with average rainfalls of about 26.6 and 7.6 inches respectively. The maximum recorded flood discharge at Kalabagh is 1,000,000 cusecs and the lowest observed flow 18,870. The bed here is narrow and if a 100 foot dam could be constructed the *minimum* power would be about 170,000 e. h. p. Below the bed widens out greatly, so the flood afflux would be small.

Jablat River.—See Haro River.

Jumna River.—(See also entry under the United Provinces). The catchment area above Tajawala is 4,400 sq. miles with an average rainfall of 73 inches. The maximum recorded flood carried about 273,000 cusecs and the lowest observed flow was 2,195 at that place.

Jhelum River, (Kashmir).—Already partly developed at Mohora (Table 2) but further power can certainly be obtained. The flume line of the existing plant is large enough for 4 times the power now installed. (Map 43 J 4). Captain (now Lieut.-Colonel) Battye, R. E., in a paper read before the Punjab Engineering Congress, 1914, suggested using this river for power at Rasul, at the head of the Lower Jhelum Canal. A flow of 4,500 cusecs and a head of 80 feet were stated to be obtainable, giving 33,000 e. h. p. (See Table 2). The catchment areas in the exterior and interior Himalayas are 7,000 and 8,000 sq. miles respectively, with average rainfalls of 39.5 and 46.2 inches. The maximum flood at Rasul carried about 500,000 cusecs and the minimum recorded discharge is 4,500 cusecs.

Kishenganga River, tributary of Jhelum (Kashmir).—No information is available, but the catchment area is certainly over 2,000 sq. miles at the junction with the main river, and it is snow fed. (Map 43 F 11, 14, 15).

Kunhar River, tributary of Jhelum.—No information is available, but the catchment area is about 1,000 sq. miles at the main junction, and the river is snow fed. (Map 43 F 6, 7, 9, 10).

Mogri River.—Rampur Bashahr State. The Chief Wazir of this State believes that a fall of 600 feet or more could be obtained in a mile or two of channel in this river, which is snow fed and has a dry weather discharge sufficient to drive about 10 of the local water mills—or say 30 to 40 cusecs. The stream is probably worth 2000 e.h.p. or more. (Map 53, E 11, 15).

Punch River, tributary of Jhelum, (Kashmir).—This appears to be worth examination near Kotli where the catchment is about 1,400 sq. miles; but no information exists regarding the river. It will be snow fed during at least the early part of the hot weather, as it rises in the Gulmarg snows. (Map 43 G 14, 15).

Bavi River.—This has not been prospected in the hills, but certainly has considerable possibilities. Where the Upper Bari Doab Canal takes off near Madhupur a gross fall of 109 feet can be obtained in 4.6 miles; 140 feet in 7½ miles; 175 feet in 9¼ miles; and 200 feet in 13 miles. Mr. Milne in a paper read before the Punjab Engineering Congress, 1919, states that the minimum recorded discharge there is 1,300 cusecs, which would give a continuous 12,000 e.h.p. on the smallest and most practicable combination of these many falls. The excess water not required for the canal could be surplussed back to the river. The project has been estimated to cost Rs. 530 per e. h. p. or Rs. 716 per kilowatt installed. See entry in table 5. The normal supply is nearer 5,000 cusecs. A cross-section is available but is not printed. The catchment area of the river is 2,500 sq. miles with an average rainfall of about 93 inches. The maximum flood discharge is about 200,000 cusecs and the minimum recorded flow 1,303 cusecs at Madhupur. (Map 43 P. 11, 14, 15 with 52 D 2).

Sutlej River; Bhakra Dam project.—The proposal to use the great power of the Sutlej where it enters the plains near Kirthpur, north of Rupar, at the head of the Sirhind Canal, is not dependant on, nor does it in any way interfere with, the project for storing some 112,000 million cubic feet of water behind this 395 foot dam. The proposals given in Mr. F. Milne's paper, read before the Punjab Engineering Congress at Lahore in April 1919, involve tunnelling through the spur round which the Sutlej makes a great loop at Oel and Anandpur; a fall of some 430 feet or 330 feet effective can be obtained in this way, and the minimum discharge of 2,700 cusecs (usually not below 4,000) which must in any case be allowed to pass down the river could be utilized to give some 81,000 e. h. p. continuously. The lake would extend above the headworks, but its storage would not be drawn on beyond the minimum flow coming in. The cost is estimated to be Rs. 313 per kilowatt installed. The only differences that the dam project makes in the hydro-electric is that, if the former is built, the tunnel will be under the pressure of a considerable head of water; whereas, if the dam is not built, a diverting weir must be built across the river at the tunnel entrance. It is probably that below the dam also some 10,000 e. h. p. could be obtained if the main scheme is blocked by the fear of interference with irrigation. This site was first suggested by Messrs. Crompton & Co. in the early nineties. The reaches further upstream have doubtless great possibilities, but at a much higher cost. The catchment areas of the river amount to 5,000 and 16,000 sq. miles in the exterior and interior Himalayas with an average rainfall of about 44 inches in the former. The maximum flood discharge is about 300,000 cusecs and the minimum recorded flow 2,818 at Rupar. (Map 53 A 7, 8, 11, 12).

For the construction of the dam, and the tunnel also, power to the extent of about 3,000 h. p. will in any case be required; and this can be obtained from a site 4 miles from Nangal, on the same loop and below the dam site. Here a minimum of about 15,000 e. h. p. can be obtained under a comparatively low head of about 30 feet, unaffected by the flood rise. The cost, including transmission to the works, is estimated to be about 10 lakhs for the power actually required, but it would seem preferable to so arrange that the whole power can be developed. If the demand later on justifies it, and the tunnel has been built (which would certainly be an advantage in constructing the dam) then the larger project could subsequently be matured. Certainly several thousand h. p. could at once be used for the Kalka-Simla Railway and other requirements within easy reach.

Sutlej River—At Khatolu gorge, $2\frac{1}{2}$ miles from Sarahan on the Hindustan-Tibet road, there are cataracts for $\frac{3}{4}$ of a mile with a single drop of 30 feet included. During the monsoon however the rise of the river practically obscures the falls, so it would only be possible to utilize it with a considerable dam for giving a head. The minimum perennial discharge will be of the order of 1,500 to 2,000 cusecs and the site appears promising, though remote. (Map 53 E, 14, 15).

Canal Falls, Punjab.

Note.—Discharges given are mostly the *normal full discharges*. Minima are being collected and will be available later. Serial numbers refer to a map on record in the Survey. Falls less than 8 feet not given.

UPPER JHELUM CANAL.

Serial.	Name of channel.	R. D.	Particulars.	Head feet.	Normal full discharge.	Minimum discharge.
1	Main Line . . .	240,000	Fall	50	3,000 See note.	...
2	Do.	418,000	Fall (combined)	20	...	1,000 See Note.
3	Gujrat Branch . . .	60	Fall	8	2,033	...
4	Do.	1,350	Do.	8	1,866	...
5	Do.	2,000	Do.	8	1,850	...

LOWER JHELUM CANAL.

1	Northern Bank . . .	342,080	Fall	3	294	...
2	Do.	343,080	Fall	3	294	...
3	Do.	343,580	Do. } can be combined {	100	294	...
4	Do.	344,080	Fall	5	294	...
5	Sulki Branch . . .	13,526	Do.	6	357	...
6	Do.	14,000	Do.	5.5	341	...

UPPER CHENAB CANAL.

1	Main Line, lower . . .	715,000	Fall and bridge	8.5	9,070	...
2	Do.	221,000	Do.	10.5	7,889	...

LOWER CHENAB CANAL.

1	Bhawana Branch . . .	7,500	Fall	9.2	423	...
2	Khewra Major Dy.	8,000	Do.	8.7	314	...
3	Burala Branch . . .	164,000	Do.	8.2	350	...
4	Upper Gugera Branch.	219,000	Do.	8.5	...	850 See Note at end.

UPPER BARI DOAB CANAL.

1	Salampur feeder . . .	6,486	Rapids No. 3 and bridge	8.3	1,895	See Note at end.
2	Do.	33,845	Rapids No. 11 and bridge	9.3	1,824	
3	Main Line	13,300	Rapids No. 2	8.0	4,796	
4	Do.	22,500	Rapids No. 6	8.5	4,782	
5	Do.	24,500	Rapids No. 7 and bridge	8.0	4,779	
6	Do.	28,500	Rapids No. 9	8.5	4,773	
7	Do.	31,500	Rapids No. 11	8.5	4,769	
8	Faridnagar feeder . . .	21,829	Rapids No. 8	9.2	1,774	
9	Do.	27,697	Rapids No. 10 and bridge	8.6	1,764	

UPPER BARI DOAB CANAL—*contd.*

Serial.	Name of channel.	R. D.	Particulars.	Head feet.	Normal full discharge.	Minimum discharge.
10	Main Line . . .	54,500	Rapids No. 16 and bridge	8.5	4,695	
11	Do.	60,000	Rapids No. 18	8.5	4,695	
12	Do.	92,142	Tughal rapid and bridge	8.0	6,292	
13	Do.	101,072	Dhambai bridge and fall	8.5	6,300	
14	Do.	114,100	Nanunangal bridge and fall.	10.0	6,330	
15	Main Branch, upper.	42,849	Dhariwal bridge and fall	11.0	4,270	
16	Do.	49,768	Kunjer bridge and fall	9.0	4,200	
17	Do.	123,500	Aliwal regr. and fall	8.0	2,631	
18	Lahore Branch	25,000	Sanchur bridge and fall	10.0	1,080	
19	Do.	96,000	Raneywal bridge and fall	8.6	872	
20	Subraon Branch	34,860	Tughel Walad bridge and fall.	8.4	790	

LOWER BARI DOAB CANAL.

1	Main Line	329,058	Fall and bridge	8	4,291	See Note at end.
2	Do.	493,759	Do.	8	3,774	

SIRHIND CANAL.

1	Abohar Branch	23,000	Khanpur	8	2,506
2	Do.	47,000	Chupki	8	2,298
3	Do.	69,500	Ballowal	8	2,820
4	Do.	105,000	Akalgarh	8.1	2,755
5	Do.	128,000	... ..	8.2	2,657
6	Do.	213,000	Doodhar	10.0	2,396
7	Do.	254,000	Gholia	8.2	1,957
8	Do.	289,000	Channowal	8.0	1,717
9	Do.	332,000	Samalsar	8.0	1,562
10	Sultej Nar.	98,000	Baraghar	9.9	400
11	Do.	110,500	Malha	10.0	400
12	Bhatunda Branch	32,250	Khatra	8.0	2,029
13	Do.	58,900	Jaghera	7.6	2,011
14	Do.	87,500	Kanganwala	10.1	1,982
15	Do.	128,000	Lohgarh	8	1,770
16	Do.	185,000	Chambhai	10	1,561
17	Do.	277,000	Ballohi	8.6	1,039
18	Do.	307,000	Sadhana	7.7	1,010
19	Kotta Branch	15,000	Dalawal	9.4	1,427
20	Do.	56,850	Solar	8	1,414
21	Do.	61,566	Banbhora	8	1,400
22	Do.	122,175	Sogra	8.1	1,006
23	Do.	185,000	Harigarh	8	847
24	Do.	215,000	Sahoki	8.9	604

SIRHIND CANAL—*contd.*

Serial.	Name of channel.	R. D.	Particulars.	Head feet.	Normal full discharge	Minimum discharge.
25	Kotta Branch	269,000	Ralla	8.5	617	
26	Ghaggar Branch	28,000	Thus	11.1	719	
27	Do.	55,000	Nidampur	8.5	676	
28	Do	185,000	Sular	8.0	311	

WESTERN JUMNA CANAL.

1	Sirsa Branch	168,000	Fatehpur	8.8	1,241	
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Of the above it has been suggested by the Chief Engineer that the 50 foot fall on the Upper Jhelum Canal, serial 1, at R. D. 240,000, could be employed usefully at Khewra Salt Mines and Dandot Collieries, but the closure would be a drawback. This may, however, be reduced when the Woolar Lake Barrage in Kashmir has been built. Sir Louis Dane also suggested the employment of this power for irrigation pumping to the tract between the North Western Railway and the Upper Jhelum Canal, where the closure would not matter, but the question of the sufficiency of the supply for the rabi crop would have to be considered. The power available on normal discharge is nearly 14,000 e. h. p. but the minimum and period of closure have not come to hand.

The 20 foot fall on the same canal (serial 2) at R. D. 418,000 could be used at Gujrat and Wazirabad, where some industries exist. The power available on minimum discharge (subject to short closures) is 1,800 e. h. p.

The falls on the upper reaches of the Upper Bari Doab Canal have been dealt with above in connection with the Ravi River. Serial 4 on the Lower Chenab Canal was at one time proposed to be utilized for the "Buchiana Lift Project" of irrigation; it is found however, that the area can probably be commanded by gravitation flow.

There are the following areas of high land within reach of the power and water of the Lower Bari Doab Canal, which could be used for irrigation pumping, *viz.*, Renala, 50,000 acres; Okara, 1,300 acres; Montgomery, 1,750 acres. The closure would not matter for this.

Apart from the power ascertained in these notes on canal falls, those not specially mentioned would yield the following amounts on the discharges given, which are mostly *normal and not minimum discharges*, *viz.* :—

Upper Jhelum Canal	4,000 e. h. p.
Lower " "	3,300 "
Upper Chenab " "	14,500 "
Lower " "	800 "
Upper Bari Doab " (58,000 total) say	46,000 "
Lower " "	5,800 "
Sirhind " "	32,800 "
Western Jumna " "	1,000 "
TOTAL	108,200 "

The power in any particular instance may here be found by e. h. p. $\frac{\text{cusecs} \times \text{fall in feet.}}{1.48}$

APPENDIX XIV.

Sites in the United Provinces.

Alaknanda.—(See also Bhagirathi River).—This river, also called the Vishnuganga, has a catchment area of some 4,500 square miles and drops 5,000 feet in 16 miles between Badrinath and Vishnuprayag. The gorge $2\frac{1}{2}$ miles above Rudraprayag would be difficult to develop and is very out of the way; but the river is snow fed and could undoubtedly be developed at a cost. It is reported that the limestone cliffs of the gorge are 150 feet above the bed of the river at this place, where it takes a sharp bend. An old channel cuts a chord across this bend, with the pilgrim route to Badrinath parallel to it. The suggestion has been made that the old bed could be cut down to the present water level and sluice gates constructed on it; the river could then be diverted while a dam is built across the gorge. Presumably a second dam of the same height would be necessary across the cutting. Arrangements would be required for passing timber over. A light railway to Karanprayag is under consideration. (Map 53 J 15-16 or N 3).

Bakher Nadi.—Tributary of Belan, Mirzapur.—There is a reservoir site here designed to hold 1,400 million cubic feet of water for irrigation purposes; but as the catchment area is 318 square miles with a good run-off and a rainfall of about 40 inches it is believed that 8,000 million cubic feet or more could be reckoned on with a higher dam. Some 87 per cent. of the rain falls between June and September. The Sirsi fall near by has a drop of 90 feet. The project makes an admirable combined irrigation and power scheme, as the tail waters could be stored lower down and yet above the canal. The site appears likely to yield at least 2,000 e.h.p. continuously, and probably much more. It is worth further investigation. (Map 63 L 9).

Baur River.—Naini Tal District.—The minimum recorded discharge at Dechauri is 9 cusecs and the stream is small and unpromising. (Map 53 O 7).

Belan Nadi.—Mirzapur.—There is a possible reservoir site (unsurveyed), believed capable of storing 5,000 million cubic feet, above the Mukha fall of 80 to 100 feet, 6 miles west of Ghorawal. It has so far not been examined as the cost of the submerged villages and land would be high, but it offers considerable possibilities for power (1,500 e.h.p. or more) and irrigation combined. The catchment area is about 250 square miles with a rainfall of about 40 inches, which practically all falls between June and September. (Map 63 L 9, 10).

Bhagirathi River.—Tributary of Ganges.—At the junction with the Alaknanda, at Devaprayag, there are rapids with a perennial snow-fed discharge. Reconnaissance is desirable, as the catchment is nearly 4,000 square miles. The President of the Council of Regency, Tehri-Garwhal State, has examined this river and its tributaries beyond Barahat, and calls particular attention to the Assi, which joins the main river 2 miles above that place. This is a perennial stream, largely snow fed, and has a fall of some 1,275 feet in 8 miles in its lower reaches, which are at an altitude of 6,000—7,000 feet. The estimated discharge between the 14th and 20th May 1919, was 400 cusecs. The site is 40 miles from Dehra Dun. (Map 53 J, 5, 6, 12).

Chandrapabha River.—Benares State.—There is a small storage site to hold some 300 million cub. feet which was surveyed but not proceeded with. A 200 foot fall is said to exist near Baraur. Site not identified, but probably north of the Son River. The power possibilities appear small, though in combination with irrigation it might be developed. A request to examine the site has been received through Government. The rainfall is about 40 inches of which about 31 inches fall between June and September. (Map 63 P).

Dabka River.—Naini Tal District.—The minimum recorded discharge is 10 cusecs at Kota, and the river only offers small prospects of power apparently. No information as to falls. (Map 53 O 3).

Ganges River.—(See also Bhagirathi River).—It has been recommended that levels should be taken from Rikhishesh up to Phul Chatti or beyond; the latter region is believed to offer possibilities, but the harnessing of such a river is likely to be very expensive. The site has not been identified at present. Being snow fed from the main Himalayan range there is of course enormous

potential power in the river, and it is within the borders of British India, though mostly unsurveyed.

Garai River.—Mirzapur.—For irrigation reasons this is said to be not worth consideration, though a fall of 180 feet exists near the present dam.

Gaula River.—Naini Tal District.—The minimum recorded discharge at Kathgodam is 82 cusecs while there are generally at least 100 cusecs through the dry season. The hills fall rapidly from the Bhim Tal District. It is worth further prospecting. Discharges are being taken. (Map 53 O 11).

Gauna Lake.—Garhwal.—This was formed by the great landslip of 1893 and burst in 1894, but the lake is still very large (3 times the size of Naini Tal Lake) and it might be possible to raise a dam there. The Birehi Ganga flows thence to the Alaknanda. (Site not identified).

Ghagar Nadi.—Mirzapur.—The water is all required for irrigation, so the power cannot be utilized unless falls exist above the headworks, as to which there is no information at present.

Jagei Lake.—Garhwal.—Formed similarly to the Gauna Lake (q.v.) and the same remarks apply. Snow fed. The Bieria Ganga flows from it to the Kaliganga. (Site not identified).

Jumna River.—The scheme of the United Provinces Power Association (Major-General Beresford Lovett) mentioned in Table 5, was a double one. The sites are at Jalanta and Binahar respectively. At the former site a double loop was to be utilized by making two short tunnels through the spur, a canal joining up the tunnels, and giving a fall from R. L. 2,362 to 2,194 or say 168 feet gross. The latter is a single loop, involving a 2 mile tunnel, giving a fall from R. L. 1,953 to 1,698 or 255 feet. The existing concession is partly in Tehri State. Minimum discharge about 750 cusecs; snow fed from a very large area. The promoters of this scheme reckoned, after full investigation, that they could obtain 26,000 e. h. p. at Binahar and 12,000 e. h. p. at Jalanta at about one-third of the cost of the larger scheme. It is a matter for regret that for various reasons these promising schemes had to be postponed; it is to be hoped that they are not abandoned. (Map 53 F 14).

Kalamia Nadi.—This is reported as unlikely to be of any use. It is to the west of the Sarda.

Kaliganga River, Garhwal.—(See also Jagei Lake).—It has been suggested that a large reservoir could be made near Launsari. The stream joins the Kail and the Pindar. (Site not identified).

Kanhar River, tributary of Sone, right bank conditions similar to Rer River (q. v.) and worth investigating. (Map 63 P. 3, 7, 8).

Karanauti, Khajuri, Dahwa and Jargo Nadis, Mirzapur District.—These small nalas rise in the lower scarp of the Vindyas and flow north to the Ganges. There are small storage sites and falls of from 50 feet upwards, but in view of the better sites in the district they are at present not worth more than record. Some power however can doubtless be developed, and might be useful to the neighbouring quarries. Rainfall about 40 inches, nearly all between June and September. (Map 63 K 12).

Karamnasa River, Benares State.—At Nangarh, 40 miles south of Benares, there is a reservoir site investigated by the Irrigation Department and found capable of storing 3,500 million cubic feet at a cost of 12 lakhs; as an irrigation project it was abandoned. A smaller site holding 700 million cubic feet was also located on the Gurwat tributary, 4 miles below Nangarh. Near here there is said to be a fall of 240 feet and another of 100 feet, on the way down to Chakia, where the reservoir of the Benares State Canal is situated; possibly they can be combined. The value to the State of the tail waters of the proposed large reservoir, in keeping the existing irrigation reservoir always supplied, is obvious. The site seems likely to afford at least 4,000 e. h. p. continuously within 40 miles of Benares, probably far more, and is well worth further examination. Details of the sites are available in the Chief Engineer's office. A request to examine the site has been received through Government on behalf of the Benares Darbar, and enquiries have been made by Messrs. Martin & Co. The rainfall is about 40 inches of which 31 inches fall between June and September. (Map 63 P. 5).

Ken River, tributary of Jumna.—At Paind village, Panna State, below junction with Sunai (Sonar?) there is a favourable reservoir site with a catch-

ment area of 5,700 square miles and a recorded flood discharge of 325,000 cusecs. The site has not been identified. (Map 54 P).

Khoh River, Garhwal.—This falls very low but does not dry up. About 4 miles above Dogadda (on the cart road to Lansdowne) a promontory almost closes the ravine. It was proposed some years ago to make a dam here to generate power for a ropeway between Lansdowne and Dogadda, but the project was dropped in 1914. Site not identified. (Map 53 K 9, 10 ?).

Kosi River, Naini Tal District.—The minimum recorded discharge at Ramnagar is 152 cusecs, and the dry weather flow is generally over 200 here; there are no gaugings higher up, where falls can certainly be developed. The river is not fed from the perpetual snows, but rises in high altitudes in the Almora district, with a rainfall of 50 to 100 inches. November and December only have averages below an inch, though July to September gets most of the rain. The river merits further investigation and is being gauged. Near Hawalbagh it is reported that damming would be feasible and power obtainable. (Map 53, O).

Mussoorie.—In addition to the existing development for Mussoorie and Dehra the Kamptee Falls on the Ringel Gad were mentioned and are to be examined. The catchment is only about 4 square miles. The discharge in 1919 fell to 4.8 cusecs as there was considerable irrigation higher up. A fall of 896 feet can be obtained with a flume of 1,850 feet, and a regulating tank can be built. The minimum discharge of the Bhatta, which supplies Mussoorie (see Table 2) was 8 cusecs in 1919. The Rispana stream had a minimum discharge of 3.8 cusecs in 1919 and a fall down to Mukrat of 720 feet with a pipe line of 4,100 feet. The Aghtar stream is more considerable; it lies between Mussoorie and the range to the north. The discharge below Tonata at the junction of the Khakrana was 54 cusecs; at the Bhilaru junction 41 cusecs; between Kempti and Bhilaru streams 68 cusecs; and at Kempti junction 41 cusecs. The average fall is 150 feet per mile for 6 miles. The country is difficult and transport of machinery would be costly, but this river seems the best for the Mussoorie-Dehra extensions. (Map 53 J 3 ?).

Naini Tal Lake.—The old proposal to utilize this lake for the supply of the hill station is again under consideration of Government. A head of 1,000 to 1,350 feet can be obtained. It is proposed to instal 600 kilowatts (450 working and one spare set) at a cost of 4 lakhs. The storage area, if a dam is built, will be considerable; but the mud flats when the water is low may prove objectionable. (Map 53 O 7).

Nandhaur River, Naini Tal District.—The minimum recorded discharge is 18 cusecs at Chorgallia canal headworks, while the average is considerably higher throughout the dry months, from 22 to 60 cusecs. Falls have not been located and the catchment is small. Rainfall 50 to 100 inches, well distributed. (Map 53 O 12, 16).

Nayar River, tributary of Ganges.—There is a waterfall in the Eastern branch of this river near the Baijran-Kainur Road, 40 miles north-east of Lansdowne (Garhwal). No details are known, but the rainfall in the large upper catchment is about 75 inches. A plan exists, fully worked out, for making an irrigation channel to take out of the Eastern Nayar, a little above its junction with the Western Nayar, to run by a siphon under the latter and then proceed along the Main Nayar to Banghat and Bilkhet. It is said to be possible to adopt a similar project for power purposes at Bilkhet where there is a broad piece of flat land and terraces with a fall of 50 feet. (Map 53 J 16; K 9, 13; N 4).

Paisuni River.—Near Markundi station there is a fall of 150 feet. The river dries up entirely, but the catchment is 175 square miles with a rainfall of 40 inches between June and September. Storage sites may be found. (Map 63 C 16; D 9, 13).

Pindar River.—This snow fed river carries a large volume of water from a very large catchment, and is said to be worth prospecting. It runs into the Alaknanda. (Map 53 N).

Ramgunga River.—This rises in the Garhwal district. At Tarag Tal, in the west Almora Forest Division, a landslip in former times blocked the valley of a tributary and formed a lake; the embankment however is far from water-tight. Below here there is believed to be a fall of 600 feet or more in $1\frac{1}{2}$ miles.

The site is worth reconnaissance, but is remote. Catchment area of tributary not known. Rainfall 50 to 75 inches. This is probably either the Gauna Lake (q. v.) or the Jagei Lake (q. v.) but the accounts received do not make it clear. (Map 53 O 1, 2, 5, 6.)

Rer River.—Tributary of Sone, right bank. (Rihand River in Atlas?).—A perennial stream, once estimated as carrying 200 cusecs in May, and therefore probably having a considerable hot weather discharge. Runs in gorges with alternate pools and rapids, but little known. Almost certainly has power, and requires prospecting. Rainfall 40 to 50 inches of which 93 per cent. falls between June and October. (Map 63 L. 15, 16 and P. 3, 4).

Sarasvatiganga River, Garhwal.—Two miles north of Badrinath this river drops 300 feet where it passes through a narrow cleft, spanned by a boulder over which the Tibetan trade route passes. The river is snow fed and has a large hot weather discharge, but as the altitude is 11,000 feet it is unlikely to be of any use. (Map 53 N 5.)

Sardah and Sarju Rivers. Naini Tal District. Details of gaugings are available in the Chief Engineer's office, the river having been completely surveyed for further canal projects. The river is snow fed and the water is used for the Rohilkhand Canals; but falls can almost certainly be developed above the head works, though they may prove to be out of British India, in the kingdom of Nepal, of which the river appears to be the boundary. The upper reaches of the Sardah are called the Sarju, and it is believed that power could be obtained near Bageswar and Rameswar, for the projected ropeways in the Almora District. On the right bank, which is in British territory, the Ledhia, Sarju, Gori, Dharma and Kuti flow in. Of these the Sarju is partly snow fed and has many rapids, and its feeder streams may possibly prove of value also for forestry. The Gori is also snow fed, and should be an excellent source of power, but it is very remote. The Dharma and Kuti also rise in glaciers but are even more out of the way. (Map 62 C 2, 3, 4, 7, 8.)

Tons River.—Lonipur in Rewah State is mentioned, the river having a catchment area of 3,400 square miles in Baghelkhand and a flood discharge of 400,000 cusecs. Site not identified. Higher up, at Poorwa, there is a fall of 100 feet, but here the catchment is reduced to 2,010 square miles. Further up still, at Chachai, 3 miles from Poorwa, there is stated to be a fall of 300 feet; but the dry weather discharge is small and a reservoir site has not been located. The rainfall is about 44 inches of which 41 inches fall between June and September (Map 63 D or H.)

Tons River. Dehra Dun. A site is mentioned near Kalsi, where this joins the Jumna (Map 53 F. 10 or 14).

Note (i).—A full report on the general features of Garhwal and its many streams has been received from the Commissioner, Kumaon Division. The more promising have been entered above, but the list will be useful to the officer examining the district.

Note (ii).—There is doubtless great power in the Nepalese rivers Karnali (or Kauriala), Sarju, Rapti, Madi, Budyar, Trisulganga and its tributaries, San Kosi and its tributaries. No data are however available regarding any of these rivers.

Canal Falls, United Provinces.

UPPER GANGES CANAL.

Anupshahr branch.—

Anikas falls.—Minimum 150 cusecs for 155 days. Fall 5 feet.

Bhagwantpur falls.—Minimum 150 cusecs for 155 days. Fall 8 feet.

Makri falls.—Minimum 220 cusecs for 160 days. Fall 8½ feet.

Jakhera falls.—Minimum 230 cusecs for 160 days. Fall 4 feet.

Dehai falls.—Minimum 250 cusecs for 160 days. Fall 12 feet.

Parichatgarh falls and regulator.—Minimum 325 cusecs for 170 days. Fall 8½ feet.

Dhakauli falls.—Minimum 300 cusecs, but 400 cusecs for 180 days. Fall 7½ feet.

Akbarpur falls.—Minimum 300 cusecs, but 400 for 180 days. Fall 8.8 feet.

Churiati falls.—Minimum 300 cusecs, but 500 for 190 days. Fall 7 feet.

NOTE.—The normal flow during most of the year is much greater.

Aligarh Division.

- Machua falls.*—Minimum 600 cusecs for 8 months. Fall $6\frac{1}{4}$ feet.
Somera falls.—Minimum 600 cusecs, but 800 for 8 months. Fall 8 feet.
Palra falls.—Minimum 600 cusecs, but 1,100 for 8 months. Fall 8 feet.

Bulandshahr Division.

- Walipura falls.*—Minimum 600 cusecs, but 1,300 for 9 months. Fall 5 feet.
Sánanta falls.—Minimum 600 cusecs, but 1,500 for 9 months. Fall $4\frac{3}{4}$ feet.
Dehra falls.—Minimum 600 cusecs, but 1,700 for 9 months. Fall 7 feet.
Dasua falls.—Minimum 600 cusecs, but 2,500 for 9 months. Fall 8 to 9 feet, increasing with low supply. Will give nearly 2,000 e. h. p. for 9 months.

Meerut Division.

- Bhola falls.*—Minimum 600 cusecs, but 2,700 for 9 months. Fall 12 feet. Will give nearly 3,000 e. h. p. for 9 months. It is anticipated that this fall will be utilized in the near future for the supply of Meerut, but only 750 kilowatts (giving 500 kW with a spare set) are to be installed at a cost of about Rs. 5,00,000. The project is now under consideration of the Local Government. The inlet channel will carry 600 cusecs. 8 miles from Meerut.
Salawa falls.—Minimum 600 cusecs, but 2,900 for 9 months. Fall 12 feet. Will give 3,000 e. h. p. for 9 months.
Chitaura falls.—Minimum 600 cusecs, but 3,000 for 9 months. Fall 10 feet. Will give some 2,700 e. h. p. for 9 months. Near Muzaffernagar.
Jauli falls.—Minimum 600 cusecs, but 3,500 for 9 months. Fall 10 feet. Will give about 3,200 e. h. p. for 9 months. Near Muzaffernagar.

Northern Division.

- Nirgajni falls.*—Minimum 600 cusecs, but 3,600 for 9 months. Fall 12 feet. Will give about 4,000 e. h. p. for 9 months. Near Muzaffernagar.
Mohammedpur falls.—Minimum 600 cusecs but 3,750 for 9 months. Fall 12.2 feet. Will give over 4,000 e. h. p. for 9 months.
Asafnagar falls.—Minimum 600 cusecs, but 3,800 for 9 months. Fall 10.7 feet. Will give 3,700 e. h. p. for 9 months. Near Roorkee.
Pathri falls.—Minimum 600 cusecs, but 4,500 for 10 months. Fall 10 feet. Will give 4,100 e. h. p. for 10 months. Midway between Roorkee and Haridwar.
Salempur and Bahadurabad falls.—Already combined and utilized in part. Minimum 600 cusecs, but 4,500 for 10 months. Combined fall 17 feet. Can be developed for nearly 7,000 e. h. p. for 10 months.
Ranipur falls.—Minimum 600 cusecs, but 4,500 for 10 months. Fall 9 feet. Will give over 3,600 e. h. p. for 10 months.

Eastern Jumna Canal Upper Division.*

Belka bridge fall.—Minimum 350 cusecs, but 740 for 9 months. Fall $14\frac{1}{2}$ feet.

Dialpur fall.—Same discharge; fall 5·8 feet.

Nogla bridge fall.—Minimum 350 cusecs, but 666 for 9 months. Fall 7 feet.

Babail fall.— Ditto.

Randoul fall.—Same discharge; fall 8·4 feet.

Ghuna and Sarkari falls.—Same discharge; might be combined to give $10\frac{1}{2}$ feet fall.

Hilapur bridge fall.—Minimum 350 cusecs, but 498 for 9 months. Fall $6\frac{1}{2}$ feet.

Megchaper fall.—Same discharge; fall 4·4 feet.

Reri fall.—Same discharge; fall 3 feet.

Malri bridge fall.—Same discharge; fall $4\frac{1}{2}$ feet.

Salampur fall.—Minimum 250 cusecs; fall 5·6 feet.

* All the above have larger discharges as a rule, from 1,000 to 1,770 cusecs.

LOWER GANGES CANAL.*Bundelkhand Tract.*

Information not yet received.

On the minimum discharges the following power is available (in small units) from these canals; on normal discharge for some 9 months 2 or 3 times the amount could be obtained, *viz.* :—

UPPER GANGES CANAL.

Anupshahr Branch	1,600 e. h. p.
Aligarh Branch	1,200 "
Bulandshahr Branch	1,400 "
Meerut Branch	2,400 "
Northern Division	2,900 "
EASTERN JUMNA CANAL	2,400 "
TOTAL	<u>11,900 e. h. p.</u>

The power in any particular instance may here be found by e. h. p.
 $\frac{\text{cusecs} \times \text{fall in feet}}{12}$.

ADDENDA TO LIST OF SITES.

Received after going to Press.

Assam.

Cachar.—In the North Cachar Hills, near Subong Tea Estate, it is stated that a valley could be dammed to form a lake in the Abong River. Other similar sites are mentioned near Loobah and Soonamganj; while the Kiang River is said to be worth investigation.

Bengal.

Tista River.—From the Tista Bridge upwards the fall is as follows :—

0 to 2½ miles	15 feet per mile.
2½ to 12½ „	18 „ „ „
12½ to 21½ „	32 „ „ „
21½ to 39½ „	43 „ „ „
39½ to 47½ „	255 „ „ „
47½ to 52½ „	228 „ „ „
52½ to 61½ „	413 „ „ „

Cold weather discharge not less than 1,250 cusecs in North Sikkim.

Bombay.

Bedti R.—Magod falls, near Yellapur (Map 48 J 9). The falls on the branch from the South, 4 miles above the junction, are 328 feet. Falls on the main river 3 miles above the junction are indicated, but not their height.

• *Ghatapraba R.*—At Gokak (q. v.). There are said to be possibilities of extensions, if a new dam is built at Daddi (4" topo. sheet 242 S. E. 4), and the rapids at Katabali (4" topo. sheet 274 S. W. 1) are also mentioned.

Kanbargi; 3 miles North of Belgaum. A combined power and irrigation scheme is suggested, a drop of 400 feet being feasible.

Markandaya R.—There is a good waterfall on 4" topo. sheet 274 N. E. 3.

Nagargali.—There is a perennial stream with a waterfall between Duggeli and Kirpoli, on 4" topo. sheet 277 N. W. 4.

Sonda Nala.—Near Ibihalli, Sirsi Taluka. The falls are over 300 feet high. (Map 48 J 13 ; 14).

Burma.

Lilu Ch., tributary of Mon, near Paungseik.—A fall of 100 feet with perennial flow reported. Shwegyin Division.

Maisakhaing Ch. near Kyankpon.—Two falls of 50 and 75 feet reported, with perennial flow. Also, higher up, two falls of 40 and 100 feet known to the Karens as the Donwe and Kyaukoh Falls.

Pada Ch., near Khedo.—A fall of 100 feet reported with perennial flow. Shwegyin Division.

Central Provinces.

Gogra R.—There are rapids near Sohagpur.

Hasdo R.—A large perennial flow over rapids of 20 feet is found 10 miles North of the Railway.

Narbada R.—Gaugings were taken at Khiranighat, near Jubbulpore, during March, April and May 1919. The catchment area there is 6,500 sq. miles. The maximum flood discharge recorded up to date is 2,395 cusecs on 20th March 1919. The mean discharges were as follows :—

March 13th to 15th	519 cusecs	} Minimum 412 cusecs.
„ 16th to 31st	938 „	
April 1st to 15th	405 „	} „ 173 „
„ 16th to 30th	254 „	
May 1st to 15th	239 „	} „ 145 „
„ 16th to 26th	215 „	

Total flow in period 2,791 million cubic feet.

The *Kapadhana Falls* below Amarkantak are about 100 feet.

Nimgahan.—At altitude 2,700 feet there is a perennial stream with a drop of 1,000 feet in a short distance.

Penganga R.—Kinwat Forest Reserve, Berar. The Sahasrakund fall near Bittargaon (Map 56 I 3) is 120 feet. A further possible site is indicated on sheet 56 I 5, in the Kelapur Forest Reserve.

Rakshadah Fall.—This is on the border of the Lurmi Range and Mandla District, near Berar Pani. Said to have a drop of 1,300 feet in a mile.

Madras.

Kolab R.—At Barga near Jeypore; (Map 65 J 9). There is a site for power here, reached by a footpath of about 4 miles from the Jeypore ghat, at mile 58-0 on the road. Three falls exist of some 150 to 180 feet in the aggregate, but by utilizing a reservoir site higher up a fall of 800 feet may be obtainable. A sketch has been forwarded, but gaugings have not so far been reported. It is worth further examination as the tail waters could be used for irrigation on the Jeypore Plateau.

Machkund R.—The Duduma waterfall near latitude $18^{\circ} 31\frac{1}{2}'$, longitude $82^{\circ} 31\frac{1}{2}'$ (or $82^{\circ} 28'$ as shown on Atlas sheet 65 J on the $\frac{1}{4}''$ scale) has been measured and found to be of 540 feet. A float gauging made at the beginning of May, said to be at the driest time showed 104 cusecs with a coefficient of 0.5. The site is reached from Bugura, 22 miles off, by a footpath. A large reservoir site exists just above the falls, and it is probable that there are many others higher up still. No details are given as to capacity, but the site is certainly good for 5,000 e. h. p. or more. Vizagapatam, where the harbour works will require power, is 80 miles distant.