HYDRO-ELECTRIC SURVEY OF INDIA

VOLUME III

TRIENNIAL REPORT

WITH A

PRELIMINARY FORECAST OF THE WATER POWER RESOURCES OF INDIA

1919 to 1921

BY

J. W. MEARES, C.I.E., F.R.A.S., M.Inst.C.E., M.Am.I.E.E.

Member of Council, Inst. E. E., Member of Council, I. E. (Ind.),
Chief Engineer, Hydro-Electric Survey of India,
and Electrical Adviser, Government of India.

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INTRODUCTION.

The Report.—This First Triennial Report of the Hydro-Electric Survey of India contains a considerable amount of technical matter which appeared in the Preliminary and Second Reports; the former is now out of date while the latter was of the nature of an *interim* report only. The present volume contains information and directions which will enable the civil and electrical engineers engaged on the practical work of the Survey to size up the potentialities of any possible source of power under investigation. If the explanations in Part I of this Report appear somewhat elementary it must be remembered that the officers in charge of the Survey in the Provinces have had, for the most part, no previous experience of the specialized problem of water-power; and, dealing with immense areas, their subordinate staffs have necessarily had to work largely on their own initiative, with no text books other than the earlier reports. Applications for copies of these reports continue to come in from all parts of the world. The first direct result was seen during the cold weather of 1920-21, when technical representatives of a number of large firms interested in plant for hydro-electric developments visited India to see for themselves what the prospects are and what are the special conditions to be met with on projects which have already been investigated.

An explanation of the change of size and make-up of this Report is obviously called for. The Preliminary Report was issued in foolscap, and the Compiler was told that the public would not read blue books; though in point of fact several thousand copies were actually distributed. The Second Report was consequently printed in quarto, in the style of the reprints of several Government Committees' and Commissions' Reports; this size however does not lend itself to the insertion of maps and diagrams, which when placed in a pocket are often left there. Now that a substantial amount of work has been done, and the speculative "sites" of the earlier reports have in many cases either been written off as useless or found to be of value, an intermediate size of page has been definitely adopted. The earlier reports also cease to be of value, as the present one contains what is still useful from them, so that it is not necessary to bind them together with this volume. The current Report of the Inspector-General of Irrigation is being issued in a similar size, and the two subjects will some day be more intimately connected than they are now.

The list of sites in Part II of the Report is set up in alphabetical order as far as possible, as shown by the full list of contents, but a complete index is also given.

The Survey, Provincial.—As a consequence of the "Reforms" the Government of India decided, in October 1920, that "all outlay on water storage and water power will be Provincial charge, and the necessary provision for hydro-electric surveys should therefore be made in the Provincial estimates from and after the year 1921-22." Consequently the funds required for carrying on the Survey from the 1st April, 1921, have been voted upon in the various Legislative Councils, and in a good many instances reductions were moved. As matters now stand the Survey is in danger of falling between the upper and the nether millstone, as the Government of India is no longer able to provide funds for the continuance of the work. Nevertheless, the slender thread that binds the Chief Engineer to his colleagues in the Provinces has proved to be of good material; and to one and all of those colleagues and their assistants he tenders his heartfelt thanks for their cordial co-operation. It cannot be too plainly urged that the completion of the survey is of the utmost importance to the industrial future of India; and that it will be carried out more efficiently if the work is done quickly and with as few changes in personnel as possible. The subjects of Water Storage, Water-power and Electricity are "Reserved." In technical matters the officers in charge in the Provinces are free, as heretofore, to consult the Chief Engineer on technical questions either by correspondence or when the latter officer is on tour; but they remain under the direction and orders of their own Chief Engineers. In the detailed sections of Part II of this Report the facts stated are taken, in most cases, directly from Provincial reconnaissance and Survey reports; the comments and (in some cases) estimates of power have been added by the present writer.

Personnel.—Mr. F. E. Bull, Chief Engineer, left India preparatory to retirement in March 1921 and was succeeded by Mr. J. W. Meares, Electrical Adviser to the Government of India, who for the second time took over the direction of the Survey in that capacity. During his absence on leave Mr. Meares spent a short time in Sweden and Norway and submitted a separate inspection note regarding the hydro-electric works visited, which has been circulated to all officers concerned.

In Assam, Mr. B. A. Blenkinsop has continued in charge, except for a short part of the summer of 1920 spent on leave in Europe. The survey is proceeding.

In Bengal, no one has hitherto been appointed to the Survey, and no progress has therefore been made; but steps are now being taken to rectify this omission.

In Bihar and Orissa, Mr. Stevens took furlough in 1920 preparatory to retirement and hitherto no whole-time officer has been appointed to take his place; the current duties have however been carried on by Mr. H. Wardle, Superintending Engineer. It is hoped that an Executive Engineer will be appointed during the current cold weather.

In Bombay, Mr. P. L. Bowers, C.I.E., M.C., has remained in charge, except for short leave during the summer of 1920. Three additional officers were selected in England to assist Mr. Bowers, of whom two took over their duties during the cold weather of 1920-21. Meantime, by Public Works Department Order No. C. W.-12193, dated 8th August, 1921, the Government of Bombay has decided that the Survey shall cease forthwith. A separate Report on the work done is being published by the Government of Bombay, and certain rain and river gaugings are to be continued.

In Burma, Mr. H. Nimmo officiated for Mr. B. Raikes during the leave of the latter in 1920. Mr. Raikes took over charge again in the cold weather of 1920-21. Two additional officers were selected in England to assist Mr. Raikes, and they have taken up their duties.

In the Central Provinces, there has been no progress in the survey, the whole staff having reverted to Irrigation owing to famine demands. The present report deals fully with the admirable work carried out by Mr. Powys Davies and his successor Mr. N. C. Bhattacharji during their one working season.

In Madras, Mr. R. T. Sneyd, M.C., officer in charge, retired from Government service during the year; he was succeeded by Mr. J. Tate, Executive Engineer, and the survey is proceeding.

Colonel B. C. Battye, R.E., D.S.O., completed his detailed survey of the Sutlej River Hydro-Electric project and its subsidiaries during 1921, and submitted his Report to the Punjab Government. Except for this project no officer has been appointed in the Province, the enormous potentialities of which are practically unknown. Steps are being taken to start a general reconnaissance this year, if an officer can be spared.

In the United Provinces, Mr. T. M. Lyle continued in charge until he proceeded on leave in May 1921, when Rai Sahib Shanker Das, Assistant Engineer, took over charge from him.

Empire water-power resources.—The final report of the Water Power Committee of the Conjoint Board of Scientific Societies has now been issued. The Report states that while "more or less adequate steps are being taken by various Governments .... taking the Empire as a whole, no attempt is being made to ascertain the total resources, to secure any uniformity in methods of investigation and recording of data, to encourage such investigations as are being made or to collect information at a central bureau." The following table from the Report shows how matters stand:—

	Hydraulic horse-power.		Per cent. of available now developed.
	Available.	Developed.	
Europe	47,300,000	8,450, 00	18·0
North America (including Canada)	50,800,000	8,805,000	17·3
British Empire (except Canada)	41,200,000	695,000	1·7

From pages 54, 55 of the present Report it will be seen that the probable water power of India for " maximum development " is some 12,680,000 kilowatts, equal to 21½ million water horse power, of which only 1¼ per cent. is developed or in course of development. The proposed " Imperial Water-Power Board " is therefore much needed. Tables 4 and 5 on pages 36, 37 will also repay perusal in comparing India with the rest of the British Empire.

SIMLA,
22nd November, 1921.

J. W. MEARES.

TRIENNIAL REPORT, 1921.

PART I.—TECHNICAL MATTERS.

CHAPTER I.—WATER POWER.

1. Basis of water power.—In order to obtain power from water it is necessary to have—

(i) a definite flow of water; and

(ii) a fall of sufficient amount, whether natural or artificial.

A perennial flow of water may be obtained—

(*a*) from the natural flow of a river or stream;

(*b*) from the artificial flow of an irrigation or navigation canal;

(*c*) from the regulated outflow of a reservoir of sufficient size; or

(*d*) from a combination of (*a*) and (*c*) or (in rare cases) of (*b*) and (*c*).

By itself such a flow of water is not of any substantial value, although the fact of flow existing at all shows that there is a fall. A sluggish river, meandering through practically flat country, can seldom be harnessed; and, without the creation of a definite fall, never.

The fall may be either—

(*e*) a natural waterfall, whether of the vertical and spectacular variety or a cascade;

(*f*) a series of rapids, not amounting to a waterfall, but equivalent to one from the present point of view;

(*g*) an artificial fall created by a "lifting dam" or barrage in a river or a weir in a canal;

(*h*) an artificial fall obtained by concentrating the gradual drop of a stream or source over a considerable length, by means of an artificial water channel constructed on a much more gradual slope on the banks or hills above the stream; or

(*i*) an artificial fall created by diverting the waters of a source at a high elevation through the water-parting.

2. Examples of combinations of flow and fall.—Combinations of most of these types of fall with the varieties of flow can be found in actual or potential power schemes; thus—

Combination a-e. Cauvery falls; Niagara, etc., etc.
,, a-f. Um Tru project, upper rapids.
,, a-g. Notodden plants and many suggested in report.
,, a-h. Simla, Darjeeling, Mussoorie.
,, a-i. Pykara river.
Combination b-e. Malakhand canal project.
,, b-f. Many canal rapids.
,, b-g. Ganges canal plant; Amritsar.
,, b-h. Not possible.
,, b-i. Incongruous.
,, c-e. Cordite factory; Rjukan, etc.
,, c-f. Trollhatten.
,, c-g. Cauvery and Bhandardara dams, etc.
,, c-h. Tata H. E. P. S. Co.
,, c-i. Andhra Valley; Nila Mula project.
,, d-e, d-f, d-g. Um Tru, lower rapids.
,, d-h. Most projects in Central Provinces.
,, d-i. Tons River, Rewah.

These examples may not always be exact, as there are combinations of every sort to be found; all may be made to yield power.

3. Computation of water power.—The *rate* at which power can be generated (expressed in horse-power or kilowatts) varies directly as the product of the *weight* of water falling per unit of time and the *vertical height* through which it falls. The total *amount* of energy so generated in any given time varies directly as the product of the *total weight* of water falling in that time and the *vertical height* through which it falls. In many countries the units used are; for the fall, metres; for the flow, cubic metres per second. In India the foot and the cubic foot per second or "cusec" are used. In America cusecs are called "seconds-feet," which is a less self-explanatory term. The weight of a cubic foot of water may be taken as 62·4 lbs. A metre is 3·28 ft. and a cubic metre 35·3 cu. ft.

The various units of power and the methods of computing are given in Appendix I. It will be sufficient here to say that the kilowatt is employed throughout this Report as the unit of power and the kilowatt-hour as the corresponding unit of energy. The power obtainable from the flow of any source can be found approximately by—

Kilowatts=flow in cusecs × head in feet/15.

The total energy obtainable from any source, whether from flow or from stored water, can similarly be found by—

Kilowatt-hours=thousands of cubic feet of water × head in feet/56.

Where large storages are in question the kilowatt-year, *i.e.*, 8,760 kWh., is a more convenient unit, and the corresponding formula becomes—

kW. years=millions of cubic feet of water × head in feet/500.

4. Abbreviations used.—The abbreviations kW. for kilowatt; kWh. or unit for kilowatt-hour; b. h p. for brake horse power; cusec for cubic foot per second; ft. for feet; cu. ft. for cubic feet; and m. c. ft. for millions of cubic feet; are used throughout this Report.

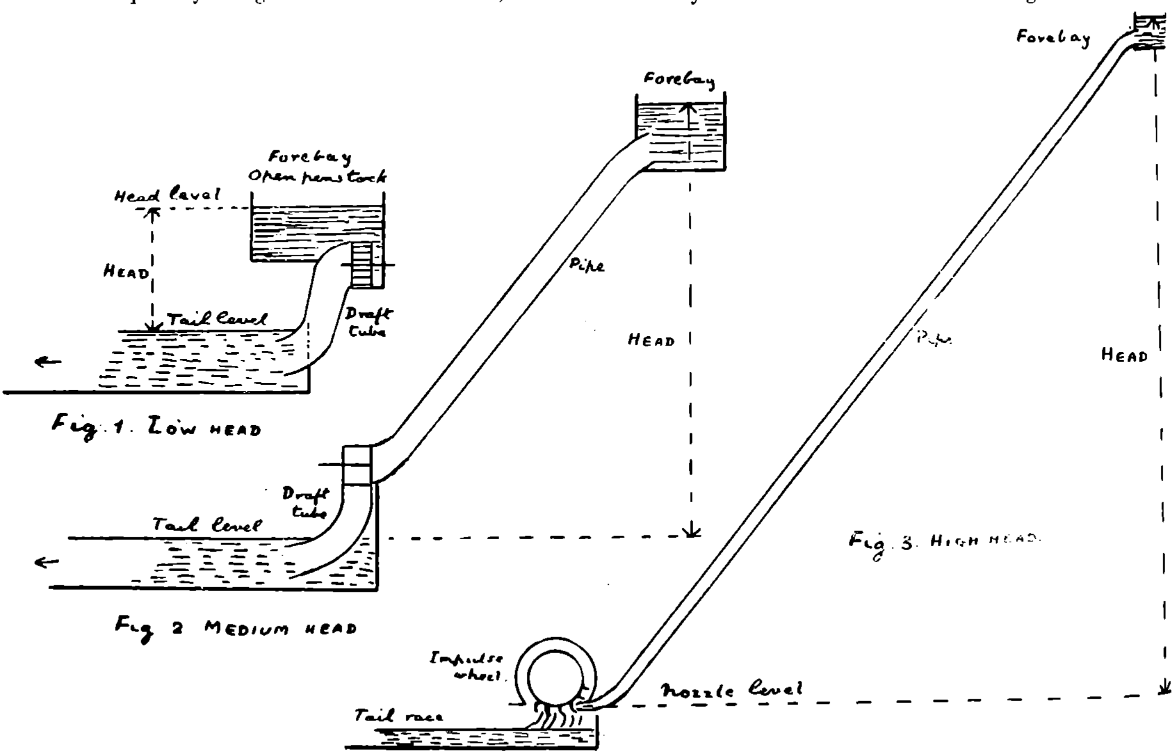
5. Flow and fall.—It is quite clear that, as the *product* of flow and fall is the measure of the power, an immense variety of conditions can be met by variation in one or the other. Thus any product of head and fall that comes to 15,000 cusec-ft. will, on the formula given, show 1,000 kW. in resulting power.

The following variations are all within the limits of actual practice, and all make up the same power (neglecting minor variations in efficiency):—

	Feet.
5,000 cusecs on a head or fall of	3
500 ,, ,, ,, ,, ...	30
50 ,, ,, ,, ,, ...	300
5 ,, ,, ,, ,, ...	3,000

6. "Working head."—Thus the value of a given total quantity or a given rate of flow of water, in terms of power, is directly proportional to the *working head;* this is the difference in level in feet between the forebay, or pipe entrance, or head waters (as the case may be) and the point where the water finally ceases to do work, diminished by the losses in the passage, except turbine losses which come into the turbine efficiency. This is illustrated by Figs. 1 to 3. Fig. 1 represents a very low-head installation, with open penstock setting and draft tube. Fig. 2 represents a medium head plant, fed by a pressure pipe and using a draft tube to the tail race. Fig. 3 represents a high head impulse turbine, and here the water has done its work after striking the buckets, and falls into the tail race freely; the draft head cannot therefore be used. The lowest head that is of practical use (except on a toy scale) is about 3 ft.; the highest so far developed in one stage is over 5,000 ft.

7. Combined irrigation and power projects.—India contains a vast system of irrigation works in the form of canals, fed both by perennial rivers and from storage works. Hitherto the combination of irrigation and power has not made any great strides, although a few canal falls have been utilized and the harnessing of the Periyar Lake has been discussed for a generation.



The main disadvantage of such power is its discontinuity; in the first place, canals fed by tanks or lakes with a limited supply can only be run when the water is needed for the crops, and, secondly, canals fed by silt-bearing rivers have to be closed periodically for repairs and cleaning out. To prevent breaches canals must be closed when rain, sufficient to take care of the crops, falls. Very few, if any, of the Northern India canals have escapes capable of disposing of the supply once the demand slackens, and very few could be provided with escapes at any reasonable cost, if at all. So long as the power is being used to pump water up to irrigate areas uncommanded by the canals themselves, or to drain water-logged land by means of tube wells, closures do not matter; for they occur when these operations would be in abeyance. Where however power is to be used for ordinary industrial purposes it may be a serious matter if both the capital and labour employed are kept idle for weeks. Reserve steam or oil plant may then be necessary, and this involves large additional capital cost.

In any part of India where further irrigation works are needed there may be an opening for the combination of these with power supply. Where large reservoirs are involved this is evident, for the tail waters from the turbines may be discharged directly into canals. It is probable that, in order to get suitable ground for such a canal, it may be necessary to sacrifice some "head" on the power plant; but that can well be faced, as such a combined project might pay where it would not do so if confined to either irrigation or power. The cost of the storage works would be met by both undertakings. In the case of the canals fed by perennial rivers the same combination offers attractions. Hitherto, as pointed out at the Punjab Engineering Congress in 1919, the possibility of utilizing canal falls for power purposes has not been taken definitely into account in their design and lay-out; thus there will often be several small falls in a few miles of canal where a single fall would have been practicable and would have been far better for power development. It is to be hoped that in future this will be borne in mind. Several small falls are however preferred for irrigation purposes on the score both of economy in construction and of facility of command.

A good many combined irrigation and power projects will be found in this Report, especially in Bombay Presidency. As a particularly interesting example of a prehistoric storage scheme, anticipating modern engineering practice in the matter of watershed crossing, the reader may be referred to the Pinjikave project in the Palni Hills, Madras (para. 105). Here a fall of over 5,000 ft. can be utilized before tailing for irrigation.

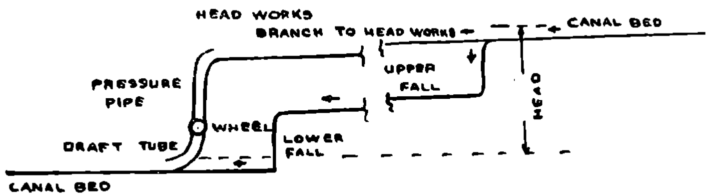
Chapter 2.—Varieties of Hydraulic Lay-out.

8. Turbines for various heads.—The many varieties of flow and fall described in paras. 1 to 4 above may be developed also in a number of ways; and it is one of the main functions of the water power engineer to determine in any given instance which method will prove the most suitable, what working head should be actually used, and so forth. Thus, where high or medium heads are involved, it is often possible to find several sites for the forebay and the power house, giving different heads, one of which will almost certainly be preferable to the others. In low head projects nature or works already constructed more often settle the head, but here again the lay-out may be of several kinds.

On *low heads*, such as canal falls or rapids in rivers, the reaction type of turbine is invariably used—the Francis wheel being the type at present employed. The disadvantage of very low heads is that only low speeds can be obtained, involving either very large generators or indirect driving of high-speed generators. Improvements however are being made; see para. 46. On very low heads an "open penstock setting" is often employed, the open wheels being fixed at the bottom of the forebay itself, with the shaft passing through a water-tight partition. The reaction type of wheel functions by water pressure, the wheel (and its casing, when there is one) being entirely full of water. The discharge from the wheel is conveyed by a draft tube, or suction pipe, to the tail race level, as shown in Fig. 1. It is immaterial up to the practical limit of suction head (depending on the altitude and the atmospheric pressure) whether the working head is above or below the wheel; both contribute in every case. Often the draft head accounts for a very large proportion of the total power.

On *medium heads*, up to several hundred feet, reaction turbines are also generally used at the present day; but there is a zone at about 350 ft. or 400 ft. where either reaction or impulse wheels may be used. The latter may be considered as high head developments. The medium head reaction wheel is fed from pressure pipes, and a draft tube utilizes the available fall below the wheel, as in low head installations (Fig. 2). The draft head is limited to a matter of about 29 ft. on small turbines at low altitudes, and can not exceed about 9 ft. with the very large pipes now often employed on large wheels. On medium heads the additional power obtained from draft is still substantial, but not so vital as on low heads. Moderate speeds, suitable to what is required by the generators, can be obtained within fairly wide limits.

On *high heads* the jet impulse turbine, or pelton wheel, is always used. This does not act by pressure, but by the velocity of a jet striking curved buckets. The casing of the wheel therefore contains air at atmospheric pressure, and the water after striking the buckets runs off freely by gravity, and not in a pipe or draft tube. The height of the tail race water does not therefore enter into the calculation of the head. High peripheral speeds, a trifle less than half that of the pressure jet [$V = 97\text{-}100\%$ of $\sqrt{(2gh)}$], are obtainable with pelton wheels, and the revolutions per minute can therefore be determined by the diameter of the wheel itself. occurring within a short distance; this is only too common (from the power point of view) on Indian canal systems. In order to combine such falls several devices may be employed. A subsidiary high level head race canal may be constructed from the upper fall to a point near the lower fall (Fig. 4), the power house being placed at the end of this so that the draft tubes discharge below the lower fall. Or again, as shown in Fig. 5, the power house may be placed near the upper fall, the draft tubes discharging into a subsidiary low level tail race channel, leading to a junction below the lower fall. Other low fall lay-outs are more

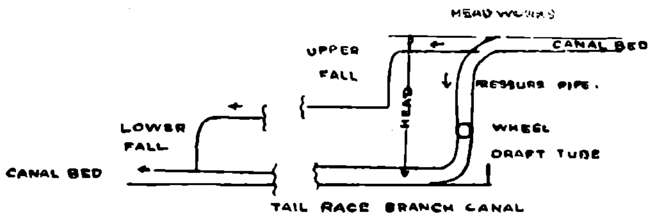


LOW HEAD LAY-OUT FOR DOUBLE CANAL FALL WITH SUBSIDIARY HEAD RACE CHANNEL.

Fig. 4.

9. Low head lay-outs.—Confining the low-head category to cases where an open-penstock setting is, or can be, used the canal fall is typical. Very low river developments are possible on similar lines. Figure 1 conveniently dealt with under medium heads, as there are many instances where the same type will do for both.

10. Medium (or low) head lay-outs.—All heads too high for an open-penstock setting, and therefore



LOW HEAD LAY-OUT FOR DOUBLE CANAL FALL WITH SUBSIDIARY TAIL RACE CHANNEL

Fig. 5.

in para. 6 above is illustrative of such a fall. There is however the special case of two or more such falls involving pressure pipes, up to the practical limit of reaction turbines with draft tubes, may be classed as

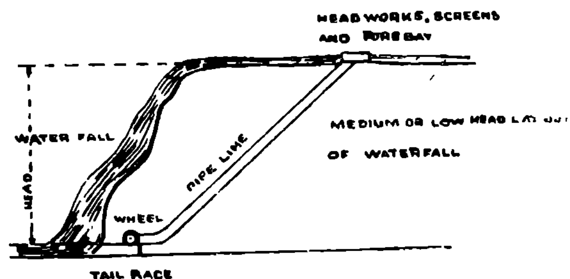


Fig. 6.

medium. Lay-outs suitable for such heads may also on occasion be the best also for high and also for quite low heads. In the first place the natural waterfall (Fig. 6) may be considered. Here a forebay is constructed either in the river, above the fall, or near by. A diverting weir will generally be required to ensure that at low discharge seasons the forebay has the first claim. If the weir has to be some distance up stream a short canal to the forebay may be necessary. From the forebay pressure pipes are taken. These are protected by screens, with isolating gates, so that the screens and pipe entry are accessible for repairs. The pipes lead to the wheels in the power house below the fall, and the draft tubes discharge into a tail race below low water level. As tail flood levels may be very much higher the generators at least must be well above it; but if necessary the turbines can be placed at a lower level than the generators, where they will be submerged at flood times. They then utilize all the draft head at low water, when it is most required. The pipe entry chamber from the forebay must be open to the air, or the very large pipes involved on low heads may collapse from air pressure if they are accidentally emptied when there are valves on the pipe at the top. Hence gates to the chambers are used instead of valves to the pipes.

A variety of the above lay-out is shown in Fig. 7, where the turbines are placed at the bottom of a vertical wheel shaft. The pipes are taken down this shaft from the forebay, and a tail race tunnel is constructed to below the falls. In the original Niagara Falls installations this lay-out was adopted, with vertical shafts driving the generators on the surface. In another American power scheme the whole power house is underground in an excavated chamber—by no means a desirable arrangement except in cases of dire necessity.

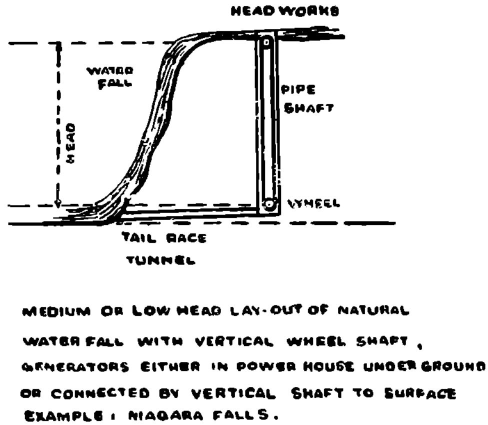


Fig. 7.

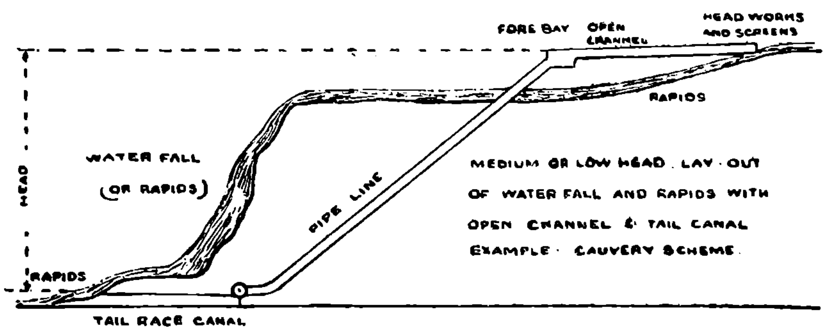


Fig. 8.

Fig. 8 shows the lay-out in the very common case where there is a natural waterfall or cascade with rapids either above it, or below it, or both above and below. Many such projects are recorded in this Report. The additional head obtained, so long as its cost is reasonable, may be of great value. When the dependable flow is known the continuous extra power due to the extra head is found at once. Converting this into units (*i.e.* kW. × 8,760) the probable sale value of these units can be taken at, say, half an anna and this revenue can be capitalized at 12 per cent. to see what capital expenditure is justified in order to get them. The general lay-out is then the same as Fig. 6 except that open head channels, or tail channels, or both, are added.

In Fig. 9 an entirely new situation is met by means of a "lifting dam." The function of the dam is to back up the waters and give a head where otherwise there would be little or none. Thus gentle rapids or a moderate bed slope over a long stretch of river may be converted into a still lake, with an artificial fall of the whole amount concentrated at one point. Provided that the perennial flow of the source is sufficient the full head due to the dam is always available, though, by using a small amount of the top water for regulating purposes, peak loads much in excess of the continuous capacity of the source can be dealt with. If the impounded water has a very large volume and water spread the storage itself may even be sufficient to increase the average power over considerable periods without seriously reducing the head. A succession of several lifting dams is often employed, as in the river which supplies the factories at Notodden in Norway; this method of development has enormous possibilities *if* floods can be regulated. The spillway for excess water is generally the dam itself. The supply pipe is taken through the dam to the wheels, or the power house (when no other better site exists) may be inside a hollow dam. With low lifting dams an open penstock setting may even be employed. The draft tubes discharge into a tail race or (more often) directly into the river below the fall.

Where a lifting dam can be placed at a site that allows of considerable storage, and there is a natural waterfall or series of rapids immediately below, the resulting lay-out is that of Fig. 10. Here the main fall is supplemented by the height of the water behind the dam, between full-supply and draw-off levels. So long as the variation is not too great the turbines can be designed to work satisfactorily on such a variable head. The reservoir then may be either simply a regulator for daily load variations or, if large enough, a source of main storage to tide over dry periods or even seasons. The pipes are taken off through the dam, leaving sufficient "dead water" space below to collect silt, and the power house is placed below the fall with draft tubes leading to the tail race level. Silting up is of course a possibility, which became a fact at the Cordite factory installation at Aruvankadu. Under sluicing at flood times is only a partial remedy. There may be cases where the fall obtainable with this class of lay-out comes under the class "high," in which case pelton wheels would be used and the fall below the wheels would not be used.

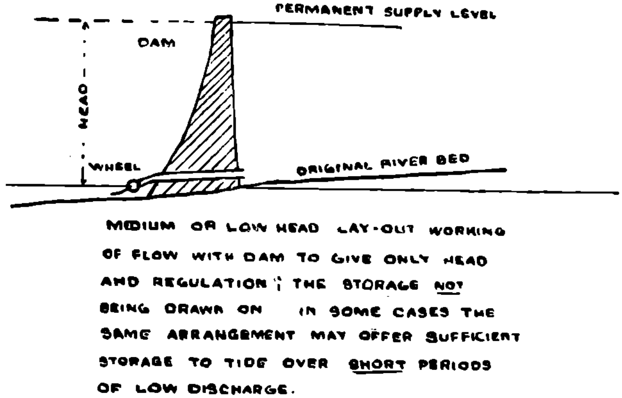


Fig. 9.

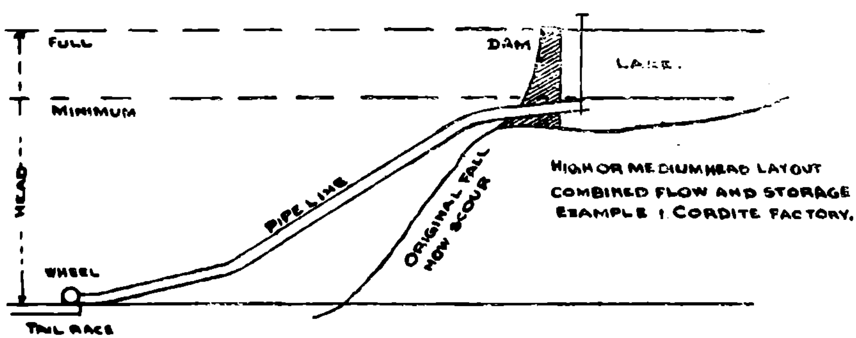


Fig. 10.

11. High (or medium) head lay-outs.—Where the flow of a source is sufficient without storage the type of lay-out shown by Fig. 11 is common. This only differs from Figs. 6 and 8 in not necessarily involving a natural waterfall. The pipe line may not be near the river, but will be wherever the fall can be obtained; this may be by short-circuiting a bend in the river, in which case a pressure tunnel may function as a pipe through an intervening spur. Again, the fall may be into a different river, or there may be a long steep bed-slope as in the Mussoorie installation.

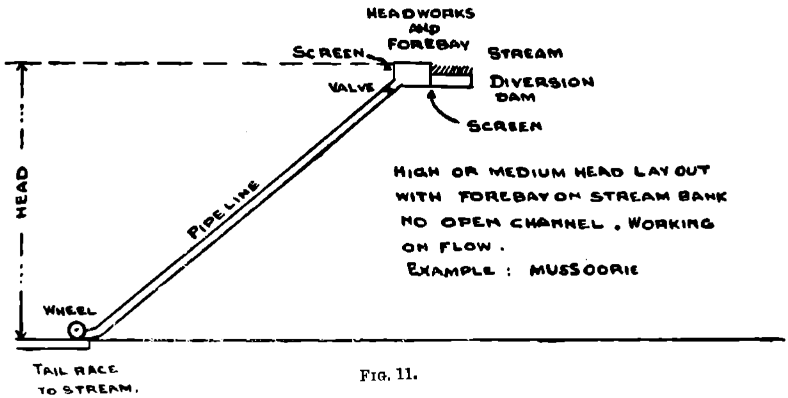


Fig. 11.

More often cases where a water-parting is penetrated are dealt with on the lines of Fig. 12, which is also applicable where the steep fall has a more gradual, but still useful, fall above it. Taking first the case of a pressure tunnel, it is plain that anything of the nature of water hammer in it might be destructive. At the same time, if pipe and tunnel are one closed up unit, water hammer is always a possibility in case of accident. A surge tower at the junction of pipe and tunnel obviates this possibility; it is open freely to the air (as a rule)* at a level above that of the supply source, and any check in the velocity in the pipe simply causes the water to rise in the surge chamber. Both the chamber and the connection between it and the pipe may be cut in the rock, in the case of tunnels, as presently illustrated.

Where the upper part of the pipe line has a comparatively small slope for a long distance a surge tower may be built up at that point; this enables a light pipe to be used, and the pressure pipes for the steep slope originates at the surge tower junction. The surge chamber has a second and equally important function in acting as a secondary forebay, supplying the demand from its storage while the column of water in the tunnel or upper pipe accelerates. The figure illustrates the case where flow is utilized, but there could be either a lifting dam or a storage dam where the forebay is shown.

* The compound surge tower may be closed and employ air under pressure. For these and differential surge towers see books on the subject.

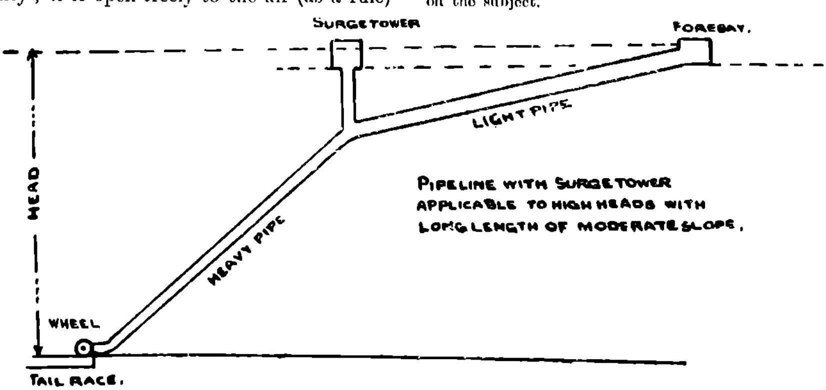


Fig. 12.

The pressure tunnel lay-out is more often employed where the supply is from storage, as illustrated by the Andhra Valley works shown in Fig. 13. The watershed here diverts the monsoon fall from the Bay of Bengal into the Indian Ocean, and utilizes the steep fall on one side of the Western Ghats where there is only a very gradual fall on the other.

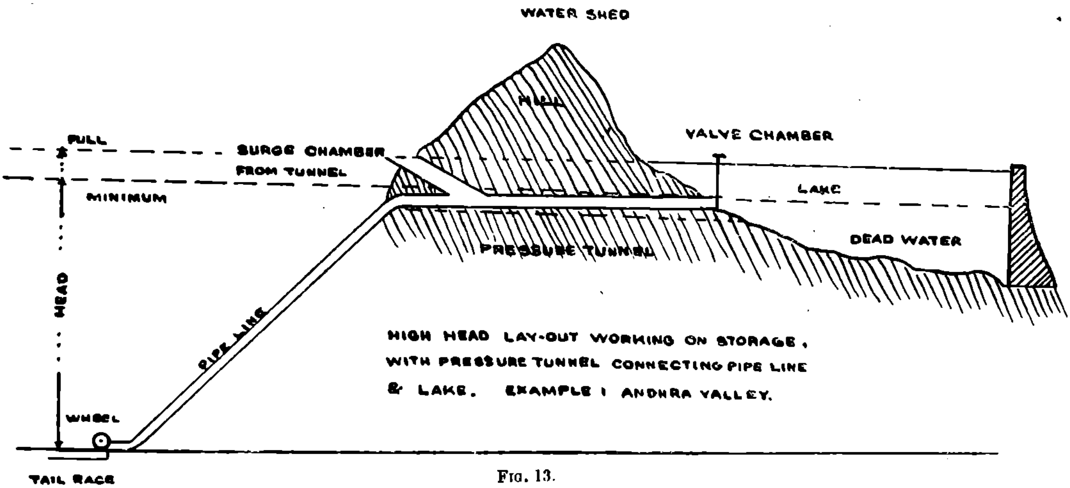


FIG. 13.

The majority of high head and many medium headworks are laid out on the lines of Fig. 14, which is very similar to Fig. 8. Here the main feature is a long open channel, or several such channels, which may carry the supply along for many miles until sufficient fall has been accumulated above the stream. This lay-out is therefore peculiarly suitable for mountainous country. There may or may not be storage at or above the headworks; if the canal or open channel is of great length there *must* be sufficient regulating storage in or near the forebay, so that sudden demands can be met while the supply in the channel is increased at the headworks. The only exception is when (or for so long as) the constant supply is in excess of the maximum demand.

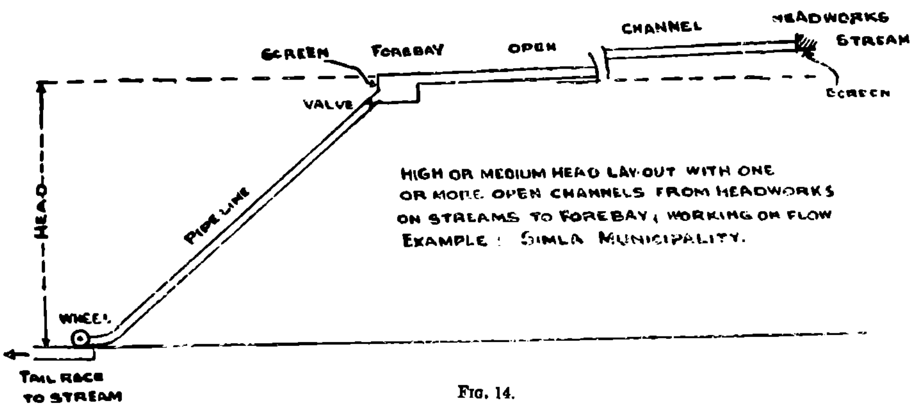


FIG. 14.

A common variation of this lay-out is where channels are brought from two or more streams to a common forebay, above their junction, the fall being then utilized to that junction.

Finally Fig. 15 illustrates a combination of Figs. 13 and 14 as carried out at the Tata Hydro-Electric P. S. Co.'s works.

Here it will be seen that the main storage (Shirawta Dam) is over the main water parting and is fed into the Walwhan lake as required. The whole supply is from monsoon storage, as there is very heavy rainfall over a small catchment, and no flow at other times. A long open channel of masonry

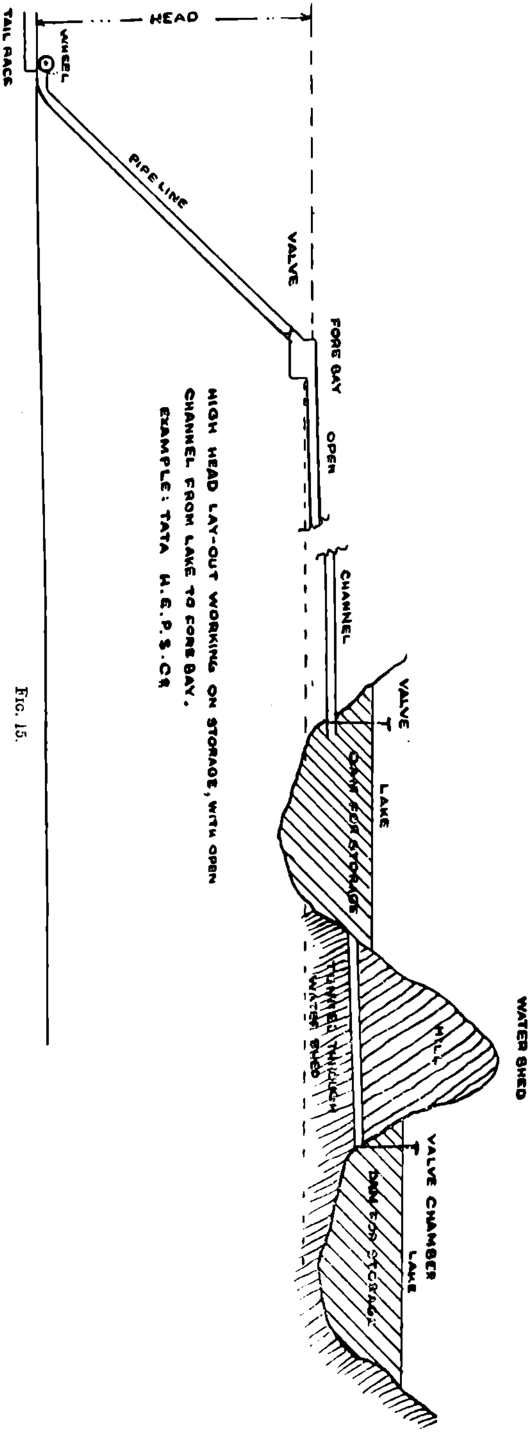


Fig. 15.

leads to the forebay and pipe line. A third lake (not shown) also exists some way along the open channel, and is now used only during the monsoon.

12. Head works.—In the case of canals the supply will generally be available without any special head-works. Similarly, in the case of a large natural reservoir, the dam itself will generally be the headworks. In both these cases the water used for power will not usually have any silt that will affect the turbines, though a reservoir will slowly silt up. In the case of river developments there is always present the liability of bringing down mud and debris from the source of supply to the turbine wheels. This liability increases with the head as torrents take the place of larger rivers, and its effect on the wheel buckets also increases with the head and the spouting velocity of the jet or nozzle. Even the finest grit under a head of 1,500 or 2,000 ft. is most destructive, and loss of efficiency soon results from worn needles and nozzles. Where the head-works have a considerable dam there is no danger from stones or heavy matter except that their deposition will reduce the capacity of the lake ; but in hill torrents this in itself is so serious a matter that high dams would seldom be justified. Such a lake could only be cleaned out at great expense, though under-sluices may enable the debris to clear itself if there is enough water to spare and if the lake is only of moderate size. If, however, such a dam is necessary it will sometimes pay to put another and smaller one further upstream, simply as a means of arresting the silt for a few years. The capital charges would generally be less than the cost of periodical cleaning out. With lower velocity in the stream such dams are often practicable, though not necessarily at the point where the water is tapped off.

Generally speaking, in the case of high and medium-head plants, a low diversion dam is all that is necessary, sufficient to ensure the possibility of getting the water into the channel or pipe under normal conditions, and also to protect the stream at this point from scouring out the channel and endangering the supply in times of flood. Cases have occurred where a few days' abnormal rainfall has lowered the level of a stream bed 30 or 40 ft. For protecting the banks above and below the headworks boulder crates, made up of large boulders enclosed in a frame-work of heavy-gauge galvanized wire, have been found invaluable in every sort of river training works. Cases will sometimes be found where a permanent dam is not necessary, the natural lie of the ground alone ensuring the supply. Timber dams are sometimes used in America for levelling the bed.

In the absence of a dam, whether the water is taken direct into pipes or into a channel—but more especially in the former case—arrangements must be made at the headworks for catching all debris. Generally there will be a succession of screens through which the water passes to a small tank, in which any heavy matter coming through will deposit. This will need constant cleaning out, and should(in the absence of other reserves) be in duplicate. Nothing but fairly fine silt should pass beyond it. If there is no open channel this tank should be large enough to remove even such silt as will deposit readily, or there should be an adjoining settling tank for this purpose. Where there is an open channel there will always be the liability of further debris being collected along it, and a forebay is necessary at the point where the pipes take off; sometimes the lie of the ground makes it convenient to put intermediate silt tanks along the route. All these should be designed for rapid clearance at several exits, controlled by gates of substantial size. By sloping the floor from all points towards the exits the flow may to a great extent be utilized to carry off the deposited mud. The size of these settling tanks should be such as to reduce the normal velocity of flow to a few inches per second. Where there is a reservoir at the pipe head it is still necessary as far as possible to prevent the accumulation of mud in it, as a large volume will become so solid that its clearance is a matter of difficulty, and a silt trap immediately before it will assist in this direction. Where water is considerably in excess of actual requirements it is possible to allow a proportion to run off continuously at the headworks chamber, through partly oven sluices, which will pass out all solid matter rolling along the bottom.

In the case of low heads the water is generally clear, as low velocity postulates a small bed slope and deposition will occur in the river itself. In any case the quantity to be dealt with is so great that artificial settling cannot be arranged for. Strainers are necessary to prevent floating matter entering the pipes, and a forebay may be required to catch anything that may pass through, as well as for regulation. A long canal is seldom necessary, and the forebay will either be at the side of the fall, parallel with the river, or across it on or in a low dam. It depends on the ground whether a diverting dam is required or whether a forebay can be opened directly into the bed of the river. In the majority of cases of very low heads the power station is built across the river, and the water flows directly through the strainers into the turbines.

13. Canals and Open Channels.—In the case where a very large canal is required in connection with a hydro-electric development, the design is carried out on lines of irrigation canals, to which no further reference is necessary. On medium and high heads the channels, if required, are of a smaller order. They may vary in length from a few hundred yards up to many miles, and may be single, duplicate, or multiple. The De Sabla plant of the Valley Counties Power Company in California collects water from a number of streams by means of ditches aggregating about 100 miles in length, like an inverted irrigation system, smaller channels feeding larger ones up to the forebay.

In the case of long channels a break might only be discovered after many hours; and even if due only to an earth fall, diverting the supply without breaking down the channel, it would take time to get this cleared and the water at the forebay again. In the absence of a substantial reserve at the forebay end this would involve complete breakdown. Water-level indicators, electrically controlled, are therefore often used in these cases. In the 10-mile flume of the Columbia Improvement Company at Tacoma, United States of America, the indicator shows every inch of rise or fall; and the large capacity of the flume itself forms no inconsiderable reserve. As a motor runs on rails above the flume little time is wasted in reaching the source of trouble.

For very high heads a comparatively small discharge is required, and this will sometimes be collected from more than one source and by more than one route. Earthwork channels can seldom be constructed in these cases, and the choice generally lies between galvanized iron (for very small discharges), masonry, concrete or timber. Wrought iron semi-circular flumes of large size are also used largely in America, carried on trestles. The first and last have the advantage that they can be carried on a structure without cutting away the ground, at least in the majority of cases. As landslips are always liable to follow the cutting of a roadway on a mountain side this is a great consideration, and an inspection path can be carried alongside or over the channel. If masonry or concrete is used, water running down the hillside behind is stopped at the channel, and either flows into it with mud and stones or sinks in and causes slips. Catch-water drains of substantial size, leading to the nearest culvert, are in such cases essential. Smaller torrents may have to be crossed on bridges, and each of these should be used to afford a discharge outlet for the water in case of accidents and for scouring. Sometimes where water is not over-plentiful it will pay to divert these small torrents into the channel through a small settling tank; for, though their discharge may be negligible ordinarily, it may be sufficient in times of heavy rainfall to tide over a breakdown in the channel higher up. Furthermore, when the main stream is in flood, the intake may have to be temporarily closed owing to floating debris, etc.; whereas the flood water of small supplementary streams will probably be clear and much collection of mud in the forebay may thus be avoided. This is not always true, but is borne out generally by the writer's experience.

Fairly low velocities, not exceeding 3½ ft. per second in unpitched earth channels and 6 ft. per second in other kinds, are generally necessary for the preservation of the channel.* The cross-section may be square, semicircular or trapezoidal, the latter being generally the best as giving the larger hydraulic mean depth. In order to lose as little head as possible (although a few feet on very high heads do not really count much) the slope should be kept small. The inter-relation between slope, velocity, dimensions and the construction and condition of the channel are stated in a number of rival formulæ, none of which are universally applicable; the most useful of these have been discussed by the writer elsewhere† and need not be referred to in detail here. In practice the slope is generally decided on first —from 1 in 500 for small channels, to 1 in 1,500 or so for large ones—and the dimensions are calculated to suit; all irrigation engineers in India are familiar with this subject. It is very necessary, however, to remember that any data found by a formula dealing with a straight length of channel will need alteration where there are bends or irregularities. An opening out of the width by an extra 5 or 10 per cent., carried back to the limit of the possible afflux, may be required to prevent overflow, or a corresponding raising of the height or increase in the slope. Uncontrolled overflow would be almost certain to produce landslides and breakdowns. As, apart from the faults in design, a small fall of earth may easily cause such an overflow, it is sound practice so to regulate the height of the side wall that overflow will take place most easily at places where it can do no harm, *i.e.*, over solid rock, or into streams passed by the way, or, in the absence of these, down artificial spillways. In order to prevent the channel being overfilled at the headworks a method often used is to place a diverting place in the fairway at a point near the headworks, such that any flow beyond the capacity of the channel is skimmed off and discharged back to the stream.

Where masonry or concrete channels are used most of the above considerations apply with equal force. Here it is necessary first to cut a roadway for the foundation, so that the liability to landslips and rock falls is greatly increased. Where the ground is at all doubtful cut-and-cover is necessary, and it is better to spend money on revetments to begin with, than to take the chance of bad ground holding up. It is essential to make culverts under, or preferably over, the channel for the very smallest lines of natural drainage, both for safety and to prevent the access of stones to the channel. Often it will be advisable to lay small drains down such places, with cross-collecting drains to prevent a wash-out. In extreme cases tunnelling may have to be resorted to, for the avoidance of bad ground. It may also pay at times to tunnel through a bluff rather than go round it. Tunnelling on a large scale is also sometimes required either to join up two sources of supply in different watersheds or to lead water collected in one area to a different watershed, where a more convenient or higher fall can be obtained. There are many examples of this class of work in America and elsewhere.

While small works on medium heads may be served by the same methods as apply to high heads, canals in earth are generally necessary. The cost of an artificial channel would generally be prohibitive over a certain size. The largest timber flume the author has seen was at Tacoma, United States of America, and was 8 ft. square and about 10 miles long, with a fall of 7 ft. per mile. No other material could then be used for a channel of this size, and timber has its drawbacks. Unless the water is running full all the time warping is certain to occur, while boring insects and rot have to be faced. The large flume of the Jhelum hydro-electric works has suffered severely in this way.

14. Forebay Reservoirs.—Whether the forebay is mainly for regulation, or whether it also holds a considerable reserve supply, it is an important link in the chain. It must be so designed that, while acting as an efficient surge tank, and as a regulator to deal with loads temporarily exceeding the capacity of the channel, it does not allow any foreign matter to get into the supply pipes. Coarse and fine strainers should be provided, and they should be of such breadth that the *full flow* required by the wheels can pass through them if the water accidentally falls low. This is often overlooked in designing. In some small installations the actual reservoir is at a little distance from the forebay or pentrough, and the two are connected by a closed pipe large enough to deal with the peak load. In such cases the reservoir performs these latter functions, while the forebay proper becomes only a surge tank.

The forebay, or forebay reservoir where these are combined, should if possible be sectionalized or duplicated to admit of cleaning out; and the design should be such as to facilitate this, as suggested above for silt traps. Where the channel discharges into it, which

* For details see Captain Garrett's "Hydraulic Tables and Diagrams" (Longmans).
† "Electrical Engineering Practice," 3rd edition, paras. 349 to 351.

should be at a point as far as possible from the pipe entry, there should first be a small chamber to take eddies and induce still water; this will also catch some of the residual silt, and as its walls will stop a foot or two below normal water-level only the clean overflow will pass into the reservoir proper, and not the bottom layers, except at cleaning-out times. (This of course assumes that the width of the sill is greatly in excess of the width of the channel.) The spill-way and scour valves of the reservoir should be near this point, where most of the mud will collect. The strainer that finally ensures no foreign matter getting into the pipe requires careful thought. The obvious plan is to put it immediately behind the bell-mouths of the pipe, and to close it in at the top. But there is a chance then that some part of it may eventually rust away and get into a nozzle. Repairs would be difficult without emptying the forebay and shutting down the plant, and it has been found in practice that the arrangement is not satisfactory. The alternative design, which should be adopted, is to put the strainers in the main forebay, at the entrance to a separate walled-off chamber feeding the pipe, and this chamber should be covered over. Rolling screens, operated by a winch, are useful because of the facilities they offer for cleaning. A point of importance is that the screens must be capable of passing the full flow when the forebay is nearly empty.

An emergency by-pass from the channel, also provided with a screen, should be made to discharge direct into the bell-mouth chamber. If repairs are required to the reservoir this will prove invaluable, and when the water is running clear it can be used while cleaning out proceeds. These small points of design may spell the difference between success and partial failure, though of course a good deal depends on whether clear or dirty water is generally brought in. For reasons already explained high heads need the most careful treatment. Medium heads may or may not need complicated forebays, and with low heads a plain tank is generally sufficient.

15. Pressure Pipes.—Although primitive water wheels, and turbines such as are found in flour mills all over the hills of India, generally use an open shoot instead of a pipe the advantages of a closed pipe appear to have been long known. Thus in Dante's "Vision of Hell," Canto xxiii, we find:—

> Never ran water with such hurrying pace
> Adown the *tube* to turn a land-mill's wheel
> When nearest it approaches to the spokes
> As then.........my master ran.

There is considerable diversity of opinion as to the best arrangement of pipes for feeding a number of turbines. Apart from the question of cost there can be no doubt that the ideal arrangement is self-contained units of pipe, turbine, generator and step-up transformer, just as in modern steam practice. Where very large units are involved no other arrangement is likely to be used, and on low heads no other arrangement is generally possible. Intermediate cases must, however, be discussed. The diameter of a short pipe on a moderate head may be such as to give a velocity as high as $0{\cdot}1\sqrt{(2g\,H)}$ or 10 per cent. of the spouting velocity. The loss of head with such velocities would soon become too great, and about 3 to 4 ft. per second is a good average. On high heads 9 to 12 ft. per second in the smallest section is about the limit used.

With very high heads comparatively small pipes of great strength are required; the locality is likely to be far from rail-head, so that carriage to site is an expensive matter. It therefore pays as a rule to keep down the weight of individual loads, and to use a single pipe for each turbine. It is, however, often advisable to interconnect the various pipes at the forebay. Each pipe should be capable of being instantly closed at the forebay in the event of a bad blow-out, either by an automatic gate or valve, or by electrical control from the power house, in conjunction with an air valve to prevent the closed pipe collapsing. Each pipe must also have an isolating valve at the forebay or a gate in the forebay.

Where conditions are favourable a single pipe is often used to serve two or more units by means of a receiver at the power house, especially in the case of small plants, but this is not ordinarily recommended.

In order to reduce the thickness of the lower sections of pipe it is customary to use two or more diameters, the smaller at the bottom, and this also economizes in freight where they can be nested. Where individual pipes serve each wheel it is advisable to interconnect them at the power house, so that in the event of a joint blowing on one pipe while another generating unit is out of service they can be cross-served. This involves extra expense in isolating valves, but is generally worth while. It is not an identical proposition with the receiver. Long lines of pipe, such as are required on high heads, require very substantial anchoring not only at the top and bottom, but at several intermediate points. These also provide safe positions for expansion joints, which can be dispensed with only where the temperature variations are small or the line has many angles in it—and not always then. Air valves are not often required, but will be where there is an unavoidable rise in the pipe line. Occasionally air cushions are provided in very long lines, to take up shocks; at the Mill Creek plant in California the pipe is 8,700 ft. long for a head of 1,950 ft., and both air valves and cushions are installed. The latter consist of duplicate cylinders for recharging at the necessary high pressure.

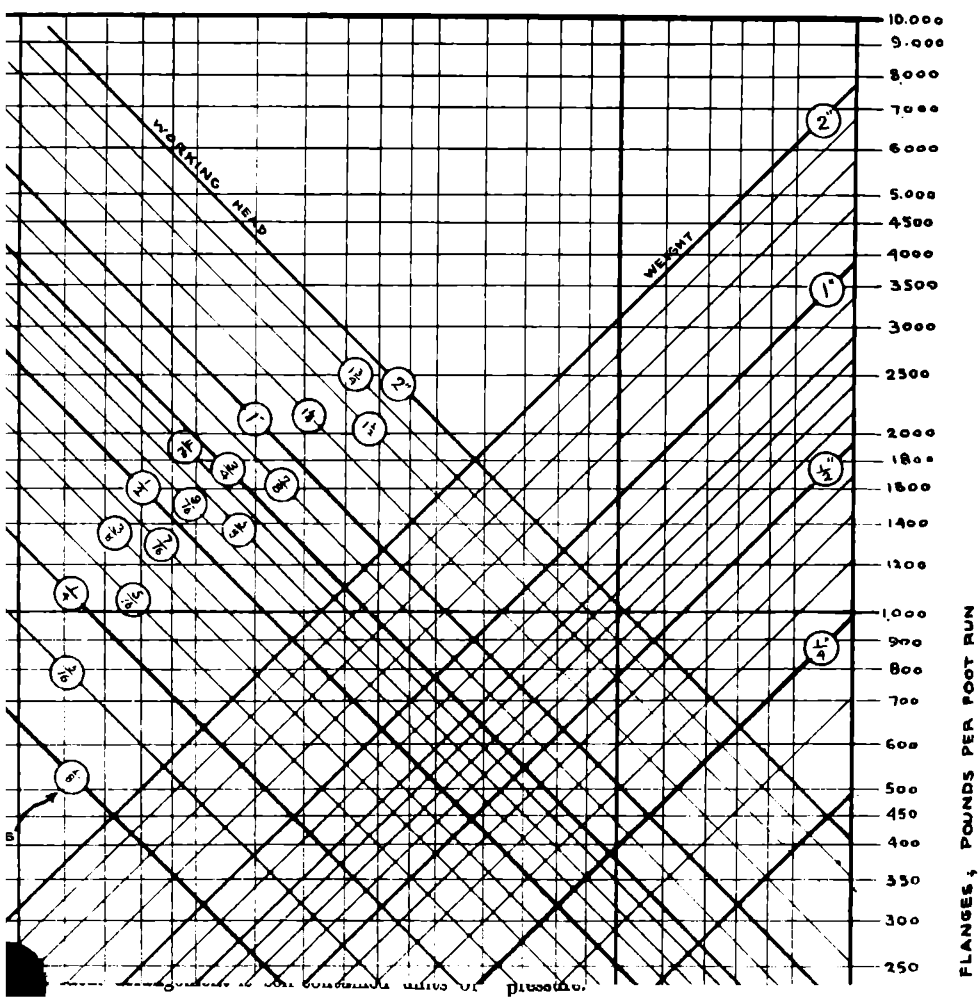
DIAGRAM 'B'

RIVETTED STEEL PIPES

WEIGHT PER FOOT RUN INCLUDING FLANGES

SAFE WORKING HEAD

PLATE VI.



The reduction of effective diameter due either to ordinary furring from lime, etc., or more particularly to fine mud deposited when the water is standing, may seriously increase the loss of head. Although cleaners of the revolving turbine type can remove a good deal of this deposit, the initial diameter should be always greater than is indicated by the velocity decided on.

There are no special points in which the pipe system on medium heads differs from that already dealt with. The pipes are of larger size, and their carriage becomes more serious unless they are built up at site, but on the other hand the locality is generally more accessible. Air valves and cushions are seldom required.

With very low heads and submerged turbines the draft tube is the only pipe required, while with somewhat higher heads there will be both pressure pipe and draft tube. With large units of plant the size of the pipes becomes very great and the internal hydraulic pressure becomes a secondary consideration. Cases are on record where an automatic gate, serving a very large pipe, was closed at the forebay and air pressure caused a complete collapse. No interconnection is usually practicable or necessary with low heads.

Plates V and VI give in a handy form the chief characteristics of steel pipes for water power work, by means of logarithmic curves. The general form of the curves follows that given in Garrett's "Hydraulic Tables and Diagrams" for cast iron pipes, and acknowledgment is due to that Author; it has the advantage that complete data for any size and thickness of pipe can be contained in one diagram. To avoid crowding however separate curves are given for A Welded pipes and B Riveted pipes.

Working head; basis of diagram.

In calculating the working head the ultimate strength of the steel is taken as 25 tons. A factor of safety of 4 is assumed and, in the case of riveted pipes, an inefficiency of 0·8. The formula then becomes

$$\text{Working head, } H = \frac{t}{r} \times k$$

$$\text{or } t = \frac{H \times r}{k}$$

where k is 32,000 for welded pipes and 26,000 for riveted pipes; r being the internal diameter and t the thickness, both in inches.

Working head; example.

The diagonals sloping *downwards* from left to right are used to find the working head for a given pipe, or the thickness of a pipe of given size to work on any head. Thus, finding the working head on the abscissæ and the diameter of the pipe on the ordinates, the diagonal at which they intersect gives the required thickness.

So, from diagram B, a riveted pipe of 50 inches internal diameter to work on a head of 260 ft. must be ¼ inch thick.

Remembering that the scales are logarithmic, interpolation can be effected by eye nearly enough. If however a slide rule is laid across any of the scales (vertical, horizontal or diagonal) in such a way that any two numbers correspond on the paper and the rule, then exact interpolation is obtained. Care must be exercised not to use the wrong set of diagonals.

In the above example, as 1 foot head = 0·433 lbs. per square inch, the static pressure will be 112 lbs.

Weight of pipes; basis of diagram.

The weights given are only approximations, as for any particular complete pipe the addition due to the weight of flanges of varying thickness may be spread over a length of 10 to 30 ft. Garrett in the book quoted above gives curves for the plain tube only, with a note as to the way to add for the flanges. The present curves are based on the weight of the tube at 41 lbs. per square foot 1 inch thick, so that:

Weight per foot run in pounds is

$$3{\cdot}14\ d\ (41 \times t)\ 12.$$

For welded pipes 25 per cent. has been added for flanges in the thinner pipes and 20 per cent. in the thicker ones. Riveted pipes have been taken as 16 per cent. to 20 per cent. heavier than plain tubes, with an addition as before for flanges. Reference to the weight list of pipes in catalogues (where flanges are included) show that the results are near enough for rough estimating purposes.

Weight of pipes; example.

The diagonals sloping *upwards* from left to right are used to find the weight of the pipe, after determining its thickness. Taking the internal diameter on the ordinates, and running up until the diagonal for the required thickness is met, the abscissa opposite will give the weight per foot run approximately. Interpolation as before will give intermediate points.

The scales have been made so comprehensive that they include pipes which would ordinarily be impracticable, as for instance a 250-inch pipe of unmechanical thinness. This however will cause no confusion, and a very thin pipe of large diameter may be used as a core in a concrete pipe.

From diagram A, a welded pipe of 50 inches internal diameter and ¼ inch thick will weigh (with flanges) about 161 lbs. per foot run; while a riveted pipe of the same size will (from diagram B) weigh about 193 lbs.

Carrying capacity and loss of head in pipes.

For convenience the following table is added to show, for a pipe of any given diameter, the flow in cusecs Q with the corresponding velocity in feet per second and loss of head L per 100 ft. of pipe. As however pipes invariably become encrusted to some extent, and sometimes to a very serious extent, it is always advisable to use a somewhat larger pipe than would serve at the first.

TABLE 1.—*Carrying capacity and loss of head in pipes.*

Diameter, inches.		Velocity in feet per second.						
		3·0	3·5	4·0	4·5	5·0	5·5	6·0
6	Q	·58	·68	·78	·88	·98	1·07	1·17
	L	·82	1·13	1·50	1·80	2·30	2·80	3·20
8	Q	1·06	1·21	1·40	1·57	1·73	1·92	2·08
	L	·56	·77	1·00	1·30	1·60	1·90	2·20
10	Q	1·62	1·92	2·18	2·45	2·72	3·00	3·26
	L	·42	·57	·75	·95	1·20	1·40	1·58
12	Q	2·30	2·58	3·14	3·54	3·92	4·30	4·72
	L	·33	·45	·59	·75	·90	1·12	1·33
14	Q	3·20	3·74	4·28	4·80	5·34	5·88	0·40
	L	·28	·39	·49	·61	·70	·92	1·10
16	Q	4·16	4·87	5·58	0·27	0·90	7·07	8·37
	L	·23	·31	·41	·52	·64	·77	·02
18	Q	5·28	6·20	7·10	7·92	8·84	9·67	10·60
	L	·20	·27	·35	·44	·55	·67	·79
21	Q	7·18	8·41	9·00	10·80	12·00	13·20	14·40
	L	·16	·22	·29	·37	·45	·56	·67
24	Q	9·42	0·00	12·60	14·10	15·70	17·20	18·90
	L	·14	·19	·25	·31	·38	·46	·55
27	Q	11·90	13·90	15·90	17·80	19·80	21·80	23·80
	L	·12	·16	·21	·27	·33	·40	·48
30	Q	14·70	17·20	19·70	22·00	24·50	26·80	29·40
	L	·11	·14	·19	·24	·29	·34	·42
33	Q	17·80	20·80	23·70	26·70	29·70	32·00	35·60
	L	·09	·13	·17	·21	·26	·31	·37
36	Q	21·20	24·70	28·30	31·70	35·40	38·80	42·30
	L	·08	·12	·15	·19	·23	·28	·34
42	Q	28·80	33·70	38·40	43·20	48·00	52·00	57·50
	L	·07	·09	·12	·16	·19	·23	·28

CHAPTER 3.—RAIN AND THE RUN-OFF FROM A CATCHMENT.

16. Rainfall and snow-fall.—Leaving aside deep-seated springs, which as a general rule are not of great importance in water power (as distinct from water supply) the day to day flow of streams and rivers is dependent mainly on the day to day rainfall ; it is modified however by the deferred rainfall due to the delaying effect of large and comparatively flat catchment areas and also by snow-fall. The latter factor is of immense importance in the great ranges of the Himalaya, with vast areas of perpetual snow feeding the rivers by glaciers ; but it is also of considerable significance in lower areas, where the snow-fall may lie for a time and by its gradual melting regulate the run-off. A snow field is an infinitely larger reservoir than any the engineer can construct, but as the sun's elevation increases the flood gates are apt to be opened with disconcerting suddenness. In certain important respects India differs from most countries whose natural resources in water power are now being investigated ; for the rainfall is seasonal, and during many months only occasional thunderstorms break the monotony of dry weather. Generally speaking there is the monsoon period and the dry period, but in the south there are two distinct monsoons, the South-West and the North-East. The variations in the rainfall in different parts of the country are enormous, and the departures from the monthly and annual normals in any given locality are also very great. The normal rainfall for every month at the many hundred rain-gauge stations in India can be obtained from the " Memoirs of the Indian Meteorological Department ; Monthly and Annual Rainfall Normals."

17. Seasona 'monsoons."—Roughly speaking there are 8 dry months and 4 wet months, with the result that the majority of the rivers in many parts of India practically dry up sometime between February and May. Of the large perennial rivers the majority are utilized for irrigation ; but as the canal headworks are practically in the plains this does not prevent them being harnessed for power higher upstream. Apart from canals, it is to the mountainous regions that we must look for water power, and here the rainfall is naturally greatest ; especially in those hills that first catch the moisture-laden winds from the sea. The great central plains of India mostly have low rainfall, but here comparatively little power would in any case be found owing to the extremely small slope of the ground and the great variations in the normal water levels. The arid area in the North-West covers mountainous districts, mostly trans-frontier, and even if power were available it is doubtful if much use could be made of it in such unsettled country. This last consideration applies also to various mountain ranges in the Northern Burma region, which are either " Unadministered Areas " or are inhabited by uncivilized tribes ; but in some of these areas there is good rainfall.

Except in localities where storage on a very large scale is possible, such as the Western Ghats and possibly the uplands of the Central Provinces, the greater part of the *monsoon* rainfall of India must necessarily pass to the great rivers and canals undeveloped for power purposes. Thus, for example, take the case of the Jaldaka River in the Bengal Duars (para. 80), a stream with considerable possibilities ; it has a catchment area in the neighbourhood of 250 square miles above the point where it enters the plains, and the annual rainfall is not less than 150 inches ; probably it may average 200 inches. This nearly all falls in the 7 months of

April to October and amounts to some 75,000 m. c. ft., giving an average flow of nearly 4,000 cusecs and a maximum flow enormously greater. Yet the flow gauged in April 1919 was no more than 170 cusecs. Clearly in the absence of a phenomenal reservoir site—and the Himalayas appear to afford few such—most of this water must run to waste. Furthermore, the control of such a river, when a single day may bring 10 inches of rain or more, is no light problem ; and this is one of the smaller rivers in the district. It serves however as a good example of many potential sources of power. The Bhakra dam project on the Sutlej, now under detailed investigation, has drawn attention to many other sites that may prove suitable for storage on other northern rivers.

18. Perennial and discontinuous power.—As the result of the conditions discussed in the preceding paragraph many of the rivers and streams of India fall to a very low ebb, or dry up altogether in their higher reaches, before the end of the dry season. Where this is so development by *monsoon storage* is the only method of getting continuous power, and this is not possible in most localities. It is true that discontinuous water power may be of value in particular instances, either for utilization in industries that are only manufacturing during the rainy season, such as tea, for which the power demand for drying and other processes is very large ; or for any purpose in combination with reserve plant driven by steam or other fuel. In either of these instances however the cost of the power will be higher than it would be if continuous, as the capital charges on the plant are higher in the second case and spread over a shorter working period in the first.

19. Measurement of a discharge.—Although it will generally pay to develop a river or site on the basis of the constant discharge which can ordinarily be depended upon in the dry season it is very desirable to determine its actual minimum discharge ; this however may mean waiting for 30 years or so, if regular records are not kept. A dry cycle has recently occurred in India ; 1918-19 gave exceptionally low results and the following year was not a good one while 1920-21 has been phenomenally dry in many districts. Unfortunately in these transitional years after the Great War, local Governments have found it impossible to spare the large staff which would be required to gauge even a fraction of the rivers of India. Only the rivers supplying, or likely to supply, irrigation canals are regularly gauged. The minimum discharge of any year is however of value, as some indication of the true minimum may then be obtained by examination of rainfall records in the neighbourhood, especially if the average run-off is known.

The amount of water in cubic feet per second (cusecs) flowing past a given point in any open channel is found by multiplying the *cross-sectional area* of the water *in square feet* by its *mean velocity* in *feet per second.* The first step is to select a straight reach of the stream where the flow is uniform, and where there are no noticeable pools, and to mark off with pegs any convenient length (say 100 ft.) 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. If possible at least three cross-sections should be taken, one near each end of the selected reach and one near the middle of it. The depth can then be measured at 10 or more points at equal distances across the width of each of these cross-sections. If the same number of measures is taken at all three places a mean cross-section can then be plotted, which will give the mean area and hydraulic mean depth. But it must be emphasized that when time does not admit of so much labour rough results from a few measures of one cross-section in a shorter reach are better than the " no information " so often recorded in this Volume.

To obtain the mean velocity of the stream current meters are generally used in accurate work at the present day, as they give definite and fairly accurate results. Where these are not available floats are used ; an orange or an empty bottle serves very well, or a small piece of wood. By taking several observations of the time required for the float to pass along the measured length (preferably with a stop-watch) a fairly accurate mean surface velocity can be obtained, though in hill streams the margin of probable error is high. A single observation with a bottle and an ordinary watch in the hands of an eminent engineer has been known to give a result correct to less than one per cent. as checked by a current meter ; but such coincidences cannot be relied on, and it is seldom likely that the results will be nearer than 5 per cent.

For rough work and conservative results 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 ft. and the floats take an average time of 50 seconds in passing along this length, in a stream having a width of 40 ft. and an average depth of $1\frac{1}{2}$ ft. This gives a cross-sectional area of 60 sq. ft. The surface velocity will then be 2 ft. a second and the discharge

$$\frac{2 \text{ ft. a second} \times 60 \text{ sq. ft.}}{2} = 60 \text{ cusecs.}$$

The reason for dividing by 2 is that the mean velocity throughout the channel is much less than the surface velocity, and the rougher and shallower the bed may be the greater will be the disproportion; in the worst cases it is about half.

More accurate results are obtained by the use of Unwin's co-efficients, depending on the régime of the channel and its hydraulic mean depth. 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 the several cross-sections along the chosen length of channel are used. For most streams and rivers in the hills the co-efficients in the *last column* will be used. It will be observed that with a hydraulic mean depth less than 0·5 foot the co-efficient is slightly below the figure suggested above; this however will almost always give conservative results. The co-efficients are as follows :—

TABLE 1-A.—*Co-efficients for ascertaining mean velocity from greatest surface velocity in channels.*

Hydraulic mean depth.	Very smooth channels—cement.	Smooth ashlar or brickwork.	Rough channels—rubble masonry.	Very rough channels—earth.	Channels with detritus.
Feet.					
·25	·83	·79	·00	·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

In the example given above the cross-sectional area was 60 sq. ft. As the width was 40 ft. the wetted perimeter with so small a depth would be about 45 ft. This would give a H. M. D. of 60/45 or 1·32. In an encumbered channel the co-efficient would be 0·6 or 60 per cent. instead of one-half.

20. Run-off or flow-off from a catchment.—The catchment area or for short "catchment" of a river at any particular point where it is proposed to utilize it is the area of the country drained by the stream at that point, and is bounded by the water-partings or watersheds from the various tributary sources up to the point where the water runs down below the site chosen.

Clearly all the rain that falls in a given catchment area will not at once (if ever) find its way to the stream in the valley; some will evaporate altogether, or sink into the ground to feed springs in other catchments, or be absorbed by vegetation, and the more gradually the rain is precipitated the greater will be these losses. Very light rain after a dry spell may not affect the flow of the stream in the slightest degree. Again, if the ground is steep, barren and rocky there will be a much more complete flow from it than if it is gently sloping and covered with vegetation. The percentage of the rainfall that reaches the stream is called the "run-off."

If the rainfall over a particular catchment area in any period is known, and the stream flowing from it can be gauged, the percentage of run-off can at once be calculated for the conditions obtaining *during that period*; but the rain-gauge readings must be taken at a number of points in the catchment—the more the better—in order to ascertain the actual amount of precipitation. In addition to the very large differences of average rainfall in different localities, and the great variations from the average in particular years, the distribution of the fall month by month and day by day must be taken into account. Minimum discharges on small catchments may vary four or fivefold in different years, and are extremely difficult to calculate; a long series of rainfall averages will, however, indicate to some extent the relation between the unknown discharge of an exceptionally dry year and the known discharge of a particular year. It may, however, be accepted that a study of the daily rainfall observations over a period of 30 years will give a fairly accurate idea of the conditions which are likely to occur in future. Intelligent guesswork of this nature presupposes knowledge of local conditions and long experience.

Formulæ for calculating the run-off from a catchment have been devised by many engineers, but they all employ co-efficients which it is impossible to ascertain without a comprehensive study of the nature of the area and the rainfall. There are two separate cases to be dealt with; first, the *maximum* run-off of a catchment which will cause a great flood discharge for a short period; secondly, the ordinary run-off over a longer period of days or weeks or a year, which will vary from time to time but which gives the total water during that period, whether in a heavy, average or light period of rainfall.

As run-off is stated as a *percentage of the total fall* the following equivalents of one inch of rain, with total or 100 per cent. run-off, are useful :—

1 inch of rain = 100 tons per acre.
= 3,600 cu. ft. per acre.
= 64,000 tons or 2·33 m. c. ft. per sq. mile.

Under the like conditions rain falling at the rate of 1 inch an hour is equivalent to 1 cusec per acre per hour or 640 cusecs per sq. mile per hour.

21. Short-period maximum or flood run-off.—In a small and compact catchment the maximum percentage of the rainfall which will reach a given spot in the river at a given time is (comparatively speaking) simple. If the rainfall is fairly uniform over the area, and the nature and slope of the ground is also uniform the conditions are the most favourable to the computer. In larger catchments, especially long and narrow ones, the water falling near the site selected will have passed away long before that at the source has had time to travel down the slopes and the stream bed. In any steep catchment, a sudden phenomenal but short-lived flood may be caused when, the ground being already saturated, a heavy storm travels down the catchment at about the same rate as the waters flow off. In such a case a flood may come down like a tidal wave; the writer has seen a hill stream rise from a few cusecs up to 40 ft. deep and 200 ft. wide in less than 10 minutes. In the design of headworks, spillway dams and waste weirs or escapes these floods have to be allowed for. In larger reservoirs they assist the filling process but are not a source of danger except when the reservoir is already full, when the flank or saddle escape or the undersluices must be able to cope with the discharge.

The whole question is full of difficulty. Buckley * has dealt fully with it and discusses Dickens', Ryves,' Rhind's, Fanning's, Craig's and Fuller's methods. It is therefore unnecessary to deal with these, but as Colonel Dickens' formula is very generally used in India it may be given.

$$D = CM^{\frac{3}{4}}$$

where D = maximum discharge of river in cusecs.
C = a co-efficient.
M = area drained by the river in sq. mile.

Dickens' value of C was 825 for annual rainfall of about 36 inch, but he held it applicable to falls from 24 to 50 inch. "The formula takes no cognizance of the size or shape of the catchment, nor of its declivity, and provides no factor taking account of the variations in the rainfall."† Buckley gives the actual constants found in 12 Indian rivers, varying from 1,795 for the Tansa down to 120 for the Ganges. Experience however will probably enable fair results to be obtained in many cases. Strange's tables † are generally used in Bombay. The data and tables in the work cited will be found invaluable.

22. Long period aggregate run-off.—An immense flood lasting for half an hour may do incalculable harm, but (unless stored) cannot be of much value for power. It is the actual amount of water which flows past a particular point, either naturally or by man's control, which determines the power obtainable. Where there is a storage reservoir of sufficient size for a year's rainfall the outflow or "draft" can be exactly controlled, and the annual run-off is the criterion. Even with smaller storage capacity a measure of control is possible, over shorter periods. In this latter case the normal flow of the river, from subsoil drainage and springs, or from snow fields, may by itself be sufficient for the purpose in hand; if it is not sufficient, supplementary storage is required; and if no site for such storage can be found the stream is useless for continuous power. Under Indian conditions, except where there is a double monsoon, the streams fall rapidly from about October, when the dry weather begins. The dry period continues until the next monsoon breaks, about the middle or end of June, except for occasional thunderstorms. Long before then many considerable rivers have dried up. To cope with this there must be sufficient stored water from the previous monsoon to keep up the required constant discharge as the flow diminishes; not only so, but also often to supplement the flow during successive years of poor monsoon rainfall (para. 29). It is therefore very important to be able to determine the total run-off from a given catchment, in millions of cubic feet, during the whole monsoon period and also in the case of casual heavy storms at other times.

In the work cited in the previous paragraph Buckley discusses the calculation of annual flow-off ‡ fully, with many tables of actuals. The flow off for 8 *large* rivers and groups varies between 29 and 47 per cent., while the Western Coast (Ghat area) is given as 87 per cent. The average for India, excluding Burma, Eastern Bengal and Assam, is given as 41·6 per cent. Averages are, of course, at best, only a very unreliable guide. "The total rainfall on these tracts in India averages 37½ inch. The Indian Irrigation Commission estimates that this depth is disposed of as follows:—

22 inch or 59 per cent. is absorbed (1) in sustaining plant life, (2) in maintaining the moisture of the soil, (3) in replenishing the subsoil water supply, and (4) by evaporation.

2·25 inch or 6 per cent. is utilized in artificial irrigation.

13·25 inch or 35 per cent. is carried away by the rivers to the sea."§

23. Barlow's method of determining run-off.—The late Mr. G. T. Barlow, C.I.E., the first Chief Engineer of this Survey, studied the problem of finding the aggregate run-off in the United Provinces, with a lifetime of irrigation experience to back his efforts. Realizing the radical inadequacy of all formulæ based on generalities, at least in a monsoon country, he tried analysing the *daily* rainfall records within given catch-

* Irrigation Pocket book, 3rd Edition, p. 299 et seq.
† loc. cit.

‡ Op. cit., p. 324 et seq.
§ Op. cit., p. 325.

ments, where the run-off could also be ascertained, in order to correlate the two. By classifying both catchments and daily rainfalls and adopting empirical constants he obtained moderately accordant results.

Barlow's classification of catchments is as follows :—

A = flat cultivated and black cotton soil catchment;	Rate of flow small; absorption and loss large; run-off small.
B = flat partly cultivated and stiff soils.	
C = average catchment.	
D = hills and plains with little cultivation.	Rate of flow large; absorption and loss small; run-off high.
E = very hilly, steep and rocky with very little cultivation.	

His classification of rainfall into light, medium and heavy daily rainfall involves the entire omission of very low rates of discontinuous rainfall, as follows :—

Light falls under ½ inch in 24 hours should be entirely omitted unless continuous for several days; falls from ½ inch to 1 inch in 24 hours should be omitted if there has been no fall before or after. Falls from 1 inch to 1½ inch in 24 hours, when not followed or preceded by similar or greater amounts, are considered light.

Medium falls are those from 1 inch to 1½ inch in 24 hours when followed or preceded by any but light falls; also all falls from 1½ inch to 3 inch per diem.

Heavy falls are those over 3 inch or continuous falls at a rate of over 2 inch a day; also all falls of an intensity of 2 inch an *hour* or over.

It will be observed that an ordinary rain gauge will give all the daily figures, and they are in fact on record for all the meteorological stations in India; but falls of any given *intensity* cannot be recorded on such gauges. Heavy falls of an intensity of 2 inch an hour or more are probably of frequent occurrence in some catchments; but such a fall, lasting even for 1½ hours, as recorded on the daily sheet, would be classed as medium; if it so happened that a total fall for 1½ hours, at the rate of 2 inch, occurred partly before and partly after the daily hour of gauge reading (8 A.M.) then the heavy fall would appear as a light one when classified from the daily records. At present this difficulty has not been circumvented.

With the above double classification the following are the percentages of the total rainfall assumed by Mr. Barlow to reach the stream :—

TABLE 2.—*Table showing percentage run-off; Barlow's Co-efficients.*

Type of fall.	Type of catchment.	A	B	C (Average)	D	E
Light falls . .	Per cent.	1	3	5	10	15
Medium falls . .	Per cent.	10	15	20	25	33
Heavy falls . .	Per cent.	20	33	40	55	70

Like all other methods this is empirical, but it has the advantage of taking into account more factors than are included in most of the methods referred to by Buckley in the work cited. On the other hand, it involves the labour of going through and classifying the whole of the daily rainfall records for the period involved, and using common sense in classifying them. In considering this method it must be remembered that it was devised from average records obtained from one Province and may be unreliable in another where the conditions are different. Clearly there are two factors of uncertainty, owing to the fact that rainfall records give *daily falls* and not *hourly intensities*. In the first place, isolated falls on a single day and classed as "light" may have actually occurred in an hour or two, when the run-off would generally be much higher than that given by the table, especially in small catchments. Secondly, exceptionally heavy rainfall would certainly give a much higher yield than that assumed, at least on certain classes of catchment. A fall of 20 or 30 inch in one day occurring at Cherrapunji, for example, would give a run-off of cent. per cent. In the Central Provinces falls of 10 inch and upwards are by no means uncommon in one day, and would certainly yield far more than is shown by the table; and these exceptional falls are generally (though not invariably) an important factor in the filling up of depleted reservoirs. At the same time neither the records nor the methods of calculation laid down take account of these factors, though *known* falls of 2 inch an hour or more are classified as heavy. Examination of the original data which form the basis of the conclusions in the following paragraph shows, however, that in tabulating daily rainfall records it would generally be possible to go further than has been the case. Thus all light falls continuing for several days, even though excluded by the instructions, should be counted. Falls near the border line between light and medium should be tabulated as medium on the second and following days. Falls near the border line between medium and heavy should similarly be counted as heavy on the second and following days. Falls of 6 inch and upwards should unquestionably be allowed higher percentages than those in the table. It has been impossible in the time available to re-classify the thousands of falls on the above lines; but the results would probably be nearer those in Table 2. To take only one example; in working out the classification, falls of 2·9 inch and 3 inch were marked as "medium" while those of 3·1 inch were marked as "heavy," in accordance with the letter of the instructions. Clearly the run-off of the latter would not be double that of the former, even in the case of isolated falls, and still less after previous rain.

24. Calculated and actual run-off in the Central Provinces (Barlow's method).—The rainfall records for a number of years have been examined (and tabulated to some extent) in the Central Provinces, for certain areas where irrigation tanks take the run-off. The actual inflow has been compared with that calculated by Barlow's method, and the results are of great interest. To what extent these can be applied in the case of far larger catchments is a matter of speculation ; but the same method has been generally applied in calculating the probable run-off of the river catchments dealt with in the list of sites for further investigation in the Central Provinces. Unfortunately the analysis of results was not completed and (especially in the matter of falls to be omitted and those following continuous rain) the classification is not always satisfactory. The present writer has however made the best of what has been done and the following are the mean percentages found for the 3 classes of catchment available, with areas from 3 to 78 sq. miles.

Catchment.	A	B (3 to 7 sq. ml.)	C (10 sq. ml).	D (78 sq. ml).	E	Average.
Light falls .	..	[43]	28	[10]	..	27
Medium falls .	..	36	51	30	..	42
Heavy falls .	..	48	55	83	..	62
Mean of percentages.	..	42	44	43	..	

The individual variations of percentage are, as would be expected, very great, but the mean results all through show that Mr. Barlow's percentages are too low in the Central Provinces. Light falls especially appear to give consistently higher run-off from medium catchments than the first table gives even for class E. Classified light falls are found to vary from 9 to 28 per cent. of the total classified falls. It would be rash to apply these somewhat tentative conclusions at all widely ; but it is probably safe to assume at least that all calculations of yield by this method in the Central Provinces are very conservative. An addition of 10 per cent. would seem to be well within the mark.

25. Automatic raingauges.—The standard raingauge is merely an air-tight vessel to collect the precipitation from a 5 inch or 8 inch circular funnel, generally involving daily readings. Tank gauges to hold the fall for a considerable period are, however, often constructed for use in places where daily readings are impossible. In this case no indication whatever is given of the times or intensity of the fall. Even with daily readings, as pointed out above, a recorded fall of 2 inch may have fallen in one hour or in 24 hours. Patent office records show that many devices involving the use of tipping devices, revolving wheels with buckets, and float and cord arrangements have been invented ; most of them however have not stood the test of practical use. The writer has no personal experience of the Wilson " Pluviograph " or the " Serpentine " registering and recording raingauge. The former is electrically operated while the latter is worked by a mechanical tipping device. Mr. Tate, Officer-in-charge of the Survey in Madras, has one of the Serpentine type in use and reports that except for minor defects in the recording pen and paper it works satisfactorily.

A point frequently overlooked is that from the point of view of irrigation or power projects, as distinct from meteorological records, a considerable percentage error is of small importance. A run-off can seldom be calculated correctly even to 10 or 20 per cent. If in a given small catchment area, possibly containing one gauge station, ten other gauges were put up, all their readings would notoriously be discordant—especially in the hills, where a heavy fall of rain and a clear sky may be separated by half a mile.

The writer hopes shortly to be able to contribute a further step in the direction sought, and is carrying out experiments with that view.

Chapter 4.—Water Storage and Water power.

26. Load factor and kilowatt-years.—The importance of the annual load factor in hydro-electric schemes, *i.e.*, the ratio of the average load to the maximum load during the year, was emphasized in the Preliminary and Second Reports. Where a project depends mainly upon storage ; or where there is sufficient regulating storage on a project dependant upon perennial flow, the total horse-power or kilowatts of working plant (exclusive of spare sets) which can be *installed* may be far in excess of the *continuous* power capacity of the source. In this Report all power calculations are expressed on the easily understood basis of constant continuous 24-hour power in kilowatts, *i.e.*, in kilowatt-years ; so that in any case the actual possibilities of the site in terms of units of electricity which can be generated per annum are found simply by multiplying the continuous kilowatts by 8760. These units, if the above conditions as to storage are fulfilled, can be generated at any time. Thus, for example, the Tata H. E. P. S. Co.'s plant generates practically the whole of its power during the 12 hours when the mills are working, and very little for the remainder of the 24 hours. The highest load factors at present obtained in India are between 40 and 50 per cent. so that the capacity of the working plant installed in these cases can be from 2 to $2\frac{1}{2}$ times the continuous capacity of the site. With a load factor of only 33 per cent. the working plant installed could aggregate 3 times the continuous capacity. Clearly the latter case, though apparently giving greater power possibilities, is really much less favourable for water-power work, as the total capital cost of a large part of the works will be proportionally higher than in the former case and the utilization of the plant will be proportionally less; in other words, the same number of units generated will have to bear higher capital charges. Should electro-chemical industries be started, load factors of the order of 90 per cent. might be obtained. The forecasting of the probable load factor in any particular case involves a detailed examination of the conditions of the whole of the probable consumer's loads, and the drawing up of load curves based on these data. In the early stages of determining the probable power at a given site this is unnecessary; but before actual development is undertaken it is essential. If the continuous power obtainable is stated, this is all that is required for the time being; it is useless as a rule to speculate on the unknown load factor in order to arrive at a low figure per kilowatt installed. In a few cases in this Report however it has been pointed out in general terms that on "commercial load factors" there would be a low cost of hydraulic development. It might however happen in such a case that, for electro-chemical work, the hydraulic development would be too expensive, as the whole capital cost would be sunk on a plant of the "continuous power" capacity shown and no more. For a practical example of how *regulating* storage, combined with flow, deals with the problem of a load curve and its peak, the reader is referred to para. 28, "Main and Regulating Storage" using for example the Um Tru River, Assam. A practical case is there worked out, with an illustrative diagram, based on such information as is available. It may however be as well to give characteristic load curve diagrams here, and to show what they imply. Of these Fig. 16 shows a load curve for a plant working a continuous electro-chemical process; Case A. The maximum load is 5,200 kW. and the average load is 5,000 kW. giving a load factor of 96 per cent. This is somewhat higher than would be obtainable in practice, for the sake of example.

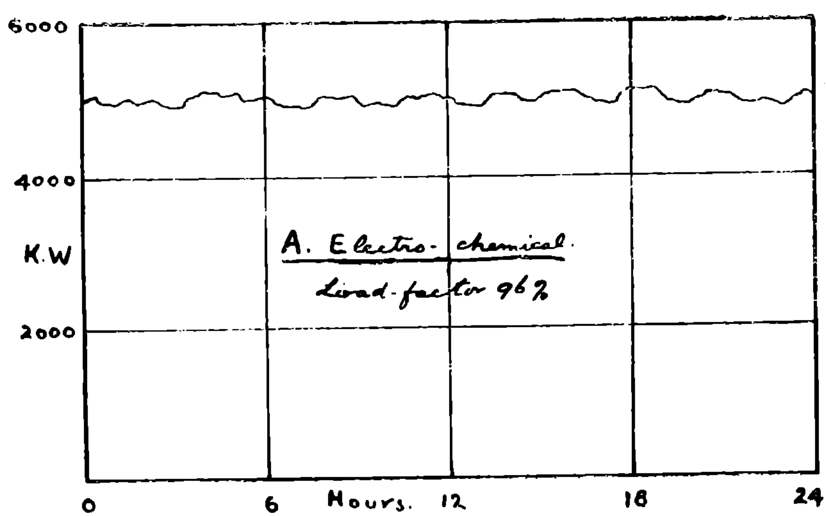


Fig. 16. Load factor diagram.

Fig. 17 shows a load curve for a plant mainly driving factory loads for 12 hours a day; Case B. With a maximum load of 5,000 kW. the load factor is now 56 per cent. The 5,000 kW. is required almost continuously for 12 hours on end. Finally Fig. 18 shows an exceptionally poor town-supply load curve, with a predominant lighting peak load of 5,000 kW. for 1 hour; Case C. The load is at 4,000 kW. or more for 2 hours and at 2,000 kW. or more for 4 hours, but the overall load factor is only 27 per cent. (In each case the load factor may be found from the curve, as the ratio of its area to the rectangle enclosing it.)

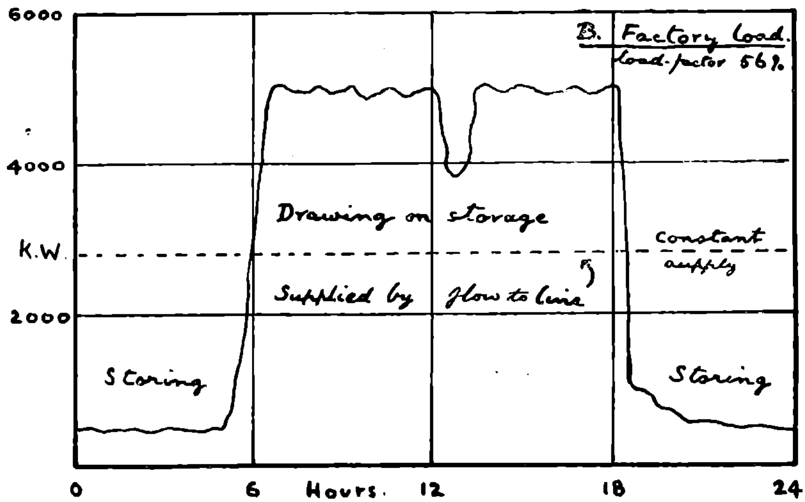


Fig. 17. Load factor diagram.

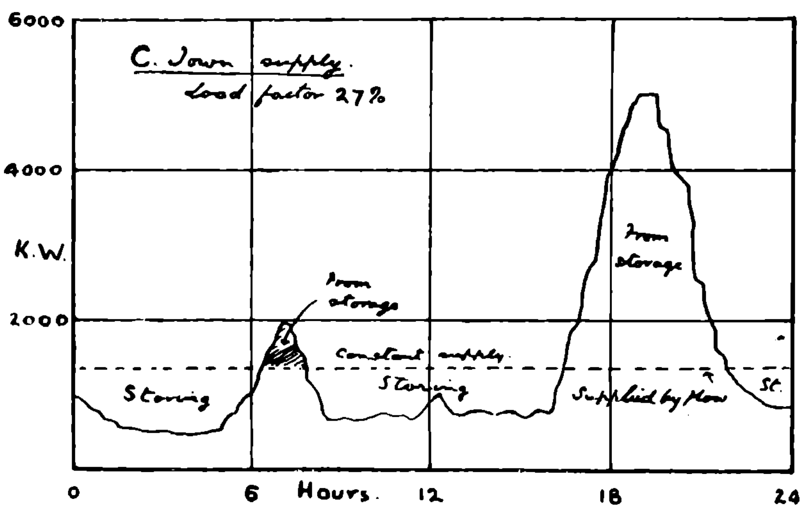


Fig. 18. Load factor diagram.

These curves may now be examined in relation to their supply by water power from flow or storage, under various conditions; thus take heads of 20 ft., 200 ft., and 2,000 ft. Then the water required will be as follows :—

TABLE 3.—*To illustrate load factor.*

Head	Output kW.	500	1350	2800	5000
feet		cusecs.	cusecs.	cusecs.	cusecs.
2,000 . . .	..	3·75	10	21	37·5
200 . . .	..	37·5	100	210	375
20 . . .	..	375	1,000	2,100	3,750

Plant A will therefore require a constant supply throughout the 24 hours of 37½, 375 or 3,750 cusecs according to the head. This minimum flow must always be available, whether it is in the form of minimum stream flow or draw-off from a main storage. If dependence is placed upon storage to any extent, it will require 8,760×37½ cu. ft. per diem on the highest head and 100 times that amount on the lowest, assuming no inflow to the reservoir (*e.g.*, Koyna Valley project in the dry weather).

Plant B, with practically the same maximum load, will require the same constant supply of water as plant A (*i.e.*, 37½ cusecs on 2,000 ft. and so on), in the absence of regulating storage; and during the whole period of low load this flow would then go to waste. But as the load factor is 56 per cent. and therefore only 56 per cent. of the full water supply (roughly) is being utilized for power, it follows that a much smaller constant flow will suffice if there is regulating storage. The average load throughout the 24 hours is in fact 2,800 kW. instead of 5,000 as in case A, so that 21 cusecs can supply it under 2,000 ft. head. But practically 12 hours supply at the rate of 37½—21 or 16½ cusecs, equal to 70,000 cu. ft., must be daily impounded during the light load period to meet the daily heavy load period with this high head. On a 200 ft. head 10 times, and on a 20 ft. head 100 times, this storage must be provided if the available flow is only the minimum of 210 or 2,100 cusecs, as the case may be.

Plant C again has the same maximum load of 5,000 kW. and on flow *alone* will require the same amount of water as in the two previous cases. Here the load factor is only 27 per cent. so only that proportion of the maximum flow will be utilized for power. Here, with storage, the plant could be worked on 10 or 100 or 1,000 cusecs on the three heads, as the average load is only 5,000×27/100 or 1,350 kW. Taking the case of the 2,000 ft. head (for the others are proportional) let it be assumed that only 10 cusecs are available for a dry period. Then all actual loads over the 1,350 kW., which that flow can supply, must be taken from storage. These loads, from the curve, total up to 11,000 kW. hours and would require some 310,000 cu. ft. of stored water under 2,000 ft. head, or 10 and 100 times that amount on the lower heads named.

Thus, in the three cases A, B, C, the smallest constant daily supply of water (whether from a running stream or from a great lake) which will give the energy generated is 37½, 21 and 10 cusecs with suitable regulating storage but 37½ cusecs in all three cases without it, under the 2,000 ft. head. Where there is a main storage reservoir with several months supply it is of course unnecessary to have subsidiary storage so long as the arrangements are such that the required water is always available when required.

27. Water storage generally.—It was stated in previous reports that water storage could seldom be usefully employed except under high heads, and this is generally true. The power obtainable from a given quantity of stored water is exactly in proportion to the working head on the turbines, and therefore it will pay to construct great dams on heads of thousands of feet when it will not pay to do so on heads reckoned in tens of feet, for one-hundredth part of the power. There is no exact point where it can be laid down that the head is too small to justify large storage works; the limit depends chiefly on the cost of the dam per million cubic feet of useful water stored behind it, and this depends in turn on the configuration of the ground and the nature of the submerged land. The cost of competing fuel-generated power also has a far-reaching influence on the decision in each case (*vide* paras. 16 to 18 of Preliminary Report). Recent investigations in the matter of tidal power in Great Britain show clearly that, although the matter is highly controversial, if the conditions for vast storage are sufficiently favourable, it may be possible to use it commercially even on low heads. There are however no circumstances other than those of tidal power of which this is true. Nevertheless the present report shows that in localities such as the Central Provinces, where the rivers are mostly not perennial, and the available falls can seldom be developed above medium height even with long channels, there is *no alternative* to storage if power is to be developed on a large scale. Among the sites of which reconnaissances have been made, and which are now recommended for further detailed examination, are many of which the "head" lies between the limits of 100 and 1,000 ft. At higher altitudes above plains level in this area the catchment areas are too small to give a useful yield, especially when highly variable annual rainfall and frequent failure of the monsoon are taken into account. The ground however offers facilities in many cases for large storage at moderate capital cost, as shown by the many existing irrigation reservoirs and the details of sites disclosed in this volume.

The Central Provinces have been taken as an example here, but the same considerations apply in a greater or less degree elsewhere throughout India. Bombay is fortunate in having higher and less irregular rainfall with elevated catchments in the Western Ghats, containing scores of excellent storage sites. Assam has also very high rainfall over the even more elevated plateaux of the Khasia hills, but with fewer discovered sites. In the Punjab and the United Provinces snow-fed perennial rivers may render storage of less importance for the development of power, though it will be invaluable for irrigation hereafter. Madras is better placed as regards rainfall than other Provinces, having two monsoons over a large area, but storage may play an important part in power schemes there; in many cases however perennial rivers offer good promise. Burma has enormous water power resources, in which storage will probably not figure predominately. Bengal and Bihar appear likely to have far less power than other parts of India, but comparatively little reconnaissance has so far been made in either Province. In some of the Native States of India there are undoubted possibilities, in which storage is generally involved. The adjoining territories in the Himalayan area unquestionaly have almost unlimited power, from snow-fed perennial rivers; but these do not fall within the scope of the Survey.

28. Main and Regulating Storage.—There has been a certain amount of misunderstanding regarding main and subsidiary or regulating storage reservoirs; also between the capacity which a site can contain, the amount of water obtainable,and the effective storage.

The limiting case of storage power schemes is where, as in the Western Ghats, there is very heavy rain over limited catchments for a few months in the monsoon and practically no inflow into the reservoirs at other times. The stored water then has to suffice for some 8 or 9 months of working; and if the rainfall varies greatly (as it does throughout India) there should be sufficient extra storage to make up the deficiency in bad seasons. It is generally found that *the two consecutive driest years* are a more severe tax than an isolated year of minimum rainfall.

Where larger catchments are involved, the rivers fed by them will generally have a considerable discharge for 8, 9 or 10 months in the year; but main storage on a large scale is required to carry over the excess monsoon water to the increasingly deficient hot weather months, with the possibility ever present of a late burst of the monsoon. Here, again, extra storage may be required to make up the deficiency in two bad seasons in succession. If sufficient carry-over storage is not, or cannot be, provided the constant discharge to be reckoned on must be reduced accordingly. The figure of 35 m. c. ft. has been generally adopted as a safe amount of storage to give 1 cusec for a year, after allowing for losses. It should perhaps be pointed out that where the storage site allows little or no carry-over from year to year the single year of absolutely lowest total run-off is the critical period, rather than the worst combination of two less deficient years.

It should also be pointed out here that cases arise where a constant discharge from a reservoir will be necessary for irrigation purposes, at certain seasons, regardless of power requirements. This should in these cases be allowed for in storage calculations, leaving the method of effecting it until such a project matures; there will then be no difficulty in designing accordingly. The governor could bye-pass the full supply through a relief valve when not required by the turbine (*see* para. "Technical Progress"); or governing could be done by diversion or deflection of the jet (in the case of impulse wheels) without using a spear in the nozzle; or, again, the deficiency could be made up by hand regulation from any power pipe not in use at the time.

Returning to those instances where main storage is largely depended upon, it is seldom necessary to have a large amount of regulating storage also. It may so happen that the project necessarily involves an upper and a lower main storage reservoir, in different catchments, and except for the expense of two dams this is advantageous. Ordinarily speaking, if the forebay site can be made to hold 24 hours' or even 12 hours' full load supply, no other subsidiary regulating storage is necessary. Such an amount will obviously deal with every possible hour-to-hour variation in the demand up to any peak load; and, except in the case of a break-down in a channel, the forebay can always be kept practically full.

If however the forebay site does not admit of sufficient storage the question turns chiefly on the length of the open channel. It will take the water about half-an-hour to traverse each mile of open channel, so that for a 10-mile channel some 5 hours will elapse between the time when the sluice is altered and that when the supply to the forebay will respond. If then the main outlet for the power is a factory load, rising from a negligible amount to full load at a certain hour, and closing down similarly, this time-lag of 5 hours would have to be reckoned with at the head-works. In such a case it would be desirable to have a subsidiary storage of about a day's supply, more or less according to its capital cost, at the nearest practicable site to the forebay. But the cost of a *large* storage here would seldom be justified unless it enabled the average draft and power to be increased commensurately. In a number of instances such large subsidiary main storages have been proposed but classified as " regulating " storage.

The proper function of regulating storage in a project depending upon main storage is merely to enable the plant to be operated under all required conditions. For example, a main storage can be depended upon for 100 cusecs continuously, year in and year out ; but the plant may sometimes require 500 cusecs for an hour or two at peak, or 200 cusecs for 8 hours on end with comparatively little for the rest of the day. (These suppositions are unfavourable for hydro-electric works, and are merely by way of example.) The function of the forebay, or, if that is too small, of the regulating storage, is to supply the extra water over and above the average draft, so that the channel from the main storage can be designed to carry that average flow constantly. The saving in cost on a long channel would probably pay for the cost of the regulating storage ; but, apart from this, the latter is a reserve against a temporary break in the channel.

These conditions may conveniently be illustrated from the case of the Um Tru River, entered under the list of sites investigated but not developed in Assam. There is good regulating storage capacity combined with a good minimum flow of 170 cusecs. The problem is to determine what size of plant can be installed. This of course can only be ascertained when the load curve is known, and if the project in question is to go forward the next step is to canvas the consumers and draw up the probable curve—a matter for the electrical engineer. For purposes of illustration a hypothetical load curve may be evolved, see Fig. 19. When the river is at its lowest flow of 170 cusecs, and with a head of 200 ft., 2,300 kW. is available for 24 hours a day, without counting on the storage. The 84 m. c. ft. of available storage, during the dry period of 2 mo., would give an extra discharge of about 2 cusecs, bringing the average power up inappreciably. Therefore in one day 2,300 × 24 or 55,200 units can be generated *and no more*. This is shown on the diagram as a dotted line at 2,300 kW. The actual load curve assumed is shown by the continuous heavy line ; for convenience it is made to run exactly on the squares, though in fact it would of course be wavy. Each square represents 1,000 kW. in power and 3 hours in time, or 3,000 kW. hours in energy and the constant power line has 18·4 such squares. The cross-hatched area *below* this line shows that 3·8 squares or 11,400 kW. hours are left over in storage in every 24 hours. These are absorbed in the cross-hatched peak load area *above* the same line. From 16 hours to 22 hours the whole flow is used and the storage is drawn on; at other hours the reservoir fills. The load factor of the plant is the ratio of the

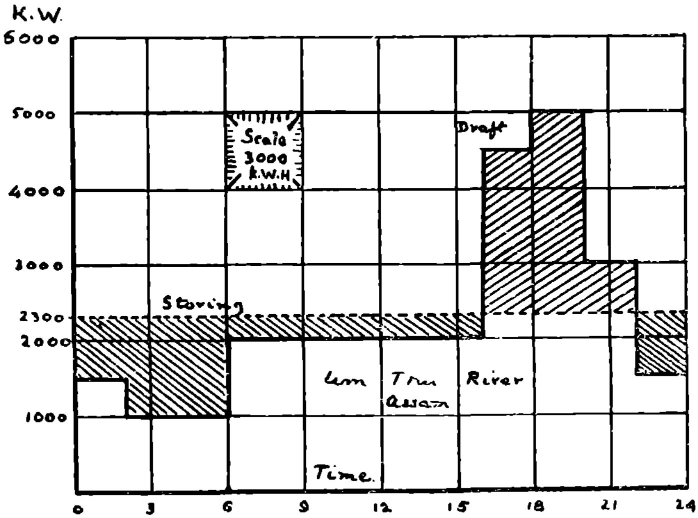


Fig. 19. Regulating storage.

load curve area to the area (40 squares) of the whole enclosing rectangle up to 5,000 kW. *i.e.*, $\frac{18 \cdot 4}{40} = 0 \cdot 46$ or 46 per cent. which is another way of illustrating the ordinary form of $\frac{\text{units generated}}{\text{units possible}}$ or $\frac{55{,}200}{5{,}000 \times 24}$. The peak load shown is 5,000 kW. *Any* other load curve could be met so long as the shaded area above the line does not exceed that below it.

29. Gross and effective storage.—Reverting to main storage reservoirs, it is preferable to confine the term " effective storage " to the actual designed capacity of a reservoir between full supply level and draw-off level. The term has in many instances been used to connote the mean yield from the catchment of the two driest consecutive years. This last figure is of course of the utmost importance in the final design of the works, but it does not, as has often been assumed, necessarily imply that this mean dry-year yield is the utmost that can be depended upon. If the site is favourable, a small addition to the height of the dam may enable a substantial volume of water to be carried over from normal year to year until required to supplement a dry year or cycle. In many cases the investigation of a storage site has been carried only to the point of finding sufficient capacity to store, in each of the two driest years, the estimated yield of that year. This ignores the possibility of carrying over sufficient water from normal years to supplement a dry cycle ; whether this is practicable is a matter of comparative estimates in the detailed survey stage.

Where rainfall data are obtainable over long periods and at sufficient points in the catchment the average yield can be calculated by such method as is locally employed ; often the mean run-off percentage in neighbouring catchments is known and can be used with discretion. Then the yield in the two driest consecutive years on record can be similarly calculated, for which Mr. Barlow's methods. (Paras 23, 24) has been considerably used. If a particular discharge can be obtained, by means of carry-over storage, throughout the second of the two driest consecutive years it may perhaps safely be assumed that the same discharge can be obtained in an isolated year of minimum lower than either of the two consecutive dry years ; this however should be subsequently checked.

Having found the probable yield in good and bad seasons trial and error methods will indicate what constant minimum discharge the catchment is capable of giving at the site ; then it is necessary to see whether the site itself is capable of dealing with the assumed amount. This investigation should preferably be made over a long series of past years, but ordinarily it will perhaps be sufficient (at least during preliminary investigations) to start with the year before the driest 2-year period. Assume that the reservoir is full at the end of the monsoon of the 1st year. Then up to the break of the second monsoon—the first of the unfavourable years—there will be a constant draft of x cusecs. The post-monsoon inflow to the reservoir will at first exceed the draft, and will be surplussed ; thereafter it will average y cusecs for the whole period, so that the net amount drawn off from the reservoir will be at the constant rate of x-y cusecs. Thus the reserve storage at the break of the second and first deficient monsoon is known. The calculated inflow from this monsoon, less the constant draft of x cusecs, will show how much water is in hand at the end of that monsoon. Treating the second dry season and the third monsoon similarly the reserve of water at the end of this latter unfavourable monsoon is found ; it must be sufficient to provide the net draft up till the break of the 4th monsoon (assumed normal), the inflow during this dry period being probably abnormally small.

These calculations may be carried out as explained, or by various graphical methods, including the mass curve and draft curve,—*see* next paragraph. The assumed draft can be modified until it can be met. As regards the reservoir capacity required in any particular case, a very small extra height will give a very great extra capacity at small cost, provided that the site is favourable and the extra submerged land is not too valuable. It is always preferable to carry the investigation of the site up to the capacity indicated by the yield of a normal year.

It need hardly be pointed out that no question of load factor (see para. 26) arises; the draft can be taken at any rate so long as the permissible total is not exceeded. These considerations will also show that where in drawing up schemes the reservoir capacity has been made to fit the assumed mean yield of two dry years there is, in fact, always some carry-over ; for the monsoons are spread over several months during which the power draft is always operative. This has often been overlooked.

30. Graphical method of calculating main storage.—It will be well here to show the common method of determining the amount of storage graphically ; and, as a concrete example is always preferable to a hypothetical one, the case of the Pench reservoir of the Silewani Ghat scheme may be taken. The data of this project are far from complete, and assumptions have to be made, but they are based on such information as is available.

Fig. 20 is a diagram extending over six years, periods of 3 months being indicated on the ordinates in each year. Where the curve rises above the zero line of the abscissae the excess of water is surplussed and lost, so that when the draft first exceeds the inflow the curve starts from the zero line. It is assumed that up till October of the first year there is a surplus going to waste. A constant draft of 250 cusecs, as proposed in the Silewani Ghat scheme, is taken to include both water for power and losses from evaporation, etc. Then the draft from October of the 1st year to January of the 2nd year is 1.950 m. c. ft., but an inflow of 550 m. c. ft. from the tail of the monsoon reduces this to 1,400 m. c. ft. as shown. From April to July no inflow

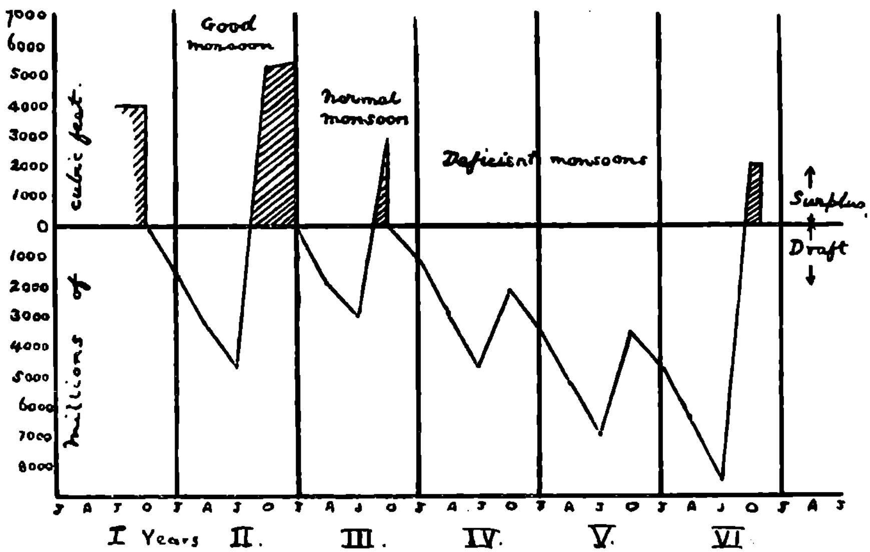


Fig. 20. Main Storage.

is assumed, so a further 1.950 m. c. ft. brings the total draft to 3.350 m. c. ft. The second monsoon is assumed to be a heavy one, giving a run-off of some 14,000 m. c. ft. Against the draft of 1.950 m. c. ft., up to July, 600 m. c. ft. are credited at the beginning of this monsoon, so that the 1.350 m. c. ft. nett draft brings the total draft to 4,700 m. c. ft. as shown. Then the reservoir is rapidly filled and the large amount shown by the shaded area goes to waste. In January of the third year the draft once more exceeds the supply. A normal monsoon follows, the figures being based on those given elsewhere in the Report. It will be sufficient to summarise the remainder of the curve.

3rd year—

January—March—

Draft	1,950 m. c. ft
Inflow	*Nil.*
Nett draft	1,950 „

April—June

Draft	1,950 „
Inflow	900 „
Nett draft	1,050 „
Add	1,950 „ previous quarter.
TOTAL DRAFT	3,000 m.c. ft.

July—September—

Draft	1,950 „
Normal monsoon inflow	7,700 „
Excess	5,750 „

After filling the reservoir, from which 3,000 m. c. ft. have been drawn, the balance spills over; and October starts afresh with full reservoir.

3rd year—

October—December—

Draft	1,950 m. c. ft.
Inflow	950 „
Nett draft	1,000 „

4th year—

January—March—

Draft	1,950 „
Inflow	*Nil.*
Add	1,000 „ previous quarter.
TOTAL DRAFT	2,950 m. c. ft.

Here the first of two consecutive bad monsoons occurs.

4th year—

April—June—

Draft	1,950 m. c. ft.	
June inflow	200	"
Nett draft	1,750	"
Add	2,950	" already drawn off
TOTAL DRAFT	4,700 m. c. ft.	

July—September—

Draft	1,950	"
1st week monsoon inflow	4,400	"
Excess	2,450	"

This excess is added to the depleted reservoir but fails to fill it. It brings it up by 4,700—2,450 to the 2,250 m. c. ft. mark as shown.

October—December—

Draft	1,950 m. c. ft.	
Inflow	850	"
Nett draft	1,100	"
Add previous deficiency	2,250	"
TOTAL DRAFT	3,350	"

5th year—

January—March—

Draft	1,950	"
Inflow	*Nil.*	
Add previous draft	3,350	"
TOTAL DRAFT	5,300	"

April—June—

Draft	1,950	"
Inflow	300	"
Nett draft	1,650	"
Add previous draft	5,300	"
TOTAL DRAFT	6,950	"

July—September—

Draft	1,950	"
2nd week monsoon inflow	5,300	"
Excess	3,350	"

This reduces the total draft to 3,600 m. c. ft. as shown.

October—December—

Draft	1,950	"
Inflow	950	"
Nett draft	1,000	"
Add previous draft	3,600	"
TOTAL DRAFT	4,600	"

6th year—

January—March—

Draft	1,950	"
Inflow	*Nil.*	
Add previous draft	4,600	"
TOTAL DRAFT	6,550	"

Here comes the critical period. The following monsoon may be normal or excessive *when it comes*; but it may break late. If it does not break till July a further 1,950 cusecs are drawn off, bringing the total draft to 8,500 m. c. ft., which is the designed effective capacity of the reservoir. As the annual draft is 7,900 m. c. ft. the carry-over in a normal or good year is 600 m. c. ft. It is a slender margin, and it would perhaps be wiser to calculate on a slightly smaller draw-off *unless* the yield of two bad years proves more than that here assumed.

31. River development by lifting dams.—Hitherto little attention has been paid in India to what is perhaps the commonest method of developing water power from large or moderate rivers, namely by means of lifting dams. (Second Report, p. 12, 2nd para.) To take a well-known example, the cyanamide industry at Notodden (Norway) depends upon a series of power stations on one river. At Rjukam, higher up the river, there are high-head developments supplied from natural snow-fed lakes which have been developed for better regulation. Below Rjukam there is another natural lake, which has been raised to afford further regulation. From this point the river originally descended in a long series of rapids. Along its course a series of low dams has been built, so that the rapids have been converted into a series of lakes and artificial falls of the order of 30 to 50 ft. each. At each lifting dam there is a power station of 10,000 h. p. or so, all of these transmitting their power to the Notodden factories. In most of these low-head installations a short pipe line is used, sometimes with a short canal also, the full available head being of course used by means of reaction turbines. In one case at least a rock tunnel is used in place of a pipe. The whole discharge of the river is available at each site, and the lakes enable the flow to be regulated with fair uniformity throughout the year. In this case there is the additional advantage that the catchment area includes perpetual snows.

It is not necessary that such a series of power stations should be constructed; hundreds of isolated plants in America are worked from single lifting dams on the natural flow of the rivers.

Applying these considerations to India the conditions vary widely. In the Himalayan area the rivers are mostly snow-fed and perennial, and few natural lakes exist which could be utilized for regulation. The Woolar Lake in Kashmir is an exception; the Jhelum river, if regulated at this lake, could be utilized fromBaramula to the plains on the lines suggested, taking the existing installation at Mohora in its stride. In other cases a regulating storage site of great capacity would have to be found and developed; and the floods during the monsoon and the melting of the snows would obviously make regulation difficult on such considerable bed slopes as are general. A suggestion however is made in a succeeding paragraph which may bear fruit.

Elsewhere in India the rivers are not snow-fed; many are not even perennial; nearly all are subject to very heavy floods. Nevertheless such examination as has already been made shows that in a large number of cases reservoir sites can be found with large capacity. It would seldom pay to develop these for the low or low medium fall available at the site of the dam, in order to get a few thousand H. P. If however a single very large storage, impounding the whole or greater part of the average yield of the catchment above it, could be utilized to give a regulated flow to a number of power stations, the aspect of the proposal changes completely. Naturally such a chain of power stations pre-supposes an industrial outlet for the power, but that is a matter apart from the determination of water power resources.

Assuming such a storage reservoir to be constructed in the higher reaches of a river, the regulated flow would continue its course down the natural channel. It would be supplemented by tributary streams, and if a further favourable site were found a second storage might be constructed.

Tributaries with very large catchments would probably have to be regulated by similar storages, as otherwise their unrestricted floods would render power stations difficult to construct and would seriously reduce the head at them. In all probability the fall from the draw-off level of each main storage would be sufficient to justify the provision of a power station, which would work on a variable head between this minimum and the high flood level of the reservoir. Wherever conditions were suitable below the main storage, a lifting dam of suitable height could be constructed to give a head of (say) 30 to 100 ft. The storage behind such a lifting dam would not generally be used except for the day-to-day regulation of output, and the meeting of peak loads. The head would therefore be constant, or nearly so, and any excess water would spill over the dam. Floods would, as always, have to be designed for; but the main storages would largely contain them. Various instances will be found in this Report where such a method of development may prove feasible; others will doubtless be found as investigation proceeds.

In certain cases where the above possibility has not been considered, or where there has been no investigation at all, the assumption has been made that the minimum flow can probably be utilized on the drop represented by the gradient of the river for so many miles. The assumption is clearly admissible in dealing with water power resources; for if flood regulation storage were possible it would also enable the minimum flow to be supplemented to some extent throughout the connected chain of stations.

32. Development by barrage.—Where the absence of flood-regulating storage makes the ordinary type of lifting dam development impossible there is still a chance of development by barrage, *i.e.*, by means of a lifting dam, with automatic or controlled flood gates along its whole length. In some cases the loss of head by the rising of the tail waters would bar this method, but conditions differ widely over India and there are almost certainly some sites where the method would be applicable. There is more than one possible manner of procedure. Generally the most efficient method, where the site admits of it, would be to take off the water in closed pipes from below cill level (probably in a tunnel in the bank) and to carry them along to the point where it is ascertained by observation that there will be the most economic fall to a possible power house site. The chief difficulty would lie in protecting the pipes and turbines from the entry of sand and stones; this however is not an insoluble problem. There would have to be as near an approach to a still back-water on the flank as could be made, so that a forebay could be screened off from the river. In a gorge this would have to be cut out of the bank, but as a rule a barrage would only be possible where the width of river is considerable. In this class of project the tail race would be at low water level, to take the discharge of the draft tubes (see para. 8, 31). In flood times both the head and tail waters would rise and so long as the two rises are of equal amount it involves no more than a transfer of the effective head from the draft tube to the pressure pipe. If however the rises were unequal it would mean a greater or less working head, and, within limits, in view of recent turbine developments (para. 46) this only modifies the output of each set and does not render the site impracticable.

Instead of a closed pipe, cases may occur where some length of canal would be required to get the best working head. If this were so it would in all probability still involve tapping off the water below cill level by means of a pipe or tunnel in order to reach the canal safely above flood level. The extra head due to flood rises at the barrage would then be lost, and the rise in the tail waters would definitely involve a diminution of the power available.

33. Flood regulation by tunnel and dam.—It has been shown above that there are difficulties in the case of low head projects, especially those developed by means of lifting dams or barrages, from lack of upstream flood regulation. In many places in this report the lifting dam method is suggested, but the remarks on the Indus (para. 118) may be taken as typical. If that great river could be regulated smaller fry would offer less engineering difficulties. It is pointed out (*loc. cit.*) that the Indus *was* temporarily regulated by a landslip dam in the 'forties, until the dam broke down and let loose the floods. Nature may here have shown the engineer a solution of a great problem, for what has been done naturally, without design or control, can surely be done by man with calculation of the effect. On a comparatively small scale it has in fact been done, with protective dams of masonry or earth, in many instances; for instance, the floods that nearly overwhelmed Hyderabad (Deccan) a few years ago are now contained in a valley above, across which a great barrage has been thrown. If such an earthen dam as was formed on the Indus in Gilgit and on the Ganges at Gohna lake (which still exists) can be constructed with an escape that renders it impossible that it shall be topped by any flood, then one of the most urgent necessities of both irrigation and power would be solved. It would be a rash man who should say that it is impossible. The whole controversy regarding the Sukkur barrage turns on the unregulated floods above.

The mean monsoon discharge of any of the great rivers, of which there are records in the Irrigation Branch, can be calculated; the maximum floods and their duration are also known; factors of safety can be applied to both. Let it be supposed for the moment that a landslip like that recorded on the Indus has blocked a gorge to a depth of a thousand feet (or any lower height in a river with less spectacular gorges) and that the consequent storage will hold up the whole flow at that point for a year (or any other period). It is then only a matter of time for the dam to be topped and the whole lake emptied suddenly and disastrously. But if a bye-pass tunnel had first been constructed, calculated so that it would carry about the mean discharge of the year (or more if necessary) under the varying conditions of head, then the dam would never be topped; in fact it could be so designed that the water could not under extreme flood conditions ever rise within 50 ft. of the top, giving a margin of untold millions of cubic feet. For as the storage level rose, so would the discharge increase as $\sqrt{\text{Head}}$.

Neither the dam nor the tunnel offers any insuperable difficulty in theory. If the tunnel were built, the earthen dam could be made either by high explosives or by hydraulic sluicing, according to the nature of the ground, and if long enough down the river bed some porosity would be immaterial. For the tunnel the ideal condition would be the short-circuiting of a small bend, with the dam at its central points, as the work would then be safe during subsequent blasting and the tunnel could be at such a height above bed level that it would take 100 years to silt up to it. Failing a bend the tunnel could enter the bank some distance above the dam site and discharge at some distance below it, giving almost equal facilities. It is even conceivable that in some of the less violent rivers with large flood discharges the tunnel might be constructed *over* a mile or so of the river bed itself, so long as the dam could be constructed by hydraulic sluicing until a sufficient cushion existed to render blasting safe (see foot-note on page 108).

Such methods need involve no regulation, though of course regulation at the tunnel intake would be of great value if the locality rendered it possible. If however the site were such that intake regulation proved impossible the tunnel would remain open, protected from the admission of anything it could not carry, and the waters behind the great dam would rise and fall within their appointed limits. A temporary flood of 250,000 cusecs for 24 hours would be impounded; the level would rise 100 ft. or 300 ft.; the discharge would increase in the known ratio; and the flood would be spread over a week or a month in the lower reaches, instead of topping the barrage at the canal headworks in the plains below and being lost.

34. Draft tubes and draft head.—In a very large number of cases calculations of power have been made which take no account of the "draft head" on low and medium falls. A power station site has been found at 10 or 20 ft. above high flood level and perhaps 80 to 100 ft. above bed level, and the head assumed has been that from the forebay to this turbine level. Only in the case of canal falls, generally of the order of 8 or 10 ft., has the draft head below the wheels been taken into account in addition to the pressure head. Wherever reaction turbines are used a draft tube is required, *i.e.*, up to the limit of head where impulse wheels are preferable, which may be 400 ft. or even more. On such a high head the gain in power is comparatively small though by no means negligible but on heads of 30 or 40 ft. the draft power may be half the total. Theoretically a draft tube can be used up to the limits of the water barometer, namely about 34 ft. Actually if this were done there would be trouble from air entry and also from the column of water breaking and causing water hammer on joining up again. The practical limit is about 25 ft. at sea level and proportionately less at high elevations; and it also varies with the size of the tube. Details are however matters for designers, and it is here only necessary to emphasize the fact that from 10 to 25 ft.

of draft head may be taken into account. If therefore the power house site, in order to be above flood level. must be considerably above bed level, various ways of utilizing this variable draft head are possible. The draft tube must of course invariably discharge below the surface of the tail race; if therefore the latter will be high above the river level at low water it must be designed so as to discharge over a weir which will keep it full; and this weir must be capable of safe submergence in floods. Within the limits of draft permissible it is desirable to lower the tail race down to the low water level of the river, though this might in many cases be impracticable where the flood rise is great. But there is the alternative of lowering the turbine itself. A vertical turbine can be erected in a wheel pit and connected by a vertical shaft to the alternator in the power house; at Niagara falls some of the wheels are below the surface power house and almost on a level with the foot of the falls. This may involve tunnelling for the tail race exit, and it is a matter of estimating to determine how far the method should be carried; the value of the additional power, capitalized, is set off against the extra cost of the works. It will almost invariably be found that it pays to develop the draft head down to the normal low water level, even though during floods some of this extra head and power will be lost.

Chapter 5.—Reconnaissance and Survey.

35. Maps available and map references.—For general geographical purposes the modern Atlas sheets of the Survey of India, "India and Adjacent countries," on the scale of one-millionth, are admirable. The "Political Edition" shows the boundaries of States, Provinces, etc., while the "Layered Edition" shows the nature of the country in extraordinary relief. *All references in this Report are based on the Atlas sheet numbers.* Thus Delhi is found on Atlas sheet 53; it is in the bottom rank of the second file, or letter H as shown in the following table adopted by the Survey of India, the sixteen "degree squares" being lettered as shown. In a good many cases modern "degree sheets" numbered as above (53 A, etc.) are published on the $\frac{1}{4}$ in. scale (1 in. =4 mi.) and old $\frac{1}{4}$ in. maps of most areas can be obtained. These are quoted as 53 A, etc. Each modern $\frac{1}{4}$ in. map is similarly divided up into 16 squares as follows:—

53.

A	E	I	M
B	F	J	N
C	G	K	O
D	H	L	P

53 A.

1	5	9	13
2	6	10	14
3	7	11	15
4	8	12	16

Each of these smaller squares, covering some 15 miles square, corresponds to a modern 1 in. to the mile map; unfortunately the number published in water power areas is small, but *in referring to a site* the correct 1 in. map is the method used throughout this report. The modern 1 in. maps are subdivided into nine squares thus:—

53 M-16

1	4	7
2	5	8
3	6	9

Jubbulpore will be found on squares 7 and 8 of map 55 M-16 while the marble rocks fall is on square 2 of the same map. Some officers seem to have found great difficulty in correctly quoting positions in this simple manner. The 1 in. maps are also marked A, B, C, horizontally and 1, 2, 3 vertically; thus C 1 and 2 correspond to squares 7 and 8 in the above instance.

36. Larger scale maps and their uses.—For the initial examination of a possible water power site no map on a scale of less than 1 inch to the mile is of much value, and then only if it is contoured. Many sheets on this scale have been issued by the Survey of India, but many still remain to be done; and, of those issued, a large number are not contoured but only show hills by "form lines" or "hill shading." Form lines are of little value in deciding how a channel can be taken from one point to another, or what capacity a dam will give, while these can be determined approximately on even a 1-inch contoured map. Hill shading is valueless for the purpose. It is particularly unfortunate to this investigation that so many of the most likely hills have hitherto not been mapped in detail, though it is quite natural that the more civilized areas should have been done first. For water power will as often as not be found in remote and inaccessible hill jungles, of interest only to the sportsman and the Forest Officer. Forest maps, on a scale of 4 inches to the mile, contoured at 500-foot intervals, with intervening form lines, are available for considerable tracts of country, including much high ground that may contain water power. Where this is so these maps are invaluable, but they are apt to end in a tantalizing manner just at the mid-point of a possible project, and there are many gaps in the middle of mapped areas. In addition to the above there are certain areas mapped on the scale of 2 inches to the mile; and the tracing out of contours on these is much less fatiguing than it is on the one inch maps.

A careful study of the largest contoured 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. 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 watershed 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.

(*i*) By tracing a contour line along both banks of a stream, from any point that appears favourable for the head works of a power scheme, some idea can be obtained as to the possibility of carrying an open channel along to where there is a steep fall. Often one bank is much more favourable than the other, owing to the absence of cliffs or large nullahs which would have to be crossed or to very bad rock, as on the Jhelum Valley road, where the clay is found now on one bank and again on the other.

Where no contoured map can be obtained it is impossible to decide whether a development is practicable or not without a special survey, a lengthy and expensive matter. An examination of the ground by a trained observer, who knows what to look for, with an Abney level, a pair of aneroid barometers, and a thermometer, will however generally indicate whether such a survey is likely to be justified or not. This however is not likely to be of much value except in cases where the minimum discharge of the stream is already known —and it rarely is—unless undertaken in the driest period of the year, when gauging of the flow can be combined with examination of the ground and the rough determination of heights.

37. Reconnaissance Form.—In order to be able to compare reports on sites and abstract them, with comments, as is done in this Report, a standard form is desirable. The form which follows has proved most useful, and is separately printed.

PART A.—RECONNAISSANCE OF SITES.

I. *Site.—Map square* according to Atlas sheet.*
Sheet Number Letter , Square ,
Square of 1 inch map. *River* , tributary of
Reached from
viâ (route, rest houses, etc.)
by motor, other vehicle, or on foot ?

* See method explained in para. 35 *supra*. The 1-inch map squares generally have 9 squares, but old ones have more. The same system may be used for these, *viz*: 1 to 9, etc. For exact location of a particular spot give bearing and distance from nearest village shown on 1-inch map.

Transport available—

II. *Type of project possible.*—Mark of which division or subdivision appears most likely from inspection of site.

High or medium heads with artificial fall—

(1) Headworks (or diverting dam) with pipe line direct to power station, and no open channel either

(*a*) with pipe line on a steep grade throughout, not involving a surge tower; or

(*b*) with upper portion of pipe line on a gentle slope, probably involving a surge tower at junction with more vertical part of pipe line.

(2) Headworks (or diverting dam) with open channel (which includes tunnels) to forebay from which pipe line will take off to power station, either

(*a*) as in 1 (*a*) above, without surge pipe;

(*b*) as in 1 (*b*) above, with surge pipe;

(*c*) variation where the open channel will pass through a watershed in a tunnel, giving a better fall on the other side.

Medium heads—

(3) Natural waterfall or series of cascades capable of development by direct pipe line from forebay at head of fall to the foot of the fall, with no open channel, as in case 1 (*a*);

(4) Natural waterfall or series of cascades where bed slope of river enables extra head to be got by development on the lines of 2 (*a*). A surge pipe is seldom necessary on medium heads.

Medium or low heads—

(5) Rapids, developed—

(*a*) by means of a headworks dam, to give extra head only (not for storage except regulation), with pipe line to power house below rapids;

(*b*) by a low diversion dam only, where the natural head cannot be increased conveniently, with a short pipe leading to the power house below the rapids, but no open channel;

(*c*) as in case (*a*) or (*b*) but with an open channel (which may include tunnels) leading to a forebay, from which a shorter pipe line will suffice.

Low heads—

(6) Single canal fall.

(7) Combination of two or more canal falls,

(*a*) by reconstruction of the length of the canal;

(*b*) by means of a subsidiary channel leading either to a power house near the lower fall or from the tail race of a power house near the upper fall, as may suit best.

(8) Special case of utilizing a fall from a high level canal to a low level canal, or from river to a canal. This might be a medium head proposition, but would generally be a low head.

III. *Head or fall.*—Approximate gross height of *natural* waterfall, ...feet.

Approximate gross height of *artificial* fall or of *natural fall increased by extra head* obtainable above or below same, by means of an open channel, ft.

State method of determination, by level, aneroid or map contours. The gross head should be estimated from the power house site to the forebay site in the case of high and medium heads. For falls classified as "low," or using draft tubes take the vertical height between head waters and tail waters.

IV. *Flow and Storage.*—State whether it appears probable that the project in the first instance will mature—

(*a*) on natural flow alone, with (or without) regulating storage only. Nearly all low falls will be of this nature as cost of storage is usually prohibitive.

(*b*) on natural flow supplemented by storage in dry months. Applicable to medium or high falls.

(*c*) on storage alone. High falls only, as a rule.

V. *Flow of rivers.*—If known give the maximum recorded flood discharge. cusecs.

If known give the minimum recorded discharge cusecs.

Recorded at (location); Date

Where records are kept give the rough average discharge that is found during the dry months in good and bad years: cusecs at (location).

Where no regular records exist give results of any special gaugings available in form:

Year , date , previous rainfall of month inch, discharge observed cusecs. When is the discharge likely to be at its lowest?

In the case of low head *river* developments of type para. II (5) above, state whether it is likely that in flood times the tail waters below will back up more than the head waters, and thus diminish the available head. In a gorge, or where there is a gorge near by down stream, this is likely to be the case. With a river narrow at the headworks and wide, with a fair bed slope, below the station site the head will probably be increased.

Is the river liable to sudden spates of great intensity ?

Is it snow-fed from permanent or from winter snow ?

VI. *Rainfall ; catchment ; run off*—

Catchment area above dam or headworks

Raingauge stations within or near same

(*a*) Average total rainfall in dry months from to inclusive, inches.

(*b*) Minimum rainfall in dry months from to inclusive, inches.

(*c*) Average for rest of year

(*d*) Minimum for rest of year

Maximum rainfall in one day, if known ; (small catchments only)

Probable annual run-off (known or estimated) in million cubic feet in average year

Probable annual run-off (known or estimated) in minimum year

VII. *Regulating Storage.*—In the case of high or medium head schemes there should be at least a few hours supply stored, preferably in or close to the forebay, but if no site exists then further back. State if such a site exists and in what position relative to the probable layout ; its capacity very roughly if an intelligent guess will give it ; whether it will be formed by a dam in the main or a subsidiary stream or by an artificial tank ; and any further information as to probable cost of construction, nature of ground, etc., so far as inspection only makes this possible.

Site for regulating storage at

Distance from forebay site

Capacity roughly cu. ft.

Whether formed by dam in main stream.

Ditto dam in subsidiary valley.

Ditto artificial tank.

Further details from inspection.

VIII. *Main Storage.*—In the case of medium or high fall projects dependent partly or entirely on storage give (as near as may be) location of dam and nature of ground, very roughly the length and height, with corresponding capacity, so far as inspection or 1-inch map will give any information.

Location of dam (on 1-inch map, by square as explained above).

Approximate length

Nature of ground

Height likely to be adopted (so far as can be seen without survey)

Probable method of surplussing flood waters

Probable capacity in million cubic feet (or approximate length and breadth of lake surface)

If data under para. VI are scanty, state if there is a reasonable probability of filling the reservoir proposed and whether the conditions render a large carry-over necessary for probable bad years (two fairly bad years are generally more dangerous than one exceptionally bad one between good years).

State nature of ground which will be submerged whether forest, jungle, waste land, good or bad agricultural land.

Does it contain any villages, temples, etc.

IX. *Headworks.*—Give particulars so far as inspection discloses them as to how the supply from the river (in cases of river development) will be regulated at the headworks, and brought into the open channel or forebay, as the case may be.

Probable location of headworks

State if the water is fairly free from, or particularly charged with, silt and detritus in the rains.

State if river is used for timber flotation, and if this is likely to interfere with its development for power.

X. *Open Channels or Canals.*—Where the site involves these the ground should be examined. In the case of low heads a canal in earth or rock alone will serve. With medium (or even high) heads where the power will be large, the same remark applies. In smaller high or medium head projects an artificial duct will generally be indicated : timber seldom lasts well, so masonry or concrete is generally used. Masonry requires special case where crabs are found, as they rapidly cause heavy leakage. For small schemes on high heads even galvanized iron troughing has been used, with a comparatively high slope.

State type of channel probable

State if the ground is favourable or whether special difficulties will be involved

State if any tunnelling, bridging or syphoning will apparently be necessary, with such brief particulars as inspection discloses

Approximate length of channel from headworks to forebay In most cases it is unnecessary at this stage to go into details as to capacity, slope, etc.

Which bank does examination show to be most favourable for the open channel or canal ?

XI. *Forebay.*—State position of forebay and whether the site is good. (This may be, but is not necessarily, the means for regulating storage ; but it must be large enough to take charge of ordinary fluctuations of load if the regulating storage is at a distance.) There must be the possibility of surplussing water not required for the power house and in some cases of dissipating considerable energy in the process. In other cases this is necessary at the main or a subsidiary reservoir.

XII. *Pipe line.*—Give approximate length of pipe line from forebay to power station site (alternatives may be suggested, with head in each case). Pipe details need not be gone into, but the line should be as short as practicable.

XIII. *Power house.*—Give information as to area of site available; approximate height above *river bed* and above *flood level* if ascertainable.

As noted in para. III, the gross head should usually be estimated from this site.

Probable location
Area of site approximately
Height above bed level
Ditto flood level
Nature of ground for building

Note that in low head installations and up to about 300 ft the power house can be placed (if necessary) up to 10 to 24 ft. above low water-level, by the use of draft tubes. Where the height is greater the turbines can be placed in a pit and connected to the generators by a long vertical shaft.

Will any difficulty occur over the tail race discharge?

XIV. *Irrigation Considerations.*—Will development of the site in any way interfere with the functions of existing irrigation works?

Are there any vested rights such as privately owned water courses for irrigation, or to feed mill wheels, between the proposed headworks and power station site?

Is the *district* one in which irrigation exists or is needed?

If this is so, would the fall it is proposed to utilize or develop have to be curtailed in order to utilize the tail waters? This will generally not be so if the power station site is at considerable altitude above the neighbouring plains, so that the tail waters would in any case continue their course in the natural channel: on the other hand, there are cases where the tail waters could conveniently be led hereafter directly into a canal, where some power head might have to be sacrificed to give command.

XV. *Facilities and materials.*—Will existing roads (rivers) carry the machinery, etc., required?

If so, by what means?

If not, what length of road approximately will be required to complete connection?

Will there be exceptional difficulties in making this road?

Are bridges involved?

Are stone, bricks, lime, suitable sand, kankar, etc., known to be available in the neighbourhood of the works?

Is labour available or would it have to be obtained from elsewhere?

XVI. *Local rates.*—State rates, if known, or probable rates, for—

Masonry in lime per cent.
Masonry in cement per cent.
Concrete in line per cent.
Concrete in cement per cent.
Excavation in earth per thousand.
Excavation in hard ground per thousand.
Blasting rock per thousand.
Contour roads, 4 feet, per 1,000 r. feet.

XVII. Additional information acquired during reconnaissance.

(NOTE.—Photographs of headworks site, power station site or any other feature may be of value. A sketch of the plan and longitudinal section should invariably accompany the report.)

Signature.

Designation.

PART B.—SURVEY OF SITES.

When reconnaissance shows that a site is probably worth developing the data require to be checked by actual survey, on the lines laid down in Part I, but sufficiently accurately to enable estimates to be framed for the civil engineering works. In the case of canal falls the survey will already exist, and what is required is a detailed report as to the best method of utilizing the fall or falls with rough estimates of the works required. In most other cases there will exist at the best a 4-inch contoured forest map and at the worst an uncontoured (and practically useless) old-style 1-inch map, so that very little exact knowledge can be obtained.

I. *Longitudinal section.*—In the first place a longitudinal section should be made of the bed of the river between the limits that may prove useful.

II. *Cross sections and contoured plan.*—The next point is to determine on which bank the works may best be placed, and for this purpose, unless the maps give a clear answer, it is necessary to take cross-sections across the valley at intervals, extending up to the highest point where there may be works. This will enable a large scale contoured plan (8 or 16 inches to the mile) to be made, on which the lay-out can be sketched out roughly. The best site for the headworks, the alignment of the canal (if any), the position of the forebay and of the regulating reservoir (if any), the best alignment for the pipes and the position of the power station can be approximately determined on this plan. There will often be many alternatives to choose from, so that it will be a case of balancing probable extra cost against extra power obtainable on a higher head. It may be noted that if the best site for the headworks is considerably above the highest level on which an open channel appears feasible the extra head can be sacrificed. Until the survey is complete it is obviously impossible to say exactly what the best lay-out will be.

III. *Site of power house and forebay and location of pipe line.*—A plan and sections on a large scale should next be prepared of the forebay site ; of the regulating reservoir if near to or combined with the forebay (none may be needed) ; of the pipe line route ; of the power house site and tail race. From this the best locations can be definitely determined, and the capacity and rough dimensions of the forebay and regulating reservoir worked out. *Pipe design need not be entered upon*, and the power house can be left over so long as the plan shows the area available for it. The tail race back to the nearest stream should be dealt with and also the overflow from the reservoir.

IV. *Survey of open channel.*—The route already determined on for the open channel (when one is involved) from the forebay up to the neighbourhood of the headworks will next be surveyed, and its nature, dimensions and slope determined according to the flow to be allowed for. If the regulating reservoir has to be placed somewhere along this channel, instead of close to (or combined with) the forebay, this will involve a break of levels ; *i.e.*, it will be fed at top level and will discharge at bottom level. Silt traps may have to be provided for in the run of the channel, unless clear water can be counted on and landslips are improbable. Tunnelling may be required, as well as means of crossing nalas on the route and of allowing overflow at safe points if the channel gets blocked.

V. *Headworks.*—Similarly the headworks site will be surveyed (it is assumed to have been definitely located before the channel is surveyed) and examined with a view to such a design as will secure the supply in times of low water and both the supply and security in times of flood. Protective works may be necessary to ensure this, probably in the form of boulder crates, and this matter should be examined.

VI. *Storage.*—If storage on a large scale is involved the dam site and submerged area will be surveyed so as to determine the dimensions and consequent capacity at draw-off level, and the practicability of the site for construction. The problem of surplussing extra water must also be dealt with in the design, by whichever method appears to suit the conditions best.

(See also enquiries in Part A.—VII.)

VII. *Project estimates.*—Rough project estimates should then be framed of the quantities involved and approximate cost, care being taken to indicate very clearly what is included and excluded. It is not intended that the estimates should do more than *indicate whether the scheme will prove cheap, moderately cheap, moderately expensive or very expensive* in terms of rupees per horse power capable of development. Beyond this point the matter can be left over until it is decided to proceed with the works.

Signature.

Date *Designation.*

PART C.—GENERAL REPORT ON SITE.

Such information as is available should be summarized in this form, which is drawn up to be progressive from the worst to the best sites.

I. The site is certainly (very probably) useless as shown by the particulars in Part A-B para. above ; *or* because the cost of works especially (the) would be prohibitive ; *or*

II. It is useless to investigate the site further until gaugings have shown what the minimum flow and/or the yield of the catchment will be ; but if these prove favourable development under a head of about feet may be feasible.

III. The site appears to be worth further investigation but its value for power is very indefinite owing to lack of knowledge of the minimum flow and/or yield of the catchment and for storage possibilities or

It is however probable that the power capable of development under a head of about feet is of the order of :

e.h.p. for the 3-4-5 driest months :
e.h.p. for the rest of the year.

IV. The site is worth a preliminary survey as it appears favourable and can be developed under a head of about ft.

It is likely to yield power of the order of :

e.h.p. for the 3-4-5 driest months :
e.h.p. for the rest of the year.

V. The site is certainly worth detailed survey. Under an available head of about ft. it will, if the results of the survey are satisfactory, yield not less than—

e.h.p. for the 3-4-5 dry months :
e.h.p. for the rest of the year.

Signature.

Designation.

Date

38. Aneroid levelling.—Notwithstanding claims made on behalf of the aneroid barometer for accurate levelling it is certainly true of most instruments by the best makers that, after the necessary corrections have been made, there remain serious discrepancies ; this is especially the case in extremes of climate, whether in the hot weather in India or in the polar regions.

Where levels, based on aneroid readings, have not been corrected at all, they may be wrong to an unnecessary degree unless the corrections happen to balance out. In the first place it must be remembered that the aneroid, even though calibrated in feet, shows the pressure of the atmosphere and *not* the altitude. Owing to a depression or to anticyclonic conditions variations of an inch or more are common enough at different times of the year, and may occur in a day during disturbed conditions ; this represents from about 900 ft. variation at sea level to 1,100 at hill station altitudes. The actual " reduced level " or height above sea level can therefore only be found (approximately) when a known altitude or contour line is included in the readings ; and then not easily in distrubed weather conditions. Nevertheless the method is most useful in hydro-electric reconnaissance, where *differences* of altitude are required.

Clearly the best results can be obtained when one instrument is left at the starting point and read at intervals, so as to give the actual atmospheric variations during the time the readings are being taken elsewhere. From the fixed instrument a curve can be constructed which will give the reading at that station at the time other readings are being taken, thus balancing out diurnal and climatic variations by simultaneous readings. This method however is seldom practicable in the field. Even when two instruments are available it is generally necessary, and always more convenient, to take both over the ground and average their reduced results. For one thing the discrepancies between them give an idea of the probable error.

The Diurnal variation offers no difficulty when it is understood, but cases are on record where a correction has been applied in the wrong manner. Molesworth's " Pocket Book " gives two curves (see " Aneroid levelling ") showing the mean annual correction for diurnal variation for Calcutta and Simla respectively, with factors for correction for latitude and altitude. The difference in these two curves, and the fact that they are only *mean results* and that the mean results elsewhere will differ from either, shows at once that unless the *actual* diurnal variation for the period in question is known there may easily be considerable uncertainty. In fact the actual variation will sometimes be half that of the curve or may be masked by other changes. Taking these curves as the basis however it will be found that the diurnal variation crosses the zero line at about 1 hour, 6 to 7 hours, 13 to 14 hours, and 20 hours. Where 2 aneroids are employed their readings should be kept separate and independently reduced. To each reading should be added or subtracted the diurnal correction in feet from the curve to give the reduced apparent altitude of the station. Thus if two readings are taken at different places at 11 hours and 16 hours some 40 to 50 ft. will be added to the apparent altitude at the former and the same amount will be subtracted from the latter, so as to reduce both readings to the zero or datum line of the curve. This may convert an apparent rise into an actual fall or *vice versâ*.

Actual mean diurnal variations, at many stations, for every month, are available in the Meteorological Department. The aneroid levelling note book issued by the Chief Engineer contains these figures for fourteen well distributed stations, with a suitable sheet for recording and reducing observations. In addition to the diurnal variation there is a second correction depending on the temperature (T + t) of the two points between which the difference of height is required. The table of K, the multiplying constant, is given in " Molesworth " and in the Note book referred to. It varies generally between 1·10 in the cold weather, in the plains up to 1·14 in the hot weather.

CHAPTER 6.—HYDRO-ELECTRIC AND STEAM POWER.

39. Census of power in India.—Enquiries were set on foot at an early stage of this investigation to ascertain the approximate power installed in various industries and localities in India. Previously this had only been done for electric power, where it was found in 1917 that the total amounted roughly to 215,000 kWs. or say 285,000 electrical horse-power, of which 36 per cent. was obtained from water power.* The total units generated amounted to only 550 millions. For demonstrating the backward state of electrical development the following comparison with other parts of the Empire will be of interest. The watts installed per head of population † are as follows :—

TABLE 4.—*Watts per capita in various countries.*

	Watts per capita.
Canada	148
Australasia	62
South Africa	57
British Isles	33=1 ordinary glow lamp.
India	1 or less.

If population is a poor criterion, the area per kilowatt (1⅓ horse power) installed may be taken.

* List of Electrical Undertakings in India, 1916-17.

† " A project for providing the Punjab with a cheap supply of Electric Power " ; F. L. Milne, A.M.I.E.E. (Proceedings of the Punjab Engineering Congress, 1919.)

TABLE 5.—*Area per kilowatt in various countries.*

British Isles	1/3 square mile per kilowatt.
South Africa	1·4 " " " "
Canada	3·5 square miles per kilowatt.
India	7·6 " " " "
Australasia	11 " " " " Largely uninhabited.

The following figures are available for the power of all kinds in use in certain parts of India at present; they are only approximations and are incomplete. They were compiled by the Directors of Industries or Controllers of Munitions for the most part, and it has been impossible to enter into full details here. The following is a summary :—

TABLE 6.—*Summary of known power in use in India.*

	B. h. p.	
Assam	22,550	
Bengal	25,318	exclusive of Calcutta area.
Calcutta area . . .	176,200	
Bihar	2,325	apart from collieries, etc.
Bombay Presidency . .	32,872	
Bombay City area . .	750,000	
Burma	17,750	exclusive of rice mills, etc.
Central Provinces . .	32,773	
Madras	60,000	
North-West Frontier Prov. .	...	
Punjab	90,000	
United Provinces . .	38,548	
GRAND TOTAL . .	1,248,336	or 936,000 kWs.

40. Mechanical and Electrical Power; explanation of units.—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 cu. ft.) are discharged per minute under a head of 100 ft. (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 $\cdot 9 \times \cdot 95 = 0\cdot 855$ 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, $0\cdot 855$ e.h.p.$\times \cdot 746$ gives the exact electrical equivalent, *viz.*, 0·636 *kW.*, as 1 e.h.p.=746 watts or ·746 kWs. 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 kW.) is exerted for one minute the resultant energy is 500/60 or 8·33 h.p.-hours or 6·21 kWhs. 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.

41. Further uses for hydro-electric power.—For a full discussion of the new industries which may arise in India, if cheap electric power is available, the Report of the Indian Industrial Commission must be referred to. The "Industrial Handbook 1919" issued by the Indian Munitions Board also merits close study. Among these industries may be mentioned the electric smelting of indigenous iron ores and electrical production of steel and its alloys; electric welding, now extensively employed; the production of aluminium from alumina, prepared from the local bauxite deposits; the manufacture of calcium carbide and its innumerable derivatives; the direct fixation of atmospheric nitrogen into the nitrates of commerce; the electrolytic production of chlorine gas and the preparation of phosphorus and of abrasives like carborundum. All these processes are in actual use in various parts of the world where the raw materials and the power are found. The maps in this report have marked on them information regarding the occurrence of certain of these raw materials. In some cases the process is electro-chemical, in others electro-thermal, but in all cheap power and large scale production are essential to success. The following extract from the Preliminary Report of the British

Water Power Committee will emphasize what has been done and what may in future be done in some of these matters:

"Electro-metallurgy and electro-chemistry have rendered it possible to handle materials not workable by any other means; have made available new materials; and have greatly cheapened the production of many important materials of wide use. Aluminium, calcium carbide, chromium, cyanide, silicon, carborundum, are products rendered commercially possible only by electrical processes, while alkalis, hypochlorite, phosphorus, magnesium, and sodium nitrate are produced most economically by such processes. Great developments have recently taken place in the production of electrolytic copper and zinc and in processes for the electric smelting and refining of metallic ores. All these processes demand relatively large amounts of energy. The world's production of calcium carbide, for example, was 340,000 tons in 1913, requiring 400,000 continuous electric horse-power for its production, while the energy used at the end of 1915 for electric furnaces in the United States alone was approximately 300,000 electric horse-power.

In the utilization of atmospheric nitrogen for the production of nitric acid and the manufacture of nitrates, great developments have taken place during the last decade, and in Norway alone over 400,000 electric horse-power is now absorbed in its production. The world's annual consumption of nitrogen in its various combinations is about 750,000 tons, representing a value of about £50,000,000 and this demand is increasing yearly. Four-fifths of this supply has been produced hitherto from natural nitrate deposits, but in view of the rapid depletion of these deposits, and of the diminution in the fertility of most of the great wheat and cotton-growing areas of the world, the production of artificial fertilizers by one or other system of nitrogen fixation must, in the near future, become a question of national importance.

At the present time the world's consumption of fertilizers amounts to close upon 6,000,000 tons per annum, and this will probably be doubled within the next 20 years. To-day, the efficiency of the electrical production is low, amounting in the case of calcium nitrate to about three-quarters of a ton per electric horse-power year. By adopting the cyanamide process the consumption of energy may be cut down to about one-fourth, but even in this case the production of the equivalent of 12,000,000 tons of fertilizers per annum would require 4,000,000 continuous electric horse-power.

It is estimated that the 200,000,000 acres of arable land in Canada alone may ultimately require some 10,000,000 tons of nitrates per annum to maintain their fertility, and this in itself would necessitate the absorption of an appreciable portion of the whole hydraulic energy of the Dominion.

When to these demands are added those of India, Australia and Africa, it is evident that the fertilizer demand of the Empire will in itself call for an enormous supply of energy."

Apart from ordinary town supply for electric lighting, heating and fans and supply to tramways and railways (especially hill lines) for traction purposes, there are many other industries in which electric power would be welcomed if it could compete with other forms, and in any area where reasonably cheap hydro-electric development is possible within transmission distance this successful competition is simply a matter of relative costs. To take one instance, in a comparatively small area of the Duars, within easy reach of water power (the Jaldaka q.v.), it is estimated that fuel equivalent to a working load of about 100,000 horse-power is used in the tea factories; partly for the production of power from steam engines, but mainly for drying purposes with hot air and fans. Both the motive power and the hot air can be obtained electrically; it is merely a question of comparative costs. Other tea districts are similarly situated. Again, the cotton mills of Bombay are now mostly driven by electric motors fed from the Tata scheme, which have replaced steam engines. There may, given cheap enough power, be a similar opening for jute mills, oil mills, timber working, sugar production, paper pulping and other industries. The two sets of rival conditions that make or mar a hydro-electric porject will presently be examined; namely, the competition between fuel and water and that between the freight on materials and the transmission of power.

As regards pumping for irrigation purposes, somewhat wild suggestions have been made under the false impression that "water power costs nothing." It is very unlikely that such pumping will pay on any water rate that could be demanded, where the lift is at all great. Under favourable conditions the overall efficiency from water to electrical horse-power at the generator terminals will be about 85 per cent. By way of example let a gross pumping head of 100 ft., from the source of water to the distributing irrigation channel, be assumed; this is probably over the economic limit, but as the power taken is practically proportional to the head the example can be reconstructed for any lower value. Assume further that 2 cu. ft. per second (*i.e.*, 12½ gallons or 125 lbs. per second) is to be pumped up this 100 ft., absorbing 22·7 theoretical water horse-power. A modern turbine pump in these circumstances will have an efficiency of 75 to 77 per cent. and will require about 30 b. h. p. to drive it. The electric motor giving this mechanical power will have an efficiency of about 90 per cent. so that it will take some 33·2 electric horse-power at its terminals. If a transformer is necessary the input into it from the line will then be about 34·2 electric horse-power or 26 kW. If the transmission losses are taken at 10 per cent. the line must be fed at the power station with 28½ kW. If there is no transformer here the generator will supply this amount of power, and on the overall efficiency assumed in this report it will use 44·7 theroretical water horse-power. *Thus the overall efficiency from water falling to water raised will be practically 50 per cent. under the best conditions.* The capital charges on the cost of the motor with its housing, its pump and its pipes, together with a share of the charges on the distribution system and power station, have to be met from the additional revenue due to the supply given. If the lift of the pump were 10 ft. instead of 100 then *ten times the amount of water* could be pumped for the same power, and *ten times the acreage* irrigated. The proposition would then become more practicable.

Experimental work in sub-soil pumping by means of tube wells has for some years been in progress at Amritsar, Punjab. Sir John Benton, K.C.I.E., late Inspector General of Irrigation, took up the matter with keen interest and the work has been in the hands of Captain John Ashford, M.I.C.E. Canal falls abound, as will be seen elsewhere in this Report, and sub-soil water is plentiful.

42. Fuel and water power.—It has already been stated that the commercial possibilities of any hydro-electric scheme depend on two factors, the capital cost of the scheme on the one hand and the cost of the competing fuel on the other. Comparing a steam or oil-driven electrical plant with one water-driven, the latter is almost invariably much more expensive to construct; and all it saves is the cost of fuel, which is only one factor in the cost of generating power. Staff and stores, office and legal expenses, repairs and depreciation are incurred in both. Thus while the actual comparison will be between the price at which electricity can be sold in both cases the real criterion of success is whether the capital charges for interest and depreciation on the *excess* cost of the water power undertaking will be substantially less than the cost of the fuel used by the other.

It is obvious that large capital expenditure is necessary on the hydraulic development; furthermore as water power must be developed where it is found a long transmission line is often necessary. For these reasons the total cost of construction is almost invariably higher than that of a steam-driven plant of the same capacity; and the annual capital charges for interest and depreciation are correspondingly higher.

Against this may be set the fact that the running costs of such a station are relatively low, as no fuel is involved. The total cost of running does not depend to any appreciable extent on whether the plant is fully or only lightly loaded; it is practically *a fixed sum per annum*; so that the cost *per unit* is practically proportional to the total number of units generated. This is not so with fuel-consuming stations. Every extra unit generated then involves the consumption of a definite amount of fuel with a definite cost; and while the total cost rises with the number of units generated and the cost per unit falls somewhat, the latter is by no means proportional to the total units. In any particular case therefore the practicability of a hydro-electric scheme depends on the cost of fuel in the locality where the power is wanted.

To take an example, assume a plant of 5,000 kWs. capacity is required at a certain place where sufficient water power exists within transmission distance. Assume the total cost of the hydro-electric scheme and transmission line to be Rs. 50,00,000. Taking interest and depreciation together at 10 per cent. the annual cost on this account will be Rs. 5,00,000.

Let the cost of a steam plant of the same capacity, built where the power is actually needed, be assumed to be Rs. 15,00,000 with similar annual capital charges of Rs. 1,50,000. Now if for simplicity it be assumed that the annual charges for wages, stores, repairs and supervision are the same in both cases (an assumption near enough to the truth) there will be the difference between Rs. 5,00,000 and Rs. 1,50,000 or Rs. 3,50,000 to set off against the cost of fuel for steam raising. Under the ideal conditions of large electro-chemical works this plant, allowing 1,000 kWs. to be kept for spare and therefore 4,000 for work, would generate about 28 million units (80 per cent. load factor). Under ordinary industrial conditions the output would be less than half this, or say about 12 million units. Clearly therefore not only the cost of coal but also the load factor of the plant (*i.e.*, in non-technical language the ratio of its actual to its possible output) is of immense importance (see para. 26). If it is assumed that the low amount of only 2 lbs. of Indian coal will be required per unit, with modern plant of large size, the consumption would be 25,000 tons for 28 million and 10,700 tons for 12 million units. As the amount available to make the costs just balance out between steam and water power is Rs. 3,50,000 it follows that with the larger output coal at Rs. 14 per ton would absorb this amount, while with the smaller output the figure would be nearly Rs. 33. From this example (in which the figures are not meant to represent estimates) it will be inferred that as the load factor rises towards the ideal limit the advantage of hydro-electric power increases. Bearing in mind the vast difference in the cost of fuel in different parts of India, due mainly to railway freight, it will also be seen that the distance from fuel supplies is a very material factor. With coal under Rs. 10 per ton it is doubtful if water power could ever compete unless (rare combination) it existed right on the spot and could be developed exceptionally cheaply. On the other hand, with fuel at over Rs. 30 a ton, water power would generally prove cheaper and, for a well-sustained industrial load, invariably. Between these limits proper estimating would be necessary.

43. Fuel consumption in power house.—Two curves are now reproduced from the report of the Hydro-electric Power Commission of Ontario to illustrate fuel consumption. Fig. 21 shows, according to the capacity of the station, the average number of pounds of coal used per horse-power hour, in America; the horse-power hours obtained per 100,000 British Thermal Units; and the load factors of the particular plants from which these curves were derived. Fig. 22 shows the number of pounds of coal consumed per unit (kilowatt hour) according to size of the plant and the load factor, based also on American data.

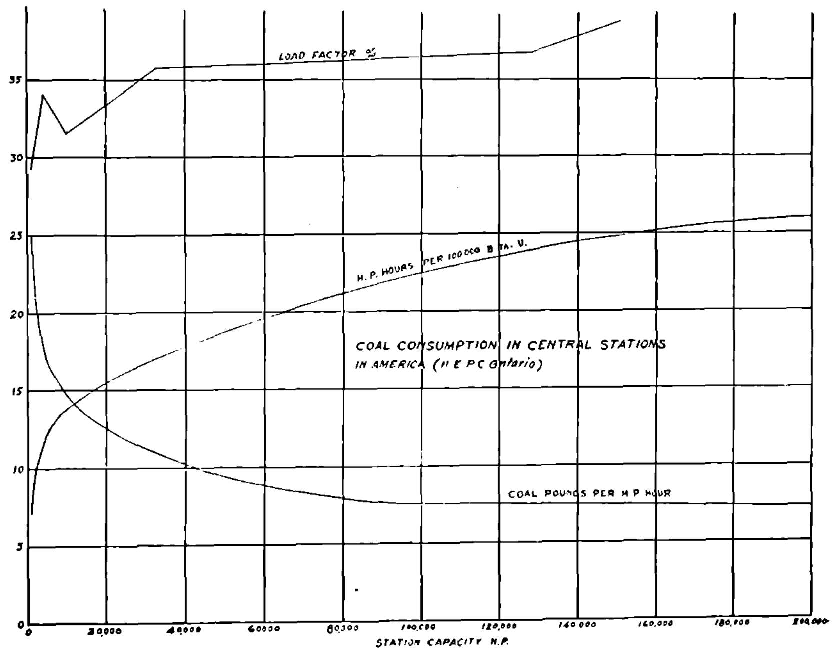
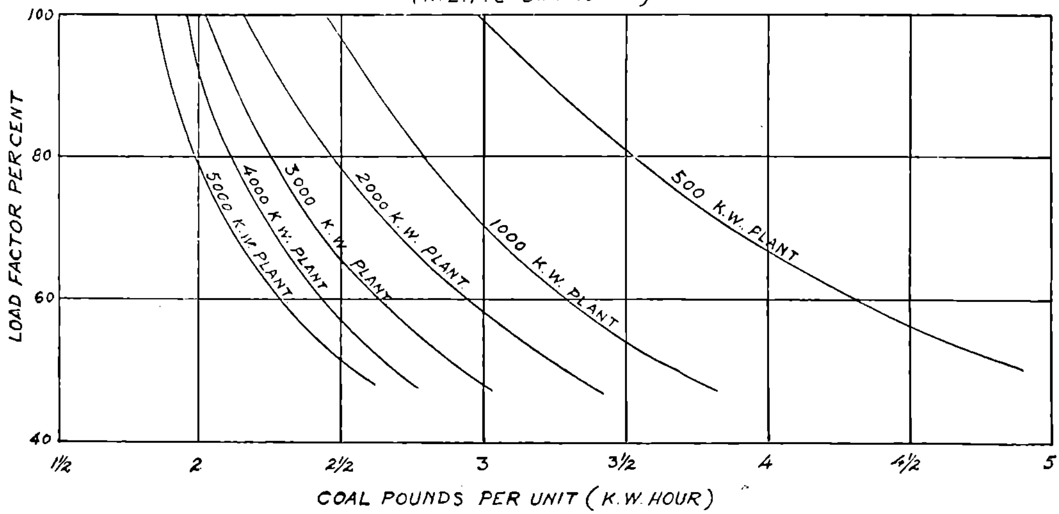


FIG. 21. Coal consumption in Central Stations.

Fig. 22. COAL CONSUMPTION PER UNIT ACCORDING TO PLANT SIZE & LOAD FACTOR.
(H. E. P. C Ontario —)



44. Cost of Fuel in India.—The cost of fuel is at present rising rapidly, oil even more so than coal; for the time being, in India, it is unlikely that even the superior thermal efficiency of the Diesel engine will enable it to compete with steam turbine plant of any size. Leaving oil out of the question, therefore, the cost of coal is made up of (i) its price at the colliery, (ii) the freight charges, by land or sea, to its destination. There has been a marked rise in every direction during the war and since the armistice, and at present little more than comparative values can be given. Through the courtesy of the Mining Engineer to the Railway Board a map was prepared in 1919 to show, on a uniform basis, the comparative cost of coal in various parts of India. It is unnecessary to reproduce the map here, as a tabular statement will serve equally well. In this statement "the price of coal has been taken at an average rather above pre-war rates and shipping rates are calculated on a pre-war basis." Taking Bengal coal as the determining factor the map shows its cost *in the coal fields area* as Rs. 5 per ton, which in fact is about the actual 1920 price. In the table the numbers correspond serially to those on the map. The area is indicated broadly, and includes the surrounding country, the centre being indicated in brackets; but at any distance from that centre additional freight may be involved, while cartage to places off the railway line may be a potent factor in the cost delivered at site.

TABLE 7.—*Approximate price of Coal in India.*

Reference number on recorded map.	Area.	Fuel referred to	1920 cost per ton on basis stated. Rs. as.
1	Chittagong area	Bengal coal by sea	15 0
2	Bengal coal fields and surrounding district (Asansol)	Bengal coal	5 0
3	Bihar and United Provinces (Sone)	Ditto	9 0
4	United Provinces (Cawnpore)	Ditto	11 8
5	United Provinces and Punjab (Saharanpur)	Ditto	13 8
6	Punjab (Lahore)	Ditto	15 0
	Ditto	Punjab coal	11 0
7	Punjab and North-West Frontier Province (Peshawar)	Bengal coal	17 0
	Ditto	Punjab coal	10 8

Reference number recorded on map.	Area.	Fuel referred to	1920 cost per ton on basis stated.
			Rs. as.
8	Punjab (Multan)	Bengal coal	16 8
	Ditto	Punjab coal	12 0
9	Baluchistan (Quetta)	Bengal coal	19 0
	Ditto	Local coal	9 0
10	Sind (Sukkur)	Bengal coal	17 8
	Ditto	Baluchistan coal	12 0
11	Sind (Karachi)	Bengal coal by sea	16 0
	Ditto	„ „ by rail	18 0
12	Rajputana and Central India (Kotah)	Bengal coal	14 0
13	Central India and Central Provinces (Katni)	„ „	11 8
	Ditto	Umaria coal	6 0
14	Central Provinces (Bilaspur)	Bengal coal	10 8
	Ditto	Umaria coal	8 8
15	Gujerat (Morvi)	Bengal coal	16 12
16	Central Provinces (Nagpur)	„ „	12 0
	Ditto	Pench coal	7 8
	Ditto	Bellarpur coal	7 8
17	Northern Bombay (Bombay)	Bengal coal by sea	16 0
	Ditto	„ „ by rail	17 8
18	Hyderabad (Itarsi)	Bengal coal	18 12
	Ditto	Singareni coal	10 0
19	Hyderabad (Singareni)	Bengal coal	17 0
	Ditto	Singareni coal	6 0
20	Northern Madras (Vizagapatam)	Bengal coal by sea	13 0
	Ditto	„ „ by rail	12 0
	Ditto	Singareni coal	12 0
21	Southern Bombay and Mysore (Mormagao)	Bengal coal by sea	15 0
	Ditto	„ „ by rail	21 0
	Ditto	Singareni coal	12 0
22	Southern Madras (Madras)	Bengal coal by sea	13 0
	Ditto	„ „ by rail	16 0
	Ditto	Singareni coal	12 0
23	Lower Burma (Rangoon)	Bengal coal by sea	16 0
24	Eastern Bengal and Southern Assam (Mymensingh)	Local coal	6 0
25	Northern Assam (Dibrugarh)	Assam coal	9 0

As regards cost, it is confidently assumed in well-informed circles that the price generally will be about *doubled* by 1924. It is already (1921) some Rs. 5 higher. In these matters it is well to look ahead, for while coal is unquestionably rising fast machinery is already dropping in cost and is likely to drop further. It will therefore be possible for hydro-electric power to compete with steam in the future where it could not do so in the past.

45. Transmission of power and of material.—The popular fallacy that " water power costs nothing " has been examined as regards the initial cost of the plant in a previous paragraph. The cost is generally further increased by that of transmission lines, since water power is seldom situated precisely where it is required. Either the power must be carried to the industry or the raw material and finished products of the industry must be taken to and from the power. Both ways cost money.

Where electro-chemical industries on a large scale are in question it is essential that the price of the power shall be very low if the manufactured product is to compete with that produced elsewhere. The cost of power is of course only one item amongst many in determining the sale price of the finished article, but it is a very important item—perhaps second only to the freight of the raw material to site and the finished product to market. Where the conditions of the hydraulic development are such that construction on a large scale is reasonably cheap ; where the locality is such that the freight of the plant and materials thereto is low ; and where the length of transmission to the factory is reasonable ; power can probably be delivered at about one-tenth of an anna per unit including all charges. Indeed, if the cost is much higher than this, the proposition becomes untenable. Obviously the undertaking must be on a fairly large scale to be of any use. The larger the individual units of plant are made the smaller becomes their prime cost per kilowatt and the higher their efficiency. The various electro-chemical industries are favourable to these low costs as they are practically continuous processes, utilizing the whole plant to almost its utmost capacity throughout the year.

In considering the value of sites that may possibly meet these ideal conditions the first point to consider is undoubtedly that of freight and carriage; for it has a triple application. In the first place the raw material must be brought to the site, unless already on it; secondly the finished product must be taken to its market; thirdly the plant must be delivered at the power house. Cases are known where the carriage of plant over 20 miles of mountain roads cost more than its freight from England to the railway terminus. Cheap power is useless if the saving is swallowed up in expensive freight. Where bulky raw material has to be brought to the factory and sent back finished the obvious course is to build an electric railway from the nearest terminus, seeing that cheap power for working will be available. In order to get the plant to the power house there must be a road, and this road should be built so as to afford a suitable track for the subsequent railway. During the construction period a light line worked by steam will probably pay as against other methods of transport of the plant.

From small beginnings electrical transmission of power has now reached the stage where it is possible to have the factory 250 miles or more from the power station, and it would be unwise to say that the limit of high pressure has been reached. In the case of water power from mountainous country there may be insuperable difficulties of ground or cost in laying out a railway to the site, though the plant can be transported there. Even if these difficulties do not exist, if the raw material of the industry is within the limits of transmission it will probably prove cheaper to erect a long transmission line rather than a railway, which may use more power than will be lost in transmission. It is simply a question of estimating which method gives the cheapest finished product. Either the material can be brought to the power house; or the power to the factory; or a combination of both methods may be the best. Mountainous country has one great asset for transmission in that the ridges form nature's own supports for the lines; with comparatively small towers the valleys offer plenty of room for the dip of the wires on long spans. It also follows that by reducing the number of points of support, by the use of long spans, there are fewer points at which damage from lightning can occur. The loss in transmission can be made almost as large or as small as the designer chooses, according to the size of the wires used; ordinarily about 10 per cent. is allowed. Where steam is used to generate the power the correct loss can be calculated according to Kelvin's law and its modifications, such that the capital charges on the conductors balance the cost of the power lost in them. If more power is required more generating sets can be added indefinitely. With unlimited water-power the cost of the lost power is of secondary importance, and larger losses may be advisable than in the former case. On the other hand, if the available power is likely to be all required—and this is generally the case—the line losses may have to be reduced to very low amounts, since every unit available for the factory is of value.

The cost of transmission lines operates detrimentally in two ways: first by increasing the prime cost and consequent capital and upkeep charges, and secondly by decreasing the available energy for sale at the far end, owing to losses in the line. These line losses can be made almost as large or as small as the designer chooses, but if they are made small it is by adding more copper wire, or larger wires, so that this reacts on the prime cost. The statement is often made that a long transmission line only means a loss of about 10 or 15 per cent. of the power generated; but it may increase the economic selling price vastly more. It has been recorded that the cost of transmission at Niagara, which extends to a distance of 250 miles, ranges from 22 to 86 per cent. of the total cost of the power delivered, according to distance. These figures would be greatly improved on under modern conditions, at any rate with pre-war prices, but they serve as an indication that water power does not "cost nothing."

CHAPTER 7.—MISCELLANEOUS TECHNICAL MATTERS.

46. Technical progress in plant.—During the year the problem of designing a turbine with a "specific speed" higher than that of the Pelton jet impulse wheel and lower than that of the Francis reaction turbine has received much attention. Two new types, the Nagler and the Kaplan turbines,* have been described in the technical press, both having the desired characteristics coupled with high efficiency. The importance of a high specific speed is greatest on low and variable heads, as it connotes a high actual speed also and enables the wheels to be direct-coupled to generators without the latter becoming unduly large and costly. American tenders for vertical wheels to work on a head of 11 ft. showed speeds nearly double those of British tenders. In the matter of comparatively low-powered turbines for low or medium falls an interesting new development is the Banki impulse turbine;† in this modified form of Poncelet wheel the water passes at its jet velocity through the horizontal vanes from the flume at the back to the centre of the wheel; and then still retaining some

* *Electrical Review*, April 1920, p. 66; and 20th August 1920, p. 254. Science Abstracts, Vol. 23, Part 3, p. 124; and Part 7, p. 332.

† Messrs. Boving and Co.'s pamphlets.

20 per cent. of its velocity, it again passes through the vanes from the centre to the front, striking the vanes in the reverse direction, so as to give up a further instalment of its power.

In the regulation of Pelton wheels a new departure is marked by the Seewer governing system,* in conjunction with the needle and nozzle. Instead of deflecting the nozzle or diverting the jet externally, when power is taken off, this system causes the jet itself to expand into a rotating cone from the nozzle, so that the water either misses the buckets or strikes them in the back. This is effected by guides between the needle and the nozzle pipe, which are instantaneously rotated through a variable angle by the governor when load is thrown off, the needle meanwhile closing gradually and restoring the normal circular jet. The power required to operate the gear is claimed to be considerably less than that needed for other types of regulator; and a single size of governor can be utilized on widely different sizes of machine.

In the matter of automatic governors of the oil pressure type, operating a servo-motor with automatic compensation, the Piccard-Pictet governor † has recently been improved; and a hydraulic relief valve for preventing water hammer has been put on the market in conjunction with the governor.

On the electrical side, generator capacities are still rising; steam turbine combined sets of 60,000 kW. at 1,000 R. P. M. have been built and water turbine sets of about the same output can be manufactured. The Hydro-Electric Power Commission of Canada now has five turbines of 55,000 pp. each, giving some 40,000 kW. In minor apparatus it is worthy of note that mercury vapour rectifiers with capacities of several hundred kilowatts have been built by Messrs. Brown Boveri and Company and Messrs. Hartman and Brown. The importance of this development to hydro-electric work is clear, for all such works will necessarily generate alternating current; for certain purposes however continuous current is required, and if this can be obtained without the use of rotary-converter sub-stations it will be a great gain. The electric fan alone is the main cause of prosperity to existing electric supply companies in the plains of India, and the C. C. fan at present is greatly preferred to the A. C. fan; it is probable that small electrolytic rectifiers will presently be used for giving individual consumers C. C. for their fans. The A. C. fan is sowemhat less advantageous to the consumer in the matter of efficiency while it costs more to instal; from the supply company's point of view the low power factor of the single phase fan is a very serious disadvantage.

* Science Abstracts, Vol. 23, Part 3, p. 122; and circulars of the English Electric Co.

† Messrs. Vickers Limited.

47. Standardization.—In closely related spheres two bodies have been at work for many years on the question of standardization, namely the International Electro-technical Commission and the British Engineering Standards Association. Both bodies have invited the co-operation of the Government of India; and the matter has been taken up, at the request of Government, by the Institution of Engineers (India). Meantime a practical advance in the desired direction has been made. The drawing up of the Sutlej River hydro-electric project, as noted upon elsewhere in this Report, has opened up great possibilities of cheap power for industrial and general development in the Punjab; and that Government at once realized the necessity of standardization so that the various connected projects could in the future be linked up. This possibility depends primarily on the British standard frequency of 50 cycles per second being adopted in *all* alternating current stations, and therefore in *all* hydro-electric plants. Should the usual American frequency of 60 cycles be used linking up would only be possible through frequency changers, and not satisfactorily then.

From the manufacturer's point of view, and therefore from the consumer's also, the standardization of pressures and of apparatus is also important. The conclusions set forth by the Committee, appointed to examine the question in the Punjab, are therefore reprinted here, with the suggestion (already made in correspondence) that similar resolutions would be of equal advantage to the rest of India.

Minutes of a meeting held at Simla on June the 9th, 1921 to discuss the question of standardizing the nature of Electric Supply in the Punjab.

In view of the probable development of hydro-electric projects in the Punjab, in the near future, and the present demand for public electric supply installations in several towns in the Province, it was considered advisable, by the Local Government, to form a Committee to discuss the advisability of standardizing, as far as possible, the nature of electric supply that should be adopted in new installations.

The advantages and disadvantages of alternating and continuous current for distribution were first discussed and it was unanimously resolved:—

Firstly.—That in view of the prospects of hydro-electric supply in the Punjab and the fact that the industrial load can, in most cases, only be dealt with by alternating current distribution; it is recommended that the Government of the Punjab shall usually favour alternating current systems, in preference to continuous current, except in special cases (such as residential areas) when there may be good reason to prefer continuous current.

The above resolution was arrived at after very careful consideration of the various uses to which electricity is and can be applied. It was decided that the supply of cheap electric energy in the Province depended, to a very great extent, on the adoption of alternating current distribution in localities where an industrial load existed or was likely to develop.

While fully recognizing the disadvantages of the alternating current fan in comparison with the continuous current fan, the Committee agreed that it would be inadvisable to sacrifice the economic development of the Province for the sake of benefiting a particular type of load that represented but a very small proportion of the total demand for electrical energy in the Province. The decision of the Committee in the matter was also greatly influenced by the obvious technical advantages to be gained by the use of alternators, now installed, as synchronous condensers at a later date, when fuel driven installations take power in bulk from hydro-electric plants.

It was pointed out that, so far as private consumers are concerned, continuous current distribution can, if necessary, be obtained from rotary converters; also that it is probable that individual continuous current fan loads may presently be worked by means of electrolytic rectifiers.

The Committee next considered the question of standardization of pressures and frequencies and were influenced in arriving at a decision in the matter by the obvious advantages which standardization and uniformity offer to electrical manufacturers and traders and also to industrialists generally in facilitating the purchase, interchange and disposal of electrical plant. In this connection the Committee resolved:—

Secondly.—That this Committee recommends to the Government of the Punjab that the British Engineering Standards Association standard frequency of 50 cycles, with their secondary standard frequency of 25 cycles for special cases (*e.g.*, electric traction) should be adopted in all alternating current schemes in the Punjab.

Thirdly.—That the British Engineering Standards Association Standard pressures should be adopted on all electric supply schemes in the Punjab. These pressures are as follows:—

Standard low pressures (C. C. or A. C.)—

(i) At the Generator:—115, 230, 460 and (for electric traction) 525, volts.

(ii) At Consumers' terminals:—110, 220, 440 and (for electric-traction) 500, volts.

also, a Secondary Standard, in three phase circuits, of 400 volts between phases, giving 230 volts between any phase and neutral.*

(iii) *Standard High pressures* (A.C).

At Generator terminals:—2,200, 3,300, 6,600, 11,000.

(iv) *Standard primary pressures for A. C.* transformers (measured at primary terminals):—2,000, 3,000, 6,000, 10,000.

(v) *Standard secondary pressures for A. C. transformers.*—Measured at the secondary terminals:—115, 230, 460 (and 525), at no load.

(vi) *Standard C. C. pressure for tramways*:—Measured at motor, 500 volts.

To meet special cases of low pressure distribution in bazaars, it is suggested that 55 (or 75) volts should also be adopted in India where a lower pressure than 110 is desirable for safety. (These pressures being, approximately ¼ and ⅓ of 220 volts.)

For transmission lines, pressures above 11,000 volts would generally be adopted, but these need not be standardised at present.

It was also resolved:—

Fourthly.—That, in the opinion of this meeting, it is desirable that in all electrical projects in the Punjab, the standards laid down from time to time by the British Engineering Standards Association, for plant and appliances, and for rating and cognate matters, should be adopted, as far as practicable.

48. Tea firing and making electrically.—Sooner or later there can be no question that the drying (technically called "firing") of tea will be carried out electrically wherever cheap water power is available; and the various mechanical processes will similarly be converted. The projects for harnessing the Ne Chu and Jaldaka rivers in Bengal (q.v.) owe their inception to this possibility. The present writer investigated the question in connection with the Laxapana-Aberdeen hydro-electric project in Ceylon, and some extracts from his report will be of interest here. Of the total fuel now used about 40 per cent. is required for mechanical power and 60 per cent. for drying the leaf. In Ceylon liquid fuel is used.

"For *power* purposes liquid fuel costs from 1½ to 2½ cents per lb. of tea made, and 2 cents will be a good average. Taking the price as 50 cents a gallon this represents 0·32 pints per lb. of tea. A Hornsby type oil engine of 20 to 50 b. h. p. will consume about 1 pint (or a little less) per b. h. p. hour (brake-horse-power-hour), so the above consumption of 0·32 pints will represent one-third of a b. h. p. hour at the engine pulley per pound of tea, costing 2 cents. Now to produce this same amount of mechanical power on the pulley of a corresponding electric motor, after allowing for losses in transformation and in the motor itself, will require less than 0·29 of a B. O. T. unit. If, therefore, the price charged for a unit is 3 cents (a figure 50 per cent. higher than is forecasted as the cost price elsewhere in this Report) the total cost of power will be under 1 cent instead of from 1½ to 2½ cents per pound. The margin in the case of mechanical power is therefore from Rs. 1,000 to Rs. 3,000 on a garden turning out 200,000 lbs. and in this proportion all along the line. The cost (to be deducted from this saving) on account of interest and other charges on the motor and transformer, etc., would be a long way below the smallest of these figures."

* NOTE.—The B. E. S. A. adopted 380 and 220 volts for this latter, but the Committee prefer the figures given.

This saving on mechanical power is in itself substantial compared with the factory cost of tea, but the drying, as foreseen by the Industries Commission of Ceylon, is the key to the situation. On this point the Report proceeds as follows: the assumed cost of fuel can be converted into terms of wood or coal when calorific value is taken into account:—

"This matter is not one involving any doubts on the score of technical difficulties; it is purely and simply a question of the relative prices of heating by fuel and electricity. Many thousands of horse power are already used in various industries for heating and drying purposes, and the matter is susceptible of fairly exact calculation. Taking the oil fuel used for drying purposes in the ratio of 60 to 40 compared with that used for power (which ratio is based on actuals for some 90 million lbs. of tea in the Duars district of Bengal confirmed by Ceylon experience), the cost will be from $2\frac{1}{4}$ to $3\frac{3}{4}$ cents per pound of made tea. Costs as low as $1\frac{1}{2}$ cents have however been shown to me. Possibly these included some wood fuel, or were exceptional for some special reason. For purposes of comparison a cost of 2·75 cents per lb. of tea may be taken. This represents (at 50 cents a gallon) 0·44 pints of oil fuel per pound of tea. The oil is burned and used to heat air which is passed through the leaf by means of a fan or blower, driven from the main engine. Now the calorific value of fuel oil may be taken as averaging 19,000 B. Th. U. (British Thermal Units) per lb. or say 13,000 B. Th. U. per pint. The consumption of 0·44 pints is therefore equivalent to the production of 5,750 B. Th. U. This heat will not all reach the tea, as there are radiation losses to be met and a considerable proportion of the heat will pass away up the flue; but the same will happen (though to a less extent) with electrical heating.

"Here an interesting comparison may be made with the fuel consumption in the Bengal Duars. A careful test was made on a large sized E. U. P. dryer using Assam coal. A 35-inch Sirocoo fan (capable of displacing 25,000 cu. ft. per minute running free at 310 revolutions) forced 10,640 cu. ft. per minute through the machine with $\frac{1}{2}''$ spread of leaf. The temperature was 110° at inlet and 220° in the machine. The machine dried 1,800 lbs. of leaf to 800 lbs. of 80 per cent. dry tea, and used 290 lbs. of Assam coal. The exact calorific value of this coal is not available, but will be about 9000 B. Th. U. per pound. The heat used was therefore about 3,300 B. Th. U. per lb. of tea made as against 5,750 assumed for Ceylon. The higher factory temperature only accounts for a small proportion of the difference.

"Under large scale factory conditions (drying cordite) electrical drying is found to have an efficiency of 74 per cent. to 78 per cent. Converting the heat used for tea drying into electrical terminology, 3,440 B. Th. U.=1 kWh. or electrical unit. This gives—

Ceylon, 5,750 B. Th. U.=1·67 units per lb. of made tea.

Duars, 3,000 B. Th. U.=0·87 units per lb. of made tea.

"Accepting the higher figure, the electric energy would have to be sold at about 1·5 cents per unit to show a saving of about 10 per cent. With the rapid exhaustion of wood supplies and the rising price of oil the saving to the Planter will be a rising one. A further point, as yet unproved, is that of *quality*. By means of thermostats the temperature regulation can be maintained with exactitude at any desired value. What the effect of this will be cannot be forecasted, but it can hardly fail to effect an improvement. Furthermore, there can be no possibility of spoiling a batch of tea owing to a leaky flue, as there will be no flue to leak and no smoke to smell."

A correction has been made in the above extract as to the calorific value of Assam coal. Coming now to the power required, the following may be quoted:—

"So far the consumption in units has been in question. It now remains to ascertain the horsepower required. Although the fuel used for drying is only half as much again as that for power its equivalent in plant installation is much greater—for the thermal efficiency of the oil engine is very low compared with that of electrical heating.

"At the risk of being tedious the direct method of ascertaining the power required for heating air will now be shown. At the average level of the tea gardens 1,000 cu. ft. of air will weigh about 65 lbs. while its specific heat is in round figures 0·24. Therefore to raise this quantity 1° Fahr. requires 65×0·24 or 15·6 B. Th. Units, equivalent to 4·6 watt-hours nearly. On tests an efficiency of 74 to 78 per cent. is obtained, bringing the power required up to (say) 6 watt-hours per 1,000 cu. ft. heated 1° F.

"For practical conditions assume an outturn of 100 lbs. of made tea per hour's use of the dryer; for any other output the figures will be proportional. From the Duars test referred in the preceding paragraph this will require about 1,330 cu. ft. of hot air per minute. If the rise of temperature required is 120 F. this will require $6 \times \frac{1,330}{1,000} \times 120 = 96$ watt-hours per minute or practically 60 units an hour, which is a rate of 60 kWs. The fan power is of course extra and is already included under motive power.

"Here an interesting side light is thrown on the efficiency of present methods. Taking both the Ceylon and Duars figures worked out from fuel consumption on the basis of 100 lbs. of tea made per hour we have :—

Ceylon, 100 lbs. using
1·67 units per lb. =167 units per hour;
=167 kWs.;

Duars, 100 lbs. (80 per cent. dry) using 0·87 units per lb. .. =87 units per hour;
=87 kWs.;

as compared with 60 kWs. estimated from actual tests with electrical drying. It therefore appears clear that about 3 times as many heat units are at present wasted as are utilized; but until electrical tea dryers have been actually used under service conditions it cannot be definitely stated that their efficiency will be as high as is assumed from other industries."

It may be added that Mr. Allan of the General Electric Co., in connection with the Duars project, which is that for Messrs. Octavius Steel & Co.'s gardens referred to above, believes that 60 units per 100 lbs. of tea will prove a conservative figure; if so, the economy will be even greater than that assumed in the Ceylon report.

Chapter 8.—The Control of Water Power.

49. The question of State Control and Assistance.—The Water Power Committee of the Conjoint Board of Scientific Societies, London, has expressed its preference for State control of hydro-electric developments in the following excerpt :—

"The considerations already outlined would indicate that the conservation and utilization of the water power resources of the Empire is likely to be one of the most important problems in our political economy. The solution of this problem involves many complex questions of law, of administration, and of engineering and economic investigation, if the public interest is to be best served by the development. In view of the immensity of the interests involved, it is urged that nothing short of statutory control of these developments is desirable. The exact method of control is not for the Committee to suggest. So far as is possible private enterprise should be encouraged, but under conditions which would prevent the perpetual rights being lost to the community.

"It should be recognized, however, that while it is essential that the State should have the right of ultimate purchase, the period of such purchase should not be unduly short or the terms too onerous. It will be remembered that such legislation had the effect of severely handicapping the electric power and lighting industry in the early days of its development."

During the course of the preliminary enquiry the question of the policy to be adopted was discussed on various occasions with public officers, firms and individual engineers. A policy suitable for one part of India may be the reverse elsewhere.

The subject of water storage and water power, although in the category of "Reserved Subjects," has now become purely a provincial matter. Government assistance is required, where a grant of the right to develop water power is given, in such matters as land acquisition, water rights, transmission of power routes and so forth.

At present there is a vicious circle of industries that require power and power looking for an assured outlet; and neither side is inclined to make a move unless certain of the co-operation of the other. An example already exists of established water power going a-begging, within transmission reach of a considerable demand, and whatever the reasons may have been that led to this *impasse* it has undoubtedly had a deterrent effect on similar enterprise elsewhere. There may be cases where the carrying out of a project by Government may be advisable, if investigation proves that the indirect benefit to the country of cheap power will counterbalance a comparatively small return on the capital invested in the power scheme.

Government aid should, it is considered, only apply to the development of water power (*a*) by a public utility company or (*b*) for the purpose of an industry in which Government has a particular interest or (*c*) for an industry which it is particularly desired to foster. A company developing power for its own factories, not coming under heads (*b*) or (*c*), would not usually require help.

The Water Power Resources Committee of the (now defunct) British Board of Trade laid down certain "fundamental principles," which may be recorded here :—

"(*a*) The whole of a watershed must be thoroughly studied and the fullest use made of its potential water power consistent with reasonable capital expenditure. A development which would only result in a part of the power being utilized should not be permitted if the ultimate use of the whole available power is thereby prejudiced.

(*b*) Proper regard must be shown to the interests of domestic and trade water supplies, fisheries, the drainage of adjacent lands, canals, and inland navigation, and in certain cases to local amenities. Neglect to give consideration to some of these requirements has been responsible in the past for failure in the promotion of some water power schemes.

(*c*) A part of the available power must be reserved for use by the local population within the watershed, both for present requirements and also for prospective developments. It is important to remember, however, that in the case of large water powers considerably in excess of local requirements, it would not, in general, be commercially practicable to ensure a cheap local supply of electricity unless the powers were developed to the maximum extent and the bulk of the output utilized by an industry requiring practically a continuous supply throughout the year."

A constructive suggestion may be put forward from German practice. "In Germany before the war, not a few of the great municipalities entrusted the management of undertakings of public utility, gas, water, electric light, tramways and so forth, to a Company in which the municipality held shares sufficient to make it an important if not a predominant shareholder. The system is understood to have worked satisfactorily. The public authority protects the public and gives the company the benefit of its superior credit, while at the same time the benefits of private enterprise are preserved."* The article here drawn on is on the subject of railway nationalization, but the proposal appears to contain the germ of a principle of very wide application. The writer goes on to point out that (as in Canada) the business could be managed by a Board of business directors, but, in the case of undertakings so combining State or municipal with Company ownership, the Board would consist partly of official nominees and partly of representatives of shareholders. The private shareholders would then receive some agreed proportion of the net profits above their guaranteed net income, as already suggested in the Preliminary Report.

50. Grants for development of water power.—After some discussion the term "Grant" for the development of water power has been adopted by the Government of India in preference to "Lease," "License," "Concession" or "Agreement." Such grants are embodied in agreements between the Secretary of State for India (represented by the local Government as Grantor) and the Grantee. Apart from actual undertakings at work (Chap. 10) or under construction (Chap. 11) agreements have been entered into, or are under consideration, between Government and the promoters for the development of the following sites. The power involved is entered elsewhere in this Report and is not given here.

List of grants or proposed grants for the development of water power (exclusive of sites developed or under construction).

Assam.—None as yet. An application has been made for developing the Um Tru river at Burnihat, and the Umkra stream at Shillong may be the subject of a grant presently.

Bihar and Orissa.—None.

Bombay.—Messrs. Tata Sons and Co. have applied for the right to develop the Koyna Valley scheme and also the Kundli Valley, which is an extension of the original Tata Hydro-Electric Power Supply Co.'s works. The Nila Mula project is temporarily held up.

(i) *Burma.*—Agreement with the Burma Mines, now the Burma Corporation Limited, relating to the Mansan falls.

(ii) Agreement with the Kanbauk (Burma) Wolfram Mines Limited, Tavoy.

Two other applications in the Tavoy District are pending.

Central Provinces.—None.

* Quarterly Review No. 460, July 1919, p. 174.

Madras.—(i) An agreement granting the right of development has been entered into for the Kundah River, with Messrs. Tata Sons and Co., who are negotiating with Coimbatore interests for working up the project.

(ii) The power rights in the Periyar Lake were granted to Mr. A. H. Garrett, who transferred them to a syndicate represented by Sir A. Chatterton, C.I.E., Industrial Adviser to Tata Sons and Co. Applications have been made in respect of various other projects, as follows:

(iii) Gundar and Kumbar project, Madura. Mr. Lee Hart has applied for the right to develop this project. It is not a promising one, and the Pinjikave-Berijam scheme near by offers far greater possibilities.

(iv) Kollimalai scheme. Mr. Perry has applied for the right to develop this and the matter is under consideration.

(v) Pykara scheme. Two applications have been made for the right to develop the Pykara beyond Ootacamund, and the matter is under consideration.

(vi) Sirumalai scheme. There are tentative proposals for utilizing this.

(vii) Vuyyuru scheme. This is a small canal project for which an application for development has been made.

Punjab.—(i) Two projects that are the subject of agreements are working at Dhariwal and Nidampur (Patiala).

(ii) An agreement with the Punjab Power Association, to which General Beresford Lovett and Sir Thomas Higham were parties, has lapsed and fresh proposals are pending for the development of the falls on the headwaters of the Upper Bari Doab Canal. The applicants are the Subera Hydro-Electric Co.

(iii) An agreement has been entered into between Government and the Punjab Hydro-Electric and Industry Development Association (Bawa Hardyal Singh) for utilizing four falls on the Upper Jhelum and Upper Chenab Canals. Construction will shortly commence, it is hoped, at the Joyanwala Fall.

(iv) A project for irrigation pumping by power from the Lower Bari Doab Canal at Renala is under consideration.

United Provinces.—Agreements were entered into many years ago with the United Provinces Power Association (General Beresford Lovett) for developing two loops on the Jumna, one of which is partly in Tehri-Garhwal. Nothing whatever has been done and the agreement expires shortly.

51. General Considerations as to "Grants."—A grant for the development of water-power for a short period would usually be valueless; the period must necessarily be long enough to enable the grantee to recover the capital sunk in the enterprise. Electrical undertakings, working under a license granted under the Indian Electricity Act, may usually be purchased after 50 years, and a similar period is reasonable in the case of hydro-electric installations.

Where a decision has to be made between the claims of two or more applicants for a Grant the claims of a public utility company should, it is considered, have precedence over an application from a purely industrial concern, because the latter can always obtain its power from a company even though it may have to pay a slightly enhanced rate for it. Furthermore, a company which is to serve the general public should be of greater value to the State than one which is serving its own interests only. Where the claims of two applicants who wish to float a public company have to be decided between, the Grant would no doubt be given to the one who also obtained a license under the Indian Electricity Act from the local Government concerned. It may be emphasized that it should be allotted to the applicant who is prepared to offer the best terms *to the general public*, rather than preferential terms to the Government; the latter invariably react on the private consumer. The same conditions should, it is considered, also govern grants for the use of water-power. The claims of two competitors who both wish to develop water-power for a purely industrial purpose should be settled, it is suggested, in the same way, according to the conditions and rates under which they purpose to sell their products to the public.

The conditions under which a grant for the use of water-power should be given to a public utility company should, it is considered, vary from those made for a company concerned with a particular industry. The works of the former can always in the last resort be taken over by a local authority or the local Government under the provisions of the Indian Electricity Act, and can be continued in use and developed for the use of the public in the case of mismanagement or the insolvency of the grantee. In the case of a grant for a purely industrial purpose, seeing that Government must be consulted as to how the site shall be developed, it appears necessary that the grant shall stipulate for the removal of any works that may interfere with the use of the power by other persons on the final expiry of the grant, or in case of its determination for breach of the conditions imposed.

The dangers to be guarded against in giving a "Grant" are:—

(*a*) *The grantee may merely hold his grant until* he is bought out by a company. This is not in itself necessarily an evil, so long as power is retained to cancel the grant if work has not been begun and completed within a reasonable time. A substantial deposit would probably be required, on which interest would be paid. This deposit should be liable to be forfeited if work is not put in hand and carried through within a reasonable time, especially if any other applicant is in the field.

(*b*) The site may be ruined by partial development. In the case of every public utility company it should be a condition that the initial works shall be so carried out that eventually the full possibilities of the site can be utilized if there is a demand for more power. If this condition would render the initial development too costly for commercial success it might, in the absence of direct help from Government, be impossible to proceed. It must always be remembered that in such matters as storage works and canals or channels it is almost essential to build for the full ultimate requirements at the very start; but it is seldom possible to put plant down for the full power, so the extra capital is for the time being unproductive. In the case of an industrial development company this condition does not appear to be *necessarily* applicable; but foresight is required if good sites are not to be spoiled by partial development.

(*c*) Existing water rights and future irrigation demands must be safeguarded, or, in other words, no grant should be given until the irrigation possibilities have been fully considered. This, as a matter of course, is always done. The small riparian rights of private persons would seldom offer any difficulty as the whole extent of a hydro-electric scheme will generally only embrace a few miles of a channel. The utilization of the tail waters of the turbines is a more complicated matter. The most effective position for a power station might be such that a possible future canal supply would be jeopardized. In such cases the conflicting claims of power and irrigation would have to be threshed out by an independent authority.

(*d*) Power should be taken in any Grant to determine the same should the grantee stop using or not make sufficient use of the water-power, provided that there are other applicants for its use.

The question of the payment of royalties for the use of water-power has been much discussed. Mr. Barlow and the present Chief Engineer advised against the payment of any royalty on the grounds that industrial development was more important than small sums obtained in this way, except in cases where promoters use works (*e.g.*, canals, etc.) already constructed. It has however been decided that a small royalty is both just and expedient; the comparatively small expenditure on the Survey will in this way soon be recouped in the Provinces concerned. As regards "public utility companies" *i.e.*, companies supplying power to all applicants in their area of supply for all purposes, as distinct from purely industrial power companies, the following considerations were put forward in the Preliminary Report :—

First.—A company which is brought into existence for the good of the public is already doing a public service, and should not be burdened with special taxes on its construction or working which will inevitably be passed on to the consumer.

Secondly.—Such a public utility company should be given every facility to fight its early struggles, and only when it has achieved a position of prosperity should Government step in to share the profits; and then only with due regard to the consumer's prospects of a cheaper supply.

Finally it is very desirable in the interest of British Trade that British Standards of pressure and frequency should be adopted in all future hydro-electric work, and the suggestion is put forward that this should be a condition of all grants and agreements for the development of water-power The matter is more fully dealt with it in para. 47 *supra*.

52. Encouragement of hydro-electric development.—In Chapter 6 of this Report a comparison is made between steam power and water-power, and in connexion with any "Grant" for development of the latter the considerations there set forth are important. So far as any industrial limited liability company is concerned the chief factor will necessarily be the total cost of the rival methods of obtaining power; the desirability of fuel conservation is admitted on all hands, but business men will only be willing to assist in conservation when their shareholders will also benefit. It may therefore be not out of place to add some remarks as to the lowest cost of producing power in India.

In the 1920 "Supplement to the List of Electrical Undertakings in India" an abstract is given of the financial and technical details of all the licensed "public utility" electrical undertakings in India. The fuel driven plants vary greatly in size and output, as well as in the cost of the power produced, and in the latter respect all have suffered from the war.

In the year 1919 the Calcutta Electric Supply Corporation generated 40·1 million units and sold 31·9 millions at an average price of 2·32 annas a unit. Their plant capacity then amounted to 22,300 kW. and the load factor for the year was 30·3 per cent. on a maximum load of 12,000 kW. Being comparatively near the Bengal coal fields the cost per ton of fuel would be low, probably about eight rupees. The actual cost of fuel per unit generated was 0·190 annas, and per unit sold 0·24 annas ; considerably below that of any other company. With an actual maximum load of 12,000 kW. the average load to generate 40·1 million units was practically 4,600 kW. on the continuous basis. The fuel cost of a killowatt year, or 8,760 units sold, was Rs. 132. Therefore any royalty of this order would render the competition of water-power out of the question, as the capital charges for water-power stations are generally much higher than that of steam stations and the power usually has to be transmitted long distances.

Lower fuel costs than the above are found in self-contained installations, such as railway works, even though they supply a small amount of power to private houses ; but the use of water-power for self-contained works comparatively near the plant is a condition not at present met with in India.

It has already been pointed out that the value of a given flow of water in horse-power is directly proportional to the head so that a royalty per cusec of flow used would be anomalous. A charge of the order of Rs. 10 per h. p. year, based on the *working* plant (exclusive of spares) would not often be sufficient to deter promoters from proceeding. At the Cauvery falls the charge (after the first 5 years) was Rs. 5 per e. h. p. year, while for the Lagylap project in Sikkim 12 annas per e. h. p. year was agreed upon and for the Jumna power scheme 4 annas per (theoretical) water h.p. year. Where existing canal works have been used, much higher royalties, up to Rs. 40 and even Rs. 60 and Rs.75 per h. p. year, have been charged.

53. Accounts of undertakings belonging to Government.—There is a general consensus of opinion, both lay and technical, that it is both impolitic and impracticable to attempt to run a Government hydro-electric project on the account systems of the Civil Account Code. There are no doubt many excellent reasons why the various Codes are necessary for the ordinary run of Government work, including such quasi-commercial undertakings as irrigation works. An electrical undertaking however is on a very different footing and it is submitted that its accounts (at any rate after construction is completed) should be kept on strictly business lines, by commercial accountants, and subject to commercial audit by a Chartered Accountant. At that stage it will doubtless be possible for the Accountant-General to take the audited accounts and pass them into the Provincial accounts in any form he thinks fit. It has been suggested by the Director of Industries, United Provinces, that the best way to compass this end would be to place the management of such a concern in the hands of a responsible firm of Managing Agents, who would deal with the concern precisely as though it were a limited liability company under their charge, subject to the decisions of a Board of Directors in which Government would have the deciding voice. No doubt grave objections will be raised to any such procedure, but it seems essential if such undertakings are to be run on sound lines ; and new departures require new methods. To take only one instance, a scheme of this nature *must* be written down for depreciation and *must* carry a reserve fund for emergencies ; otherwise its real financial position will never be known. A canal does not depreciate beyond the extent to which periodical repairs will bring it back to its original condition ; whereas plant not only wears out but may become obsolete while still in full working order, by which time it will have been already written down to scrap value so that there will be no disturbance in the acounts. No Accounts Code takes account of "obsolescence," if the use of this Americanism is permissible ; hence examples can be found of plant working in Government factories that has been obsolete for many years but has been retained because it will still work. The success of a company-run electrical scheme depends on the dividends which the balance of revenue over expenditure and capital charges enables it to pay, after providing for contingencies. This margin is increased by enlarging the sphere of operations and the sales ; and the sales are increased by judiciously lowering the rates charged for energy so as to bring in new consumers. While the same careful provision for the future in the matter of depreciation and reserves is necessary in a Government concern—indeed, without it, the real position can never be gauged—there is no necessity to pay regular dividends beyond the provision of the ordinary rate of interest on capital. If there is a further surplus in a particular year the rates charged for energy should be lowered in the following year, thus increasing the demand on the concern and its utility to the public and increasing the industrial prosperity of India. The indirect benefit from the expansion of industry and amenities of life will, it is submitted, take the place of a direct return in cash. As regards reserve funds, it may at first sight appear absurd that an undertaking with Government behind it should require such a fund; but reflection will show that what is sound finance in company management will not be the reverse in this case. The reserve fund, as is often the case in companies, can be " invested in the business " and used for extensions; and, by having it, the management and progress of the undertaking will be strictly comparable with other similar but purely commercial concerns. The genesis of the above suggestions was in the writer's report on the " Laxapana-Aberdeen " Hydro-Electric project in Ceylon.

54. " Model Form " of " Grant for the development of water-power."—A draft Model Form prepared by the present writer in 1919 and the proposals contained in it have since been discussed between the Government of India and local Governments. Generally speaking the form as modified during these discussions has been accepted as a reasonable basis to work upon; but the Government of India have decided not to issue a model Form themselves, but to leave the matter in the hands of the Chief Engineer, Hydro-Electric Survey. The Model Form now printed in Appendix II is therefore no more than it professes to be, *viz.*, a suggested form covering all points likely to arise when there are negotiation between Government and a promoter for the use of the water-power available at a given site. Anything of the nature of rigid uniformity is neither necessary nor desirable, but a reminder of points apt to be overlooked cannot fail to be of value. The Model Form is accompanied by explanatory notes and a suggested form of application. The value of the latter lies in the fact that it can only be filled in when the site has been investigated reasonably beforehand, so that genuine applications can be separated from purely speculative ones.

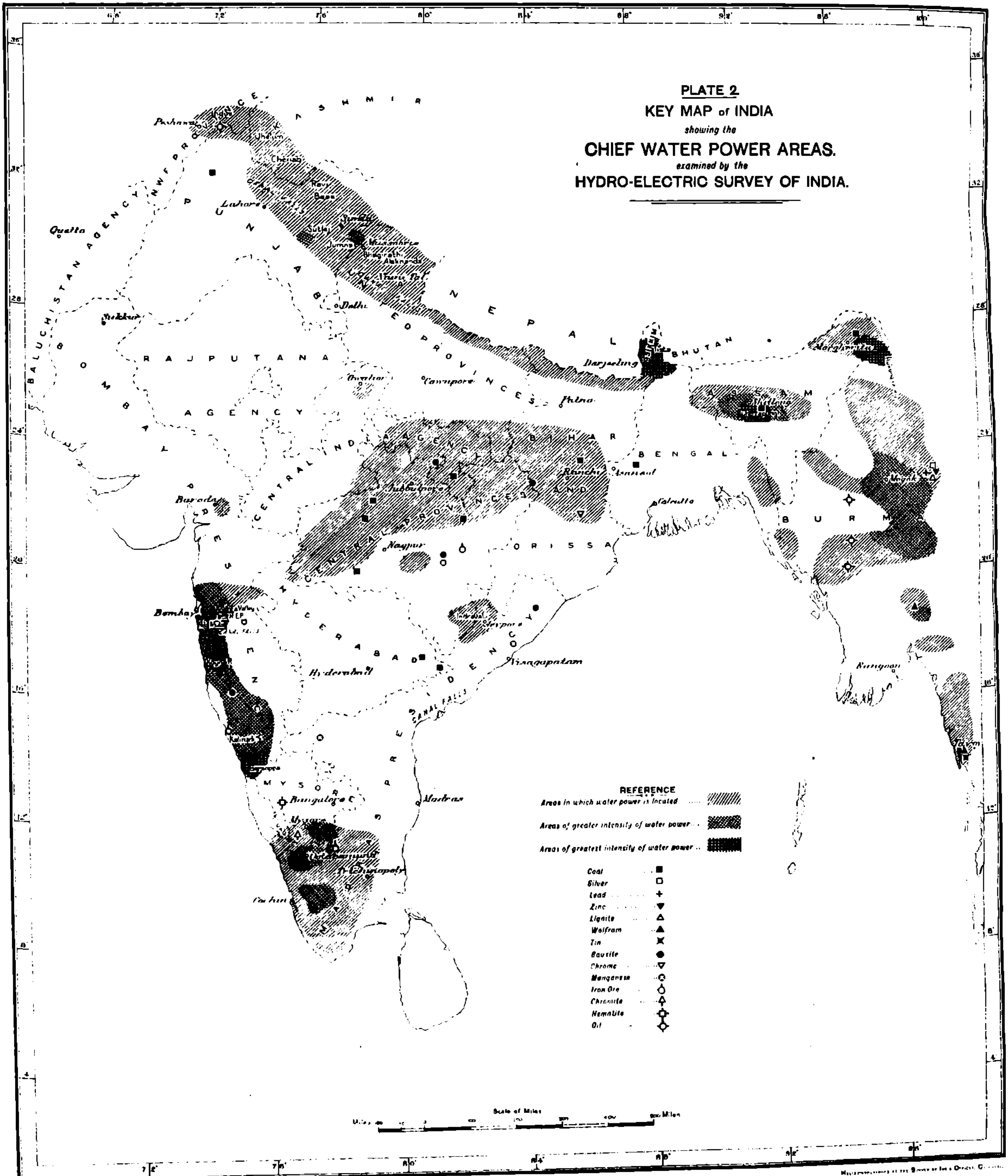


PLATE 2.
KEY MAP of INDIA
showing the
CHIEF WATER POWER AREAS.
examined by the
HYDRO-ELECTRIC SURVEY OF INDIA.
REFERENCE
Areas in which water power is located
Areas of greater intensity of water power
Areas of greatest intensity of water power
Coal
Silver
Lead
Zinc
Lignite
Wolfram
Tin
Bauxite
Chrome
Manganese
Iron Ore
Chromite
Hematite
Oil
Scale of Miles
KASHMIR
PUNJAB
NEPAL
BHUTAN
RAJPUTANA
BOMBAY
BALUCHISTAN AGENCY
CENTRAL INDIA AGENCY
BIHAR AND ORISSA
BENGAL
ASSAM
BURMA
CENTRAL PROVINCES
HYDERABAD
MYSORE
Quetta
Lahore
Delhi
Cawnpore
Patna
Darjeeling
Calcutta
Nagpur
Bombay
Baroda
Hyderabad
Vizagapatam
Madras
Bangalore
Cochin
Rangoon

S. D. O. No. [illegible] Oct. [illegible]

PART II.—THE WATER POWER RESOURCES OF INDIA.

CHAPTER 9.—PRELIMINARY FORECAST OF THE WATER POWER OF INDIA.

55. Categories into which sites are divided; maps.—In the Preliminary Report no attempt was made to achieve the impossible by forecasting the water power of India. Even now any such attempt is of necessity largely guess-work :

" No pent-up Utica contracts your powers
But the whole boundless continent is yours."

The area with which this Survey is to some extent concerned is about 1,800,000 sq. miles of which over 1 million sq. miles are under British Administration. " The Indian Empire is equal to the whole of Europe, except Russia. Burma is about the same size as (pre-war) Austria-Hungary ; Bombay is comparable in point of area with Spain ; Madras, the Punjab, Baluchistan, the Central Provinces and Berar, and Rajputana are all larger than the British Isles ; the United Provinces and Bihar and Orissa than Italy."* Over this immense area, in common with other parts of the British Empire a hydro-electric survey was initiated in 1918 ; but hitherto only a fraction of the water-power resources has been examined. The following categories are dealt with :—

I. Water power now developed ; Chapter 10.

II. Plants under construction ; Chapter 11.

III. Areas investigated (not necessarily exhaustively) but not developed. This includes most sites where the available power can be gauged with considerable confidence ; Chapter 12.

IV. Known sites of which detailed examination is desirable. In these an estimate of the *probable* power is given whenever the data allow, but examination has not proceeded far enough to show whether the development is practicable from the engineering or the financial standpoint ; Chapter 13.

V. Areas and sites not examined. This list embraces many possible sites mentioned in the Preliminary Report of which practically nothing is known. Only in a few cases is a very speculative figure given for possible power, on the basis of such information as is obtainable from outside sources ; Chapter 14.

VI. Useless sites. In order that time may not be wasted on sites which have been examined and found useless these are entered, with reasons where these are known. Most of them were mentioned in the Preliminary Report, and having been given currency should now be cancelled ; Chapter 15.

The key map (Plate II) indicates generally the areas in which water power is known to exist, according to the depth of shading. The general map (Plate VII) in the pocket at the end of the volume has most known or probable sites marked on it, but the *positions are only approximate* ; where known, the text gives references to the 1-inch maps. The circles of 100 miles radius around the larger known sites (full) and probable sites (dotted) serve to show areas which could be served by interlinked systems.

56. Definition of minimum power ; power on ordinary minimum flow ; power for maximum development.—No endeavour has been made to assess the discontinuous power of individual sources which may be available for 6 to 8 months in the year. In every country this is much greater than the continuous power available on minimum flow in the worst years ; but in India, where the wet season is confined to a few months, the excess of power available during the time that the effect of the monsoon is still felt is beyond any attempt at calculation ; monsoon storage schemes are an exception, for here the *whole* available power is averaged throughout the year and the maximum power is also the actual. Furthermore, when the hot weather begins, there is a great rise in the discharge of all snow-fed rivers, which lengthens the discontinuous period. The Dominion Water Power Branch of Canada, which has taken up the question exhaustively, shows that the " Power for maximum development," dependable for 6 months, is very nearly double that obtainable on " ordinary minimum flow," *not* absolute minimum flow as in this Report. " Ordinary minimum flow " is defined as being " based on the averages of the minimum flow for the two lowest consecutive seven day periods in each year, over the period for which records are available." The " Estimated flow for Maximum Development " is based upon " the continuous power indicated by the flow of the stream for six months in

* The Indian Year Book, 1919.

the year. The actual method to determine this flow is to arrange the months of each year according to the day of the lowest flow in each; the lowest of the six high months is taken as the basic month; the average flow of the lowest seven consecutive days in this month determines the maximum for that year. The average of such maximum figures for all the years in the period for which data are available is the estimated maximum used in the calculation." In India it will be conservative to assume that the continuous power on "ordinary minimum flow" as defined above is, for the whole of India except Bombay and the Central Provinces, 50 per cent. in excess of the figures taken in this Report. These two areas are excepted because they depend almost entirely on monsoon storage, and an addition of 20 per cent. will be near the mark. The North-West Frontier Province has been left unaltered, as it is doubtful if the Indus will, in fact, ever be harnessed.

The "power for maximum development," again excluding these two areas (though the exclusion would not by any means be universal), may be taken as generally at least 3 times the ordinary minimum continuous power shown in this Report. For the excluded areas, to allow for projects not based on storage, 60 per cent. is added for Bombay and 30 per cent. for the Central Provinces. The table however varies somewhat from these figures, and is in round numbers.

57. Summary of results and anticipations; minimum continuous power.—The following table is a rough preliminary forecast of so much of the water power of India (based on minimum discharges) as it is in any way possible to indicate at present. The total power shown amounts to 5,582,000 kWs. or 7,400,000 electrical horse power; and as the basis is *minimum continuous power* the figures represent kilowatt-years. Diagrammatically the distribution among the chief divisions of India may be represented as shown in figure 23, where the scale is 1 sq. milimetre to 1,000 kWs.

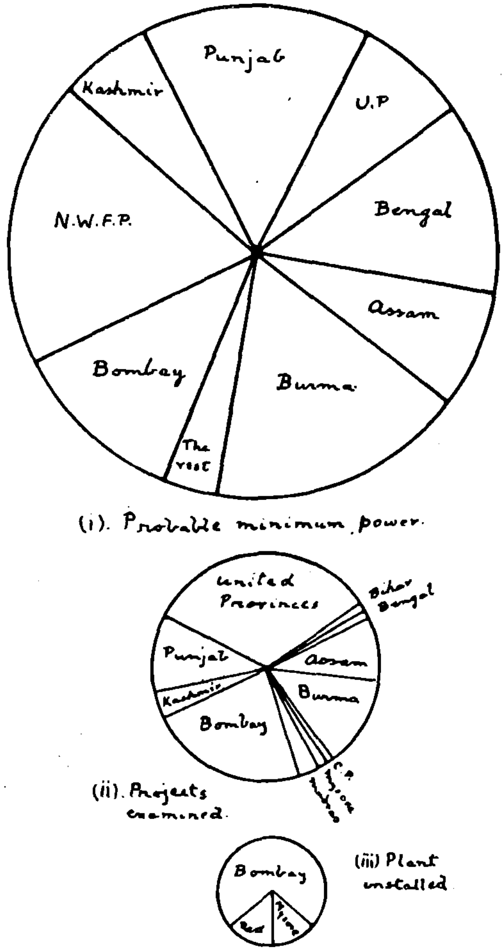


Fig. 23. The Water power of India.

TABLE 8.—*Summary of probable minimum continuous water power in India.*

Province or State.	Water power now developed (site capacity). kW. continuous.	Plants under construction. kW. continuous.	Areas investigated but not developed. kW. continuous.	Known sites of which detailed examination is desirable. Probable kW.	Areas and sites not investigated. Probable kW.	Probable total. kWs.
1	2	3	4	5	6	7
Assam	..	..	109,000	5,000	300,000	**414,000**
Baroda	..	..	4,000	..	..	**4,000**
Bengal	600	..	14,250	5,000	650,000	**669,850**

TABLE 8—*Summary of probable minimum continuous water power in India* —cotinued.

Province or State.	Water power now developed (site capacity) kW. continuous.	Plants under construction. kW. continuous.	Areas investigated but not developed. kW. continuous.	Known sites of which detailed examination is desirable. Probable kW.	Areas and sites not investigated. Probable kW.	Probable total. kWs.
1	2	3	4	5	6	7
Brought forward .	600	...	127,250	10,0000	950,000	**1,087,850**
Bihar and Orissa	..	..	12,550	20,000	30,000	**62,550**
Bombay	71,400	50,000	272,500	230,350	20,000	**644,310**
Burma	3,370	..	155,800	492,400	300,000	**951,570**
Central India	..	..	280	400	..	**680**
Central Provinces and Berar .	..	..	13,700	113,860	10,000	**137,560**
Cochin	..	..	4,000	..	..	**4,000**
Coorg	..	..	..	1,500	..	**1,500**
Gwalior	..	1,000	42,300	..	..	**43,300**
Jammu and Kashmir . . .	105,830	..	..	179,500	20,000	**305,330**
Madras	740	..	32,670	53,900	5,000× x	**92,310**
Mysore	24,000	4,500	20,000	..	..	**48,500**
North West Frontier	[250]	..	..	..	[1,000,000]	**[1,000,000]**
Patiala	290	..	..	..	..	**290**
Punjab and canals	1,880	..	129,270	See cols. 4 & 6	662,000	**793,150**
Rajputana	..	..	..	160	..	**160**
Sikkim	..	..	5,000	..	..	**5,000**
Travancore	450	..	..	..	..	**450**
United Provinces and canals . .	4,330	140	378,900	See cols. 4 & 6	20,000	**403,370**
TOTALS . .	**213,140**	**55,640**	**1,194,280**	**1,102,070**	**3,017,000**	**5,582,000**

Of the projects or sites included in the above summary the following list shows the order of magnitude of the projects suggested or known; but, as regards the first entry,* only 4,000 kWs. can be developed on the present layout of open channel :—

Minimum power available, kW.	Developed.	Under construction.	Investigated.	Known, but not fully examined.	Probable.	Possible.	TOTAL.
Over 100,000 . .	1*	..	1	3	No indcaition is possible.	No indication is possible.	5
50—100,000 . .	..	1	1	2			4
20— 50,000 . .	3	..	6	5			14
10— 20,000 . .	..	..	6	14			20
5— 10,000 . .	..	..	9	10			19
1,000— 5,000 . .	3	2	29	20			63
TOTAL	7	3	52	63	..	..	125

There doubtless remain many other unknown sites, and the future possibilities of development by lifting dam offer an untold number of sites in the smaller categories.

58. Total power on "ordinary minimum flow" and for "maximum development."—This need not detain the reader for long, as it is speculative and based on the minimum of reliable information. Using the definitions and multipliers suggested in para. 56 the following are *probably* conservative figures. Only the main areas are entered.

TABLE 9.—*Summary of ordinary and maximum power.*

Province or State.	Probable ordinary minimum power;	Probable power for maximum development;
	kW.	kW.
Assam	621,000	1,200,000
Bengal	1,000,000	1,500,000
Bihar and Orissa . .	95,000	150,000
Bombay	773,000	1,000,000
Burma	1,327,000	3,000,000
Central Provinces . .	165,000	180,000
Jammu and Kashmir . .	458,000	650,000
Madras	138,000	300,000
N. W. F. Province . .	[1,000,000]	[1,000,000]
Punjab	1,190,000	2,400,000
United Provinces . .	605,000	1,000,000
Other areas entered in preceding table	160,000	300,000
TOTAL .	7,532,000	12,080,000

Chapter 10.—Water Power now developed in India.

59. Summary of water power now developed.—In para. 23 of the preliminary Report, Table 2 showed the water power then actually in being in (geographical) India. The *plant installed* amounted to 83,900 kWs. (111,860 e. h. p.) but this did not of course represent the continuous power value of the sites. Thus the largest contribution to the total came from the Tata H. E. P. S. Co. in Bombay, which has virtually a 12-hour working day, so that when the varying load factor of the working day is taken into account the plant installed can be, and in fact is, much more than double the continuous 24-hour, 365 day power. Throughout this report the *continuous power* basis is employed, though where the plant installed (or to be installed) is known its capacity is also given. The present position as regards water power actually developed is indicated in the following table by Provinces and States, and further details are given in succeeding paragraphs :—

Table 10.—*Summary of water power now developed.*

Province or State.	Number of sites developed.	Plant installed, kWs.	Ultimate capacity of the sites on minimum flow. kWs. continuous.
Bengal	2	600	610
Bombay	4	102,600	71,400
Burma	3	6,790	3,370
Jammu and Kashmir	2	4,670	105,830
Madras	3	1,125	740
Mysore	1	16,900	24,000
North-West Frontier Province	1	250	250
Patiala State	1	210	200
Punjab	3	2,945	1,880
Travancore	1	450	450
United Provinces	2	2,240	4,330
India	22	138,786 kW.	Total 213,150 kW. continuous.

60. Bengal ; water power developed.—This at present consists only of the pioneer installation at Darjeeling. The Municipal hydro-electric supply is obtained from three small hill nalas, tributaries of the Rangeet and Tista rivers, map 78 A/8. The original development carried out by the present writer in 1896 utilized the Hospital jhora and Kotwali jhora, by means of open channels meeting above the confluence. Subsequently the Municipal Engineer, the late Mr. Robertson, brought in a third nala, the Barbutia jhora, by means of a flume carried on a considerable suspension bridge, over the deep gorge of the Kotwali. Later on the Hospital Jhora was tapped at a point higher up stream, and an upper power house was built, of which the tail race discharges into the regulating reservoir of the original and lower scheme. The following are the remaining data of both works :—

—	*Upper site.*	*Lower site.*
Minimum flow of sources.	About 10 cusecs.	About 10 cusecs.
Regulating storage, cub. ft.	45,000	228,000
Working head in ft.	650	275
Open channel, miles	1	2·9
Capacity of channel, cusecs	4·0	4·7
Length of pipe line, ft.	2,130	720
Plant installed, kW.	130	470

Continuous power available. On the *minimum flow* recorded this is :—

$$\left.\begin{array}{l}10\times 650/15 = 430\text{ kW.}\\ 10\times 275/15 = 180\text{ kW.}\end{array}\right\}\ 610\text{ kW.}$$

As however the open channels are only designed to carry 4 to $4\frac{1}{2}$ cusecs the actual continuous power is at present limited to this flow, or say 265 kWs., the storage merely sufficing to meet varying actual loads.

61. Bombay ; water power developed.—The plants now developed in Bombay consist of that at the Bhatghar Dam, the Tata and Andhra Valley works, and the Gokak Mills Co.'s plant. Of these the first was put up for the construction of the new and larger dam at Lake Whiting, which has been built on the existing site and passes through the present structure. The Gokak Mills scheme has been working for factory use for many years. Of the two Tata schemes, the Tata H. E. P. S. Co. has been working for some years ; but owing to the failure of the monsoon before the main Shirawta dam was completed, and when its great lake had not been filled, the supply had to be restricted during 1920. The Andhra Valley project is practically complete, and the whole of its power has been taken up. The Nila Mula project is under construction (see para. 72) by the same firm, but progress has been hampered by the industrial and financial situation.

All these three Tata projects depend exclusively on monsoon storage in great lakes at a high elevation, with passages through the water-partings. The original scheme has 3 lakes, of which the largest (Shirawta) is connected to the Walwhan Lake by a tunnel through

TABLE 11.—*Bombay H. E. works.*

Undertaking.	Andhra Valley.	Bhatghar.	Gokak Mills Co.	Tata H. E. P. S. Co.
Location	W. Ghats near Poona	32 miles from Poona; 3 miles from Bhor.	Gokak, W. Ghats	Lonavla, W. Ghats.
Map	47 F	47 F/12, 16		47 F.
Source of supply	Andhra Lake	Lake Whiting	Ghataprabha R.	Shirawta, Walwhan and Lonavla lakes.
Minimum perennial flow, cusecs	Storage alone	150 (from storage)	130	Storage alone.
Main storage, m. c. ft.	12,000	5,312	Nil	9,938
Regulating storage, m. c. ft.	Nil	Nil	1,100	2·7 in duct and forebay.
Working head, ft.	1,743	46 to 101	210	1,725
Length of open channel, ft.	Tunnel 1·65 by 82·8 sq. ft.	Nil	½	4·6
Capacity of channel, cusecs	600	...	200	480
Length of pipe line, ft.	4,700	440	275	13,000
Plant installed, KVA.	50,000	1,024	1,570	50,000
Extensions in progress, KVA.	...	Nil	Nil	10,000

the parting. A considerable open channel, with a forebay far too small, leads to the power house in the plains at the foot of the Ghats. These works have been fully described in papers read before engineering societies.* The Andhra Valley is a far finer natural site. Here an immense lake is impounded by a dam that is quite narrow over its deeper parts; and a pressure tunnel at the upper end of this lake, tapping off a comparatively small depth of water but most of the useful capacity, leads directly to the pipe line and a surge tower cut in the rock. The technical data of these works are given in the above table.

Continuous 24-hour power. At the Andhra Valley works the continuous discharge possible with 12,000 m. c. ft. of effective storage, allowing for losses, is about 320 cusecs so the continuous power may be put at 37,000 kWs.

At Bhatghar the minimum flow is dependant on irrigation considerations, and is now 130 cusecs, giving say 640 kWs. on average head. Large pipes are being built into the new dam, so that some 2,500 kWs. will be capable of development during the irrigation season of 8 months.

At Gokak it is 1,900 kWs.

At the Tata H. E. works the continuous discharge possible is some 260 cusecs, so the continuous power is some 30,000 kWs.

For the four plants it is 71,400 kWs. continuous against 102,600 KVA installed.

62. Burma; water power developed.—The plants now working in Burma are all in connection with mining areas; *viz.* the Burma Mines Ltd., the Burma Ruby Mines, Ltd., and the Kanbauk Wolfram Mines, Ltd. The following table (Table 12) gives particulars of these three plants :—

TABLE 12.—*Burma H. E. works.*

Undertaking	Burma Mines.	Ruby Mines.	Kanbauk Mines.
Location	Namtu, N. Shan States.	Mogok, U. Burma.	Tavoy.
Map			
Source of water	Mansan falls in the Nam Yam, trib. of Nam Tu.	Yaynee and Yaybu streams.	Sin Yat Chaung.
Minimum flow, cusecs	134	30	Nil
Main storage, m. c. ft.	Nil	Nil	62
Regulating storage	Nil	Nil	Nil
Working head, ft.	270	205	2,000
Length of open channel, miles.	½	Nil	Nil
Capacity of channel, cusecs	254	..	..
Length of pipe line, ft.	090	2,250	14,510
Plant installed, KVA.	6,000	418	375
Extensions in progress, kW.	Nil	Nil	Nil

Continuous 24-hour power. At Mansan falls, on the figures given, the continuous power available under the worst conditions is 2,400 kWs. The river flow

* Journal I. E. E., 1915, Vol. LIII, p. 092; Proc. I. C. E., 3rd December 1918.

is in fact all passed through the wheels at such times. At the Ruby Mines the minimum continuous power is 30×205/15 or 410 kWs. At Kanbauk the site could be developed for 560 kWs. continuously with the present dam, since the flow will take the power during the rains ; the run-off in 1920 was estimated at 580 m. c. ft. It is interesting to note that the dam here is of the "rock-fill" type, with reinforced cement concrete face and loose stone backing.

The continuous power of the three plants aggregates 3,370 kWs. under minimum conditions.

63. Jammu and Kashmir ; water power developed.—The two plants recorded in the Preliminary Report on this State remain unaltered, as follows :—

TABLE 13.—*Jammu and Kashmir H. E. works.*

Undertaking.	Jammu Power Installation.	Jhelum River.
Location	Jammu, Tawi	Mohora, Kashmir Road.
Source of water	Ranbir Canal	Rapids in Jhelum.
Minimum perennial flow, cusecs.	500	4,000
Storage	Nil	Nil
Working head, ft.	25	390
Length of open channel	Nil	6½ miles.
Capacity of channel, cusecs	...	560
Length of pipe line, ft.	Nil open penstock.	750
Plant installed, kW.	670	4,000
Ultimate capacity, continuous power, kW.	830	105,000 on minimum flow ; 14,500 on present open channel.

The total available power at these two sites is therefore 105,830 kWs. against 4,670 kWs. installed.

64. Madras ; water power developed.—The plants working in Madras are three in number, as shown in the following table :—

TABLE 14.—*Madras H. E. works.*

Undertaking.	Annalley scheme (Anglo-American D. Tea T. Co.).	Cordite factory (Government).	Kolagudi ropeway of Kanan Devan Hills Produce Co.
Location	Anamalai Hills	Karteri, Nilgiris.	Bodinayakanur. Madura.
Source of water	Hill stream	Hill streams	Hill streams.
Minimum flow, cusecs	3½	3	3½
Main storage, m. c. ft.	Nil	Nil, but large regulating storage.	Nil
Regulating storage	Nil	21 m. c. ft. in two lakes.	Nil
Working head, ft.	800	650	700
Length of open channel	300 ft.	Nil	½ mi.
Capacity of channel, cusecs.	3½	..	3½
Length of pipe line, ft.	3,000	2,130	1,780
Plant installed, kW.	55	1,000	70
Extensions in progress, kW.	55	Nil	Nil
Continuous power available at site, kW.	180	About 400	160

The total continuous power at the three sites, under minimum conditions, may therefore be taken as 740 kWs.

65. Mysore ; water power developed.—The only plant at present working is the Cauvery Power scheme, of which the particulars follow :—

Location.—Sivasamudram.
Source of water and minimum flow.—Cauvery River and falls. The great reservoir which is being constructed above these works will completely alter the power situation. Without this storage the minimum flow is 100 cusecs. With the first stage of the storage this minimum will be raised to 750 cusecs and eventually to 900 cusecs.

Main storage	11,000 m. c. ft.
Regulating storage at two anikats	300 and 800 m.c. ft. respectively.
Working head	410 to 425 ft.
Length of open channel	3·2 mi.
Capacity of channel	1,000 cusecs.
Length of pipe line	950 to 1,100 ft.
Plant installed	16,900 kW.
Extensions in progress	8,467 kW.

The ultimate capacity of the site, continuous power, will be 900×410/15 or 24,000 kWs.

66. North West Frontier Province ; water power developed.—The small plant erected for the construction of the Malakhand tunnel is the only one in this Province. The undeveloped power of the Swat Canal itself at this site is dealt with elsewhere, para. 118. The plant is supplied by a power channel, 2½ miles long, taken directly from the Swat River, a mile above the canal headworks. Carrying 125 cusecs and utilizing a 30 ft. fall the power available is some 250 kW. This is also the plant installed.

67. Patiala States ; water power developed.—The Patiala Hydro-electric scheme utilizes an 8 ft.

fall on the Ghagar branch of the Sirhind Canal, at Nidampur. With a minimum flow of 550 cusecs 290 kW. continuous is available, and 213 kW. are installed.

68. Punjab; water power developed.—There are three plants now working in the Punjab, at Amritsar, Dhariwal and Simla. Particulars follow in tabular form.

TABLE 15.—*Punjab H. E. works.*

Undertaking.	Amritsar H. E. pumping installation.	New Egerton Woollen Mills.	Simla Municipal Electric Dept.
Location	Near Amritsar	Dhariwal	Chaba near Simla.
Source of water	Main branch lower, Upper Bari Doab Canal, Grand Trunk rapid.	Fall in Upper Bari Doab Canal.	Nauti Khad, tributary of Sutlej.
Minimum perennial flow, cusecs.	30 days closure 65 days of 350 normal 1,050.	200 (generally 500-600).	10
Main storage	Nil	Nil	Nil
Regulating storage cu. ft.	Nil	Nil	642,000
Working head, ft.	5 to 9·8	11	540
Length of open channel	Short diversion.	Nil	2¼ mi.
Capacity of channel, cusecs.	2,300	..	35
Length of pipe line	Open penstock	Open penstock	1,300 ft.
Plant installed, kW.	525	670	1,750
Extensions in progress	Nil	Nil	Nil
Ultimate capacity of site, continuous power, kW.	525 (except by remodelling).	670	685 on minimum flow.

69. Travancore; water power developed.—The small Pulivassal scheme at Munnar is the only one at present developed. With a head of 400 ft. 450 kWs. are developed.

70. United Provinces; water power developed.—At present the small plant put up at Bahadurabad, for use on the construction of the new Ganges Canal head works at Hardwar, and the Mussoorie-Dehra Municipal H. E. scheme are alone. Details follow:—

TABLE 16.—*United Provinces H. E. works.*

Undertaking.	Ganges head-works supply.	Mussoorie-Dehra Municipal H. E. scheme.
Location	Bahadurabad	3 mi. from Mussoorie.
Source of water	Two falls in the Ganges canal, combined.	Two hill streams.
Minimum perennial flow, cusecs.	3,000	8
Main storage	Nil	Nil; but a reservoir of 11 m. c. ft. under consideration.
Regulating storage	Nil	Small.
Working head, ft.	19	1,000
Length of open channel	Short diversion	Nil
Length of pipe line	Nil; open penstock.	4,350 ft.
Plant installed, kW.	450	1,790
Extensions in progress	Nil	Nil
Ultimate capacity of site, continuous power, kW.	3,800	530 on minimum flow.

CHAPTER 11.—HYDRO-ELECTRIC PLANTS UNDER CONSTRUCTION.

71. Summary of plants under construction.—In the Preliminary Report, page 37, Table 4 gave a summary of plants then under construction; of these the Sikkim project was incorrectly entered as it is not even now actually under construction, although it is ready when favourable times come. The Andhra Valley scheme is now practically complete, and has been placed among existing plants. The following is a summary of the projects enumerated below:—

TABLE 17.—*Summary of plants under construction.*

Province or State.	Number of projects.	Plant to be installed, kWs.	Capacity of site in kWs. continuous.
Bombay	1	105,000	50,000
Gwalior	1	1,000	1,000
Mysore	1	4,500	4,500
Punjab	1	2,000	Included in Punjab canals.
United Provinces	1	450	140
	5	112,950	55,640

72. Bombay; plants under construction.—In addition to the two plants now working near Bombay, Messrs. Tata Sons & Co. have also fully investigated a third, the Nila-Mula scheme, in connection with which the civil engineering works are in progress; as soon as the general situation in the engineering trade settles down, and financial conditions become stable, this company will forge ahead. As in the other two cases, the project is purely a storage one, a great lake being formed in the elevated valley of the Mula River, West of Poona, and South of the Tata and Andhra Valley sites. The lake will carry 16,500 m. c. ft. of effective storage on the East side of the Western Ghats, and a tunnel 3 miles long will lead through the watershed as in the case of the Andhra Valley. The tunnel will carry 1,000 cusecs, and a pipe line 5,800 ft. long will then give a total head (inclusive of that of the pressure tunnel) of 1,660 ft. It is proposed to instal 105,000 kWs. of plant and the project will be tied in with the existing ones for the further supply of the Bombay industrial area. In terms of continuous power the lake may be rated to give some 450 cusecs all the year round, though some carry-over will have to be kept in reserve. On this basis the 24-hour power is 50,000 kWs.

73. Gwalior; hydro-electric plants under construction.—Reference is made elsewhere in this report (para. 87) to several great irrigation and power projects investigated under the direction of Mr. S. K.

Gurtu, M.A., M.Inst.C.E., M.I.E. (Ind.), Member of the Board of Revenue for Irrigation, Gwalior. Of these one, the Parbatti project, is at present under construction so far as the hydraulic works are concerned, and the following brief account is given through the courtesy of Mr. Gurtu. It is a very complicated scheme, primarily for irrigation coupled with water supply to the town of Lashkar, and estimated to cost 129 lakhs. A reservoir with a capacity of 6,000 m. c. ft. is to be constructed on the Parbatti River at Kaketo, 6 miles North West of Mohona railway station and 38 miles from Gwalior. The dam now under construction is to rise 125 ft. above bed level, the take-off being 75 ft. up. A canal over 30 miles long, partly in tunnel and aqueduct, will carry the water to a balancing tank at Sirsa, 18 miles from the dam, which is also under construction. Here the canal bifurcates, the power scheme being served by the larger branch with a capacity of 50 (eventually 65) cusecs. From a forebay at Malipura there is a drop of 300 ft. with a very long pipe line of 12,500 ft., the tail race water being used for irrigation. The continuous power available will be 50×300/15 or 1,000 kWs. The discharge of the river rises to 100,000 cusecs in the rains, but the stream dries up later.

74. Mysore ; plants under construction.—In connection with the Cauvery dam at Krishnaraja reservoir site the Mysore Darbar is installing penstock and forebay equipment for generating some 4,500 kWs. when the dam is completed. This installation will no doubt work in with the existing Cauvery installation, enlarged as the extra flow from the reservoir becomes available (see paras. 65, 89).

75. Punjab ; plants under construction.—An agreement has been entered into between the Punjab Government and the Punjab Hydro-Electric and Industries Depelopment Association (Bawa Hardyal Singh) for developing certain canal falls, as noted in dealing with "Grants for the development of water power." These falls (and their power) are included in the list of canal falls in the Punjab. The most important is the main line fall at R. D. 241,000 of the Upper Jhelum Canal, at Rasul, where there is a fall of about 70 ft. back into the Jhelum river above the headworks of the Lower Jhelum Canal. The normal flow is about 3,000 cusecs, which could be carried in the canal and dropped through turbines instead of flowing down the stream. A very short length of branch canal will serve the pipe line at the outlet point, together with a tail canal back to the river. Two further falls on the same canal at Bhimber weir, R. D. 419,000 and at 426,000, near where the canal tails into the Chenab, near Gujrat, can be combined to give some 25 ft. of head normally, with from 2,000 to 6,000 cuseos ; this flow is available when the Rasul site above is not taking off the water. The third fall to be used by the Syndicate is 2 miles from Gujranwala, on the Upper Chenab Canal, main line lower, at a 7-span bridge, R. D. 221,000, and amounts to 10½ ft. A fourth fall is the Joyanwala fall also on the Upper Chenab Canal, at Chichoki near Lahore, where 9 or possibly 11 ft. can be obtained ; this is to be harnessed first, and tenders are being invited for the plant. The minimum power is included in that of the Punjab Canals, in para. 91 of this Report.

76. United Provinces ; plants under construction.—The suggestion to use the Naini Tal lake and neighbouring springs for power generation has been under discussion for 20 years or more, and many different schemes have been considered. The water available is so small that only a small project for the town itself is possible. The sanctioned project is based upon the lake as a storage reservoir. A head of 1,400 ft. is available with a pipe line 5,800 ft. long. It is estimated that for 3 months annually the rainfall and springs will much more than balance the draft for power. The records of the discharge over the lake waste weir show that 55 m. c. ft. is the lowest record, in 1894, and that a less quantity will supply the scheme drawn up. It is estimated that only 18 m. c. ft. will be required to tide over the 9 months during which, in dry years, no addition to the lake will come from rainfall. As the lake area is 5¼ m. sq. ft. an extra depth of 3·44 ft. is required to give this storage (see below). It is also calculated that the greatest variation in lake level, when the scheme is working, will be 7·15 ft. in a year of great drought ; this corresponds to 37½ m. c. ft. It is proposed to instal three 150 kWs. sets ; on normal full load of two working sets (one being spare) the water required will amount to practically 3¼ cusecs. It is estimated that the total demand in Naini Tal will come to 705,000 units per annum, including 255,000 units for pumping. This is a little more than the old established installations at Darjeeling and Mussoorie sell, and both are comparable in size and general conditions ; the former has a seasonal tea-garden load and the latter a pumping load. The units generated, taking the proportion of units sold to generated in these two places, will be 900,000 in Naini Tal. The *average* load on the generators throughout the year will therefore be 104 kWs. If the peak load is 300 kWs. as assumed the load factor will be 34 per cent. or the same as that of Mussoorie ; by adjusting pumping hours not to overlap the normal peak an even better load factor should be obtained, by diminishing the maximum load.

Taking an average load of 104 kWs. for 9 months (*i.e.* 79½ kilowatt-years) as that to be supplied from storage the quantity of water required will probably be not less than 32 m. c. ft., as the wheels will often be working on very low efficiency. This is a draft of 1·37 cusecs for the 9 months, and involves a lowering of the lake level by about 32/5·25 or say 6 ft. which might be increased by a further 8 in. if the monsoon broke a month late. The 18 m. c. ft. assumed in the report appears to be definitely low; it would probably require this amount in the first working year, as the turbines must run (and pass water) even if the load is negligible. The 55 m. c. ft. which now go to waste will however suffice, *provided* that the lake is raised sufficiently to ensure extra storage to the extent required. The lake will be filled in the monsoon and thereafter, in a cycle of dry seasons, there will be a continuous draft at the average rate mentioned above, with nothing coming in, up till the (possibly late) breaking of the next monsoon. For the purposes of this report the continuous 24-hour power ultimately available may be reckoned on 50 m. c. ft. of water or $50 \times 1{,}400/500 = 140$ kilowatt-years, or 1·2 million units.

Chapter 12.—Water Power sites investigated but not developed.

77. Summary of investigated sites.—The present chapter contains the major part of the results achieved by the various officers in charge of the Hydro-Electric Survey throughout India, together with a few sites (including some of the most promising) known before the Survey began. The succeeding paragraphs deal with the various Provinces in alphabetical order; and the rivers in each Province are similarly arranged, so as to afford ready reference. The following table gives a summary of the whole:—

Table 18.—*Summary of investigated sites.*

Para.	Province or State.	Number of sites.	Minimum continuous power kW.
78	Assam	16	109,070
79	Baroda	1	4,000
80	Bengal	3	14,250
81	Bihar and Orissa	2	12,650
82	Bombay	6	272,500
83	Burma	11	156,800
84	Central India	2	285
85	Central Provinces	1	13,700
86	Cochin	1	4,000
87	Gwalior	2	42,300
88	Madras	7	32,675
89	Mysore	1	20,000
90	Punjab	3	89,270
91	" canals	68	40,000
92	Sikkim	1	5,000
93	United Provinces	29	370,000
94	" " canal falls	37	8,900
	Total	190	1,194,280

78. Assam; sites examined.—As will be seen from the alphabetical list of sites investigated, Mr. Blenkinsop has so far concentrated on a few rivers and sites that seemed promising; and of these the Hukong Valley is likely to prove by far the best if any means of utilizing its great potentialities can be found. There are not many sites in India capable of giving some 68,000 killowatt-years with a very cheap development. It is highly desirable that this project should be surveyed in detail so that estimates may be prepared for the whole of the civil engineering works; presumably the section of the projected railway up to the site, from near Margherita, has already reached a stage where estimates can be made. This section of the railway will be essential to the power scheme.

Of other sites examined, the Cherrapunji plateau is less promising as to cost, but the survey has not been carried to the point of estimating yet; indeed the basis of development suggested in this Report is radically different from that tentatively put forward locally. It seems probable that some 17,000 kilowatt-years can be obtained, and a capital cost of 50 to 60 lakhs would be permissible if electro-chemical work is to be undertaken.

The Burnihat project on the Um Tru is an excellent one on a small scale; the other sites are less favourably placed. Details of the above will be found in the lists, as well as brief notes on sites not yet examined or examined and found useless, in other sections of this Report. The following table gives a summary of the power at the sites which follow.

TABLE 19.—*Assam; Summary of sites examined.*

Serial.	River or site.	Nature of supply.	Site number.	Minimum constant flow assumed, cusecs.	Head, ft.	Minimum continuous power, kWs.	REMARKS.
(1)	Cherrapunji plateau	4 months storage	(i)	35	350	800	The 2nd and 4th sections comprise reservoirs and open channels between sites, all of which are in series. No. (i) would be developed last if at all.
		Storage from i & ii	(iii)	62	550	2,260	
		Ditto	(v)	62	650	2,700	
		Ditto	(vi)	62	1,500	6,200	
		Ditto	(vii)	62	1,400	5,700	
(2)	Hukong Valley	Storage	...	600	1,700	68,000	With pressure tunnel.
(3)	Maibang River	Storage	(i)	90	260	1,560	
		Ditto	(ii)	195	200	2,600	
		Lifting dams	(iii)	190	400	5,000	
(4)	Shillong	Flow of two nalas	...	5	590	200	
(5)	Someswari River	Flow	(i)	800	80	4,000	
		Flow and Storage	(ii)	1,400	60	5,500	
(6)	Um Tru River	Flow Storage	(i)	237	200	3,100	
		Flow only	(ii)	170	130	1,450	
		Flow	(iii)	...	...	...	Falls combined. Power less than above separate developments.
					TOTAL	109,070	

(1) *Cherrapunji Plateau.*—The latent possibilities of this plateau, famous for its enormous rainfall, were referred to under the heading of the Shella River in the Preliminary Report, page 67, and also in the general remarks on Assam on page 40. The plateau has now been examined, and, despite the great fall of over 4,000 ft. which exists to the plains, proves somewhat disappointing at first sight in the reconnaissance reports. The hills are situated in an area subject to severe earthquakes, which renders really high dams out of the question. Any dam built would clearly have to be of reinforced concrete; even so, while the danger of actual destruction would be practically *nil*, there would perhaps be some chance of fissuring. At the present day, however, one finds it hard to believe that a hollow reinforced concrete dam cannot be designed up to 100 or 120 ft. in height with perfect confidence. Unfortunately the plateau has only one moderately good reservoir site; all others examined give but small storage capacity, as the slope of the ground is considerable. This area has been mooted as a possible source of power for electro-chemical industries, and Mr. Blenkinsop therefore examined its possibilities both as a source of continuous power and from the point of view of the six months rains period. It is however certain that no project working for only six months could supply power at the price required for electro-chemical work. No other outlet for power is in sight.

Six possible reservoir sites for spillway dams have been examined in the area covered by map 78 O/11, which is available on the 1½-inch scale. They are as follows:—

TABLE 20.—*Storage sites at Cherrapunji.*

Name.	Height of dam. ft.	Length of dam. ft.	R. L. at base ft.	Catchment area square mile.	Height of flood over crest. ft.	Capacity m. c. ft.
Um Sohphi 1	60	700	5,461	?	9	34
Um Sohphi 2	50	280	5,370	?	3	28
Laitryngew	90	800	5,304	2	5	408
Laitlyndop	80	2,000	5,225	1	5	70
Raitong	80	1,430	4,932	1·02	5	180
Pomdalol	60	1,500	4,885	1	5	90

A map prepared on a scale of 4-inch to the mile shows these sites. The two Um Sohphi dams are in the Um Pynjngithuli stream, above the Laitryngew site; there is ample run-off for all. The Pomdaloi site is further down the same stream. The Laitlyndop site is on the parallel stream to the West, but its stored water can be put into the Pomdaloi reservoir. The Raitong site is on the Um Long, to the East, but can similarly be joined up to the Pomdaloi.

The schemes prepared by Mr. Blenkinsop are as follows :—

First alternative.—For the "six months" project Mr. Blenkinsop proposed to use the two last reservoirs in the table, the storage in which would merely supplement the rainfall on deficient days during the six wet months. The longest dry period recorded in this season is eighteen days. The run-off on 330 inches is about 600 m. c. ft. per square mile, which on these two catchments of 5·35 square miles gives an average run-off during six months of nearly 200 cusecs. But single falls of 20 and 25 inches occur and over 30 inches have fallen in a day. Any such fall would be far in excess of the reservoir capacity; it would not therefore be possible to depend on utilizing the mean run-off. The project prepared would allow 180 cusecs from storage for eighteen dry days. An open channel 7,000 ft. long would lead to a forebay near the edge of the cliff, but the pipe line to utilize the whole fall of 4,080 ft. would be 20,000 ft. long. It is very doubtful if so long a pipe line would be practicable on such a head; in any case it would be absolutely prohibitive in cost. The power would be some 48,000 kW. *for six months only.* With a shorter and more practicable pipe line, and a lower head, the proposition would not be much more favourable. This scheme may be considered as useless.

Second alternative.—Of all the six reservoir sites that at Laitryngew is by far the best. Mr. Blenkinsop's second alternative is based on this reservoir, but should it materialize the other reservoirs could eventually be inter-connected with it. During the four driest months (November to February) the natural flow is very small; the mean monthly rainfall is 1·3 inch only, out of some 400 inches per annum. The Laitryngew storage of 498 m. c. ft. will give 40 cusecs throughout these four dry months, and will collect such showers as occur; the run-off is exceptionally high at all times. For the rest of the year, with the reservoir to act as a regulator, a much greater discharge can generally be obtained. But in both March and October the rainfall has been known to fall practically to zero, so there is some uncertainty about the assumptions made above.

During the rains water only comes into question as regards the spillway. The Laitryngew reservoir is $3\frac{1}{4}$ miles away from the edge of the cliff, and there is a fall of about 1,000 ft. in this distance; a further fall of some 3,770 ft. occurs in 4 miles from the edge of the cliff. The reconnaissance and map do not indicate the route examined nor the locality suggested for the power house. Unfortunately a pipe line of over 7 miles in length, as proposed, is out of the question and this project will need to be completely recast, to render it in any way practical.

Probable method of development.—If this project is to be utilized it must certainly be on different lines to those proposed, and in stages. Examination of the existing contoured maps indicates possibilities; although the clinometric contours are "approximate" only, they are generally found to be very fairly accurate. For the descent of the great cliff into Sylhet the best route is almost certainly one near the existing foot-track, but on the left bank of the Um Sohkhylleng instead of the right bank, ending up at Therriaghat R. L. about 100 ft. It is perfectly clear that the development must be in stages, and these stages can only be determined by levelling over the ground. The object should be so to lay out the plan that the most favourable stretch can be actually developed first, without preventing other falls being developed as and when required, unless it is decided to initiate electro-chemical works on a large scale right away.

(i) Starting therefore from the proposed dam 2 miles W. of Laitryngew, on the Um Pynjngithuli, at R. L. 5,300, an open channel could be taken along the L. bank for just over a mile, where a fall to about the 4,950 ft. contour could be obtained (350 ft.) back into the stream at the Pomdaloi reservoir site. This small fall, and therefore the channel feeding it, should clearly wait until it is wanted; meantime the water from the upper reservoir would simply run down the bed of the stream to Pomdaloi. The dam at Pomdaloi, 4,885 ft., would in any case have to be constructed as a pick-up weir, but its additional 96 m. c. ft. will be useful. It is very doubtful if it would ever pay to develop the 350 ft. fall except possibly in the form of an "automatic" subsidiary plant.

(ii) From the draw-off level at Pomdaloi, an open channel would have to be constructed (in the first instance) along the 4,900 ft. contour, or thereabout, towards Cherrapunji, crossing the two branches of the Um Long by culvert or syphon and arriving (after the second crossing) at mile $30\frac{5}{8}$ of the main road. (The contours on the map do not quite agree with the levels shown in the reconnaissance report, but these are details for survey.) Thence the open channel would proceed round the Northern half of the town, on the W. side, probably ending up ½ mile W. of the spot level 4,607 in the N. part of the town, but at about 4,900 ft. The Raitong reservoir, when constructed, would discharge into this channel.

(iii) At the termination of this channel, which will be some 4 miles in length, a forebay of sufficient size for regulation will be essential; some 300,000 c. ft. at least. From here it is impossible to follow the contour lines clearly, but the object is to arrive at a point on the road near Mawsmai village, in the corner of the N.-E. square of map 78 O/12, at about R. L. 3,950. The distance as the crow flies is 3 miles, and the fall about 900 ft. nett. Such a pipe line would be prohibitive. But the fall from 4900 to 4350 ft. or 550 ft. in 1 mile, to a point on the Laitkynsew branch road ½ mile W. of the Post Office, could possibly be used if needed. If this head (or more) can be obtained with a reasonable pipe length it would make a good beginning.

(iv) A difficult mile from the last-named point would apparently have to be negotiated in order to get to the stream bed flowing to Mawsmai village, while avoiding the stream to the East of it. There is little doubt however that it can be done, in channel and tunnel. Having arrived at this stream its bed would be utilized up to a pick-up weir immediately W. of mile 36 of the road, where two branch nalas join at about R. L. 3650. The 700 ft. of head here involved would have to be cascaded in all probability, but this can only be decided by survey. It may be possible to utilize it.

(v) From the pick-up weir at mile 36 a fall from 3,650 to 3,000 ft. or 650 ft. can be obtained with 1 mile of pipe. It seems probable that this would be the first good development to undertake, unless No. (iii) above proves feasible. In the latter case the difficult mile of channel in (iv) would be avoided for the time being. The power house site would be at, or just short of, mile 37 on the road, the pipe line running close to the road on the West.

(vi) Thence an open channel of about 1 mile would run along the 3,000 ft. contour (approximately) to where it crosses Long. 91°45′, at the boundary of maps 78 O/12 and 16. Here the large falls begin. From this point a pipe line ¾ mile long, down or through the cliff, would give a fall from 3,000 to about 1,500 ft., or 1,500 ft., to the S.-W. corner of Sohbar village, where a power station would be placed.

(vii) From the latter point an open channel of ¾ mile would reach a point ½ mile S. of the spot level 1,878 (Sohbar), where a fall from 1,500 to 100 ft., or 1,400 ft., could be obtained to immediately above Therriaghat, with a pipe line of about 1½ mile.

Stated in the above form, which *primâ facie* offers the only practicable solution of the problem, the omens are not favourable; but nevertheless the final results may be better than they look at first sight. The possibility of 5 dry months must be faced, as mentioned above, though the contingency is seldom likely to occur. The storage at Laitryngew will give 100 m. c. ft. per month for five months or say 35 cusecs after allowing for losses. Pomdaloi will give another 7 cusecs, and must (as explained) be constructed at the same time. To this 42 cusecs it would eventually be possible to add the yield of the other 4 reservoirs, namely a further 20 cusecs; whether this would pay is a matter for further examination, but it is essential to determine whether the open channels are to carry 42 or 62 cusecs. The minimum power available, on the plan outlined above, can now be determined; while the power for 8 or 9 months in the year would be enormously greater.

TABLE 21.—*Power from Cherrapunji plateau.*

Section of project.	Location.	Flow in dry months, cusecs.	Head, ft.	Continuous power, kWs.
(i)	Laitryngew to Pomdaloi	35	350	[800]
(ii)	Pomdaloi to N. of Cherrapunji.	4	Open channel	*Nil*
(iii)	To point named, W. of Post office (with other reservoirs brought in).	62	550	2,200
(iv)	To mile 36 of road .	62	Open channel and bed of stream.	*Nil*
(v)	Mile 36 to mile 37 .	62	650	2,700
(vi)	From end of open channel described up to Sohbar	62	1,500	6,200
(vii)	From end of Sohbar open channel to Therria-ghat.	62	1,400	5,700
	TOTAL .	..	4,450	17,600

Thus about 4,450 ft. out of the total fall of 5,200 ft. from the main reservoir could probably be utilized to produce some 17,600 kWs. continuously; or, using the bed of the stream in place of (i), nearly 17,000 kWs. in two large and two small interconnected power stations. This block of continuous power is sufficient to be worth serious consideration for electro-chemical purposes. It is well worth surveying in detail, so that estimates can be drawn up. Although an alarming variety of works are contemplated, reminiscent of the original Silewani Ghat scheme, there are no outstanding works of great cost involved. It would probably not be necessary to duplicate *all* the plant with spare; the capital charges on such idle plant would be far greater than the loss of revenue from an occasional temporary breakdown of machinery. This much may be hazarded. On electro-chemical work, where the load factor of the plant would be about 82 per cent., the units generated would be $17,000 \times \frac{82}{100} \times 24 \times 365$ or say 122 million per annum. The works would be near-by and for rough purposes we may take it that 110 million would be utilized. At a cost of one-tenth of an anna per unit this would come to practically seven lakhs of rupees. Capitalized at 14 per cent. to cover all charges and working expenses this would be equivalent to a capital cost of 50 lakhs. In these days an overall cost so low as one-tenth anna a unit is not easily obtained, and if the project could be carried out for 55 or even 60 lakhs it would probably prove remunerative. The 50 lakhs represents about Rs. 300 per kilowatt of continuous load, while 60 lakhs would be Rs. 350—not a high figure, if it proves a possible one. In a case like this it would not be necessary to instal much more plant than is represented by that load, unless further plant were installed to use the great excess of water in the 8 wet months.

Finally, the 90 ft. dam at Laitryngew would have a water spread of 12¾ m. sq. ft. An extra 10 feet only in height would therefore give at least an additional 130 m. c. ft. or 9 cusecs, increasing the total power by one-seventh. Cannot an earthquake proof reinforced dam 100 or even 110 ft. high be designed? The answer must surely be in the affirmative. And there will be no difficulty in filling it.

(2) *Hukong Valley, Patkai range, Nongyoung River.*—The possibilities of this remote valley, some 30 miles E. of Margherita, in the confines of Northern Assam, were brought to notice in connection with the northern route proposed for the Assam-Burma railway connection. A map of the area on the scale of 1 inch=4 miles has now been prepared, and a reconnaissance has been made for power. The results are beyond expectation, as some 90,000 h. p. is found available at one site.

The Nongyoung River is a tributary of the Loglai River, which joins the Turong Ko (or Tarong) and the Chindwin. The site is on map 92 A., S.-W., but is not clear on the 1 millionth Atlas sheets. The catchment area is 134 square miles of which a large proportion is a swamp, between Maium (shown in Atlas) and Mongseang Lake. The Patkai range at Maium has a trigonometrical station R. L. 6,850, overlooking the site. There is a rainfall station at Namchik (N. of the area) where the precipitation from March to October 1920 was 80 inch. A tank gauge was placed in the catchment at Nongyoung Camp and recorded 13·3 inch between 16th March and 7th April, 1921, in 22 days; during the same period the Namchik gauge, 40 miles distant, only recorded ⅓ inch. The lake catchment probably gets much heavier rainfall as the steep range bounds it on the N. and catches the current from the S. The hills round the lake site are very steep and the distance the water has to flow averages only 2 or 2½ miles. The soil is largely clay with big jungle trees and little undergrowth. The run-off will therefore be extremely high, especially as rain falls almost throughout the year and the ground is always sodden. Mr. Blenkinsop estimates a run-off of 80 per cent., and though exceptional this is probably justifiable.

The northern rain gauges in the Upper Chindwin valley, some 50 to 100 miles S., show average rainfall from 70 to 90 inches, the months of December to February giving comparatively little fall. The Dibrugarh and Margherita gauges have averages of 112 and 102 inches, with November and December each under an inch. The Naga Hill gauges similarly show about 100 inches. It is very unlikely that the catchment will have a lower average than 90 inches or minimum of 75 inches. The average total run-off is therefore probably about 23,000 m. c. ft. and the minimum about 19,000 m. c. ft. It is probable that these estimates are too low. The project will be purely a storage one, in the sense that a great lake will be formed into which and from which the whole supply will be taken. Owing to the great natural swamp or lake a dam only 50 ft. high and 450 ft. long will impound 50,000 m. c. ft. of water. Thus, when once filled, a huge carry-over will be available, and if the actual run-off exceed expectations the power will be greater than is anticipated. The whole submerged area is a swamp.

Two alternative methods of development are suggested; one employing an open channel 7 miles long to a forebay, with a pipe of 2,000 ft. in length and a head of 1,000 ft. on the S. side of the Patkai range; the other employing a *pressure* tunnel through the watershed (on the lines of the Andhra Valley and Sutlej River works) to the N. side of the range (*i.e.*, into the Brahmaputra catchment) and a pipe line 4,000 ft. long, giving a head of 1,700 ft. The length of the tunnel is 8,000 ft. only, and as it doubles the power available there can be no question that it is the correct solution for this fine project. A surge tower at its exit would of course be essential.

The storage can be depended upon to give at least 600 cusecs throughout the year, so that the continuous power available is $600 \times 1{,}700/15$ or 68,000 kWs. Probably the extra head due to the average height of the water above the tunnel should be added to the 1,700 ft. given; at any rate it will more than balance the losses.

If the Burma-Assam railway were constructed on the northern alignment it would pass the site of the power station; if the power project were carried out it would be necessary to build either a road or a railway to this point. But electrical working of such railway would not necessarily be adopted; with coal available locally and so little traffic it would probably not pay under ordinary conditions. It would however pay to work this short section, if the power scheme were developed for some electro-chemical process. That is, in fact, the *only possible outlet* for the power. If it were used the traffic both ways between the works and the present railhead would be constant and heavy, and as the gradients are steep electrification would then unquestionably be necessary.

(3) *Maibang River, tributary of Kalang and Brahmaputra.*—This project is near Maibang station on the Assam-Bengal Railway, map 83 G/3. It is unlikely to materialize at present as it would submerge both part of the railway (involving a not very expensive diversion) and Maibang village. Nevertheless the project has good points and should be placed on record. The site was noted by Mr. Barlow when passing through from Haflong, and is referred to on page 67 of the Preliminary Report.

Levelling shows that the most favourable development would be a double one, with an upper reservoir feeding a lower reservoir through its power station and a second power station below. These stages could be developed separately.

The rainfall at Haflong averages 84 inches; this hill station is at the top of the catchment area of 80 square miles, which presumably applies to the upper reservoir, though the fact is not stated. Mr. Blenkinsop estimates the minimum run-off as 6,700 m. c. ft. Discharges in November and December 1920 averaged 5½ cusecs, so the flow probably ceases in the spring and storage is the basis of the project.

(i) *Upper site.*—The upper reservoir site is at mile 324½ of the railway and involves a dam 1,500 ft. long and 100 ft. high with a capacity of 3,000 m. c. ft. This will give some 90 cusecs throughout the year. The excess run-off will spill over and be impounded (eventually) in the lower reservoir. From this upper reservoir a flume 5½ miles long leads to a forebay above the site of the lower reservoir. Mr. Blenkinsop proposes to place the upper power house inside the lower (hollow) dam, but this appears both unnecessary and undesirable; unnecessary because such special construction is only adopted when no other alternative site offers, and undesirable because the second dam would not otherwise have to be built for some years. It would clearly be preferable so to place the upper power house near the lower site that the tail waters from the draft tube will (eventually) fall into the lower flume; but the power house should be independent of the dam. The sketch plan shows the bed level at the upper dam site to be 1,078 ft. and at the lower dam site 876 ft., giving a gross head of 202 ft. *plus* the average height of the water above draw-off level. If the draw-off level is 30 ft. up the minimum fall will be 232 ft. and the maximum 300 ft. or a mean nett head of about 260 ft. The report gives 182 ft. only, *as obtained by levelling*, but the discrepancy is not explained. The pipe line will (it is said) be 300 ft. long; if the sketch plan is correct it will perhaps be longer to give a fall of 202 ft. The power available will be about 90×260/15 or 1,560 kWs. continuous.

(ii) *Lower site.*—The lower reservoir site is at mile 328 and is proposed of the same dimensions, with a capacity of 3,500 m. c. ft, giving a constant discharge of 105 cusecs. The estimated minimum run-off is more than sufficient to fill both reservoirs, and if gauging and more rainfall records in the catchment show higher results the reservoir sites are capable of much greater capacity. Some further carry-over in the lower reservoir is in any case desirable. From this reservoir an open channel 4½ miles long is required to reach the forebay at mile 333½ on the line. A pipe line of 400 ft. then gives a fall of 200 ft. to a power house below the railway tunnel at mile 333½. The tail race of the upper station will ultimately discharge into the open channel of the lower one, thus giving a total constant discharge of 195 cusecs and power of 195×200/15 or 2,600 kWs. continuously. The draft head appears to have been left out of account at this lower site, and probably at the upper site also; it is stated that the power house site is "quite safe from the highest floods" so that, when the floods are regulated and modified by the dams, probably a further 20 ft. or more of head may be available.

(iii) *Further power.*—If the above storage reservoirs were built (apart from their direct power) the whole reach of the river below from about 800 ft. altitude down to the plains level of 300 ft. could also certainly be developed by lifting dams. At the lowest computation an *additional* 190×400/15 or 5,000 kWs. could thus be obtained at small cost.

(4) *Shillong: Um Kra and Um Shirpi.*—These two small nalas were investigated many years ago; see Preliminary Report, page 67. A natural fall of 590 ft. is available and with both streams joined up it

is probable that 150 to 200 kWs. continuous could be obtained. If gaugings have been continued since the earlier investigation it should now be possible to say what the actual minimum discharges are. Sufficient regulation to meet peak loads is possible.

(5) *Someswari River, tributary of Brahmaputra, Garo Hills.*—Two projects have been examined in this river; the upper one in the stretch from Jankeray to Siju (map 78 K/11, 15) and the lower near Bagmora (map 78 K/11,12). See Preliminary Report, page 68 and Second Report, page 65.

Upper site.—This is reached from Jharia Jhanjail. From Siju up to the junction of the Rangkhai tributary there is an ascertained fall of 77 ft. which can be increased by 58 ft. and (apparently) by most of a further 34 ft. which is the height of the power station site over the stream bed; by dropping the site somewhat and utilizing the draft head it would seem that at least 160 ft. can be obtained The levels from the Rangkhai junction to Jankeray have not yet been determined exactly, but aneroid levelling indicates a total fall of 180 ft. from the Jankeray to (apparently) the power house site at Siju; if this is correct the available fall is 210 ft. gross or about 200 ft. nett, and this figure may be taken. The reconnaissance form (Second Report, page 20), under item III, asks for—

(i) Approximate gross height of *natural waterfall.*

(ii) Approximate gross height of artificial fall *or* of natural fall increased by extra head obtainable above or below the same.

Sub-head (i) is clearly not intended to apply to scattered rapids; the two rapids in the Um Tru in this section of the report are practically waterfalls; but the Someswari does not appear to have any waterfall proper. The reconnaissance form gives (i) 77 ft. (ii) 51 ft.; but (ii) must clearly always be greater than (i) by the extra head obtainable. It is not clear if the available head is 51 ft., 77 ft., 128 ft., or 162 ft. with the draft head, or 180 ft.

The scheme would mature on natural flow, with only regulating storage. The discharge measured on 6th May 1921, at Siju, was 1,150 cusecs after several practically dry days, and the catchment is such that the previous rainfall will have almost entirely run off. The estimated annual run-off from the 544 square miles of catchment is of the order of 70,000 m. c. ft, and the minimum discharge is likely to be about 800 cusecs. There is rain in these hills at all times and seasons, averaging well over 100 inches in this area. The headworks would be near Jankeray, where a low diversion dam and regulator will be necessary. An open flume (probably timber) would run for 6 miles on the L. bank over difficult country, involving some tunnelling and bridging of nalas, ending up in a small regulating reservoir and forebay (preferably combined) above Siju. The power house site chosen is 34 ft. over bed level, but it is not clear if this is included in the fall shown or not; clearly most of it can be utilized by draft tubes. It seems probable that the cost of a flume for the whole distance would be very high, and that not more than about 80 ft. can be economically obtained. In that case the power available will be about 800×80/15 or say 4,000 kWs. continuously. The catchment of the Rangkhai is comparatively small and it may prove that the fall between its entry and Jankeray is more easily manageable.

Lower site.—For this it is proposed to build a lifting dam 3 miles from Bagmora, 100 ft. high and some 660 ft. long. This would give a lake of some 14 square miles waterspread and using the top 20 ft. for storage a supplementary 420 cusecs would be obtained for the 6 driest months. The minimum discharge is about 1,000 cusecs (possibly 1,200) so that 1,400 cusecs could be assured. The submerged land will be mostly agricultural, with 12 villages; surplussing would be over the dam, which is calculated to be long enough for the purpose. It is proposed to use the interior of the hollow dam for the power station. The carrying out of this scheme is rendered unlikely by the fact that the projected Bagmora-Sipi-Jankeray railway is intended to run in what would be the submerged area. With a head of 60 ft. between low water level and tail race level (rising to 80 ft. or more at times) the minimum power available on 1,400 cusecs is 5,500 kWs. continuous.

(6) *Um Tru River, tributary of Brahmaputra, Burnihat, Khasia and Jaintia Hills.*—In this river, a few miles upstream of the Gauhati-Shillong road bridge, there are two series of rapids (almost amounting to waterfalls) with a level stretch in between. These falls were referred to in the Preliminary Report, page 68, and the result of a first rough reconnaissance was given on page 60 of the Second Report. The river has been thoroughly examined now and a number of alternative schemes have been worked out roughly. There are no long period gaugings available, but the lowest record in 1921 was 170 cusecs on 3rd March. As the season was exceptionally dry this is probably not far off the actual minimum discharge. The catchment area above the rapids is 390 square miles. There are no raingauges within it, but a tank gauge has now been fixed. In any case the annual run-off, estimated at about 30,000 m. c. ft. minimum, is such that not more than a minute percentage of it can be stored. Above the upper rapids only small regulating storage

(15 m. c. ft.) is possible with a 60 ft. dam. This therefore practically limits the upper rapids or a combination of the upper and lower rapids, in a single scheme, to the minimum flow of the river. The level stretch between the two rapids is more favourable for storage and allows 84 m. c. ft. to be impounded with an 80 ft. dam some 420 ft. long only.

From the longitudinal section prepared it appears that the high flood reduced level, below the lower rapids, is 188 ft. At the site of the lower dam, at the top of the lower rapids, 6,800 ft. upstream, the bed level is 344·8, giving a drop (apart from any dam) of 156 ft. (as against 136 ft. in the report). There follows a long pool and minor rapids above here, for a horizontal distance of 7,250 ft., where the bed level is 366·3 ft. The bed level at the site of the upper dam, above the upper rapids, is at 494 ft. and 5,300 ft. above the last-named spot. The upper rapid therefore has a natural fall of 494—366 or 128 ft. (as against 104 ft. in the report). The whole natural fall from the upper pool to H. F. L. below the lower rapids is 494—188 or 306 ft. The discrepancies between plan and report appear to be due to neglect of the draft head; the plan is correct.

The alternatives that offer are interesting.

(*a*) *Lower rapids only.*—Net head say 150 ft. (i). On flow alone, power available 170×150/15=1,700 kWs. continuously. (ii) On flow, with a low dam above these rapids storing 15 m. c. ft. which would give sufficient regulating storage to enable a high peak load to be met. (iii) On flow, with a higher dam (80 ft.) giving 84 m. c. ft. storage, which would supplement the supply in the two driest months, *viz.*, February and March. Here the average head would be with the dam about ⅔ full (most of the storage being at the top) and the head would be 150+⅔ of 80 or say 200 ft. With 237 cusecs the power would now be 3,100 kWs. continuous—a far finer proposition than subheads (i) or (ii).

(*b*) *Upper rapids only.*—(i) It must be assumed that the lower dam will be built, if the two falls are to be separatively developed; in that case it is certain that the lower dam would be constructed first of all. Therefore the upper fall will be from 494 bed level to 424·6 at the crest of the dam *i.e.*, 70 ft., or a little less at flood times. The power available on flow alone will be 170×70/15 or 800 kWs. continuous. (ii) With a very low dam, to store 5 m. c. ft. only, there would be little gain. (iii) With a 60 ft. dam, storing 15 m. c. ft., the head would be raised to 130 ft. The extra storage might be useful, but the extra head would probably be more useful, so the reservoir would be merely treated as a silt trap behind a lifting dam. The power would be 170×130/15 or 1,450 kWs. A *plus* B with *separate* developments can therefore give 3,100+1,450 or 4,550 kWs. continuously, and, with the lower storage proposed, any load factor or peak load could be met within reason, so long as the total energy developed does not exceed 4,550×24 units per day.

(*c*) *Both falls combined.*—(i) On flow alone, taking the net head as 287 ft. (as in the report) the power available is 170×287/15=3,250 kWs. continuously; with the small storage above the upper rapids any load factor or peak load could be met so long as the *average* power required in the two dry months does not exceed the above value. With the 60 ft. dam proposed under head B (iii), and 15 m. c. ft. storage, the discharge during the two comparatively dry months could be slightly increased (a matter of under 3 cusecs) but an extra 75,000 units could be generated over and above that which the minimum flow could give. Here the storage would be more valuable than the extra head.

The above discussion makes it abundantly clear that the combined development would be inadvisable. The total amount of power obtainable by it (in kilowatt years), on the basis obtainable in the two driest months, is actually less on the combined fall than on the two separate falls; but the initial capital expenditure would be much greater. The lower rapids in fact form a very favourable scheme in every way, and if the demand should rise beyond the capacity of the site the upper rapids could be harnessed at a later date, as a useful supplement.

Considering the lower rapids in greater detail, it is quite clear that this excellent site would be irretrievably ruined if its possible regulating storage capacity were not utilized to the *full*. The proposal to build a 15 ft. dam 200 ft. long and storing 15 m. c. ft. should not be encouraged. With an 80 ft. dam 420 ft. long, offering a far better spill-way for the great floods which occur, 84 m. c. ft. would be obtained. This is the useful capacity above draw-off level, which would have to be about 20 ft. up to allow for silting. It is not stated if this is the practicable limit of height. From the reservoir the alternatives are either an open channel 10,000 ft. long, with a short pipe line of 560 ft.; or a long direct pipe line alone, of 7,500 ft. with a surge tower above the same short steep fall at the end. (It is not clear if the 7,500 ft. includes or excludes the 560 ft. of pressure pipe.) The latter has the advantage of utilizing the (variable) head in the reservoir between draw-off level and actual level; this will vary from *nil* up to 60 ft. (on an 80 ft. dam) when the power is fully used, but the whole 60 ft.

will be available for 10 months in the year and for the remaining two months for some time to come. It is therefore plain that the proper method of development is to take a single closed pipe (probably of reinforced concrete) from the reservoir along the hill side, at little more than the hydraulic gradient, up to where the shortest pressure pipes for the wheels can be laid down; at the junction a surge tower would be required, but this would not need to be vertical; it would be laid up the hill side to an open tank (both surge tank and forebay) of sufficient capacity to meet the variations of velocity in the pipe line from no-load to full-load. The arrangement would in fact amount to an inverted syphon feeding the forebay, except that the steel pipes would not need to be taken up to the forebay but would originate at the junction point. The height of the chosen site for the power house is 20 ft. above stream level; this will of course be utilized by draft tubes. The actual gross head will therefore vary between 176 ft. and 236 ft. according to the condition of the lake; for the purposes of the continous power available the head may be taken as 200 ft. nett, as above, giving continuous power of 3,100 kWs.

The case is an interesting one from the point of view of the plant which can be installed, and has been used as an example of regulating storage, worked out graphically, in para. 28 of this Report.

79. Baroda; sites examined; the Sankheda Taluka Project (Orsang, Heran and Unch Rivers).—(Second Report, page 60.) This project, drawn up by Mr. A. Loving, was examined by Messrs. Bull and Meares in 1920, and reported on as feasible. The site is 24 miles from Baroda, where a considerable demand exists; it is on map 46 F/11, 12, 15, 16. The area is subject to great deficiencies of rainfall, and the project depends mainly on storage; some data are available from the canal works which take off at Jojwa headworks, adjoining the proposed works. A storage of some 7,000 m. c. ft. has been surveyed, to be fed by the 3 rivers named, by means of short canals, cutting through the low intervening water-partings. The problem turns almost entirely on whether there will be sufficient carry-over in a bad series of years. It appears probable that at rare intervals there will be an insufficient carry-over, but if the project can supply power more economically than is possible with fuel for 19 years out of 20 a reserve plant could be installed to meet the contingency. Into the main storage, which is on the Unch River, the smaller reservoirs on the Orsang to the N. and the Heran to the S. discharge; these small reservoirs will function mainly by intercepting minor floods and diverting them to the main storage. Such floods, coming down from the Chhota Oodeypur hills, are severe; the catchment of the Unch itself is comparatively small, but it offers the best storage site. The catchment areas at the dams are:—Orsang, 820 square miles; Heran, 394 square miles mostly in the hills; Unch 167 square miles. Rainfall records for 41 years are available at Sankheda, while at Jojwa and Chhota Oodeypur they are available for 15 years and Shivrajpur and Chorangla have shorter records. An average annual fall of 42 inches is estimated, with a maximum of 66 inches and a minimum of 13¾, *except* in one year, 1899, when Sankheda recorded 6 inches. Mr. Loving estimates the average run-off to be some 70,000 m. c. ft. but a minimum of 4,000 m. c. ft. on 13¾ inches of rain and practically *nil* in a famine year such as 1899. Unfortunately the storage will only carry a fraction of the average run-off, and great floods will have to be surplussed. Even so the interconnecting canals will require to be of very large capacity.

At the main dam site a head of only about 75 ft. can be obtained; it is a question of estimates whether this should be used or the larger head obtainable as presently explained. The Orsang drops about 6 ft. a mile below the Sankheda dam site, and the possibility was considered of piping the supply for some 10 miles to where a fall of 140 ft. is obtainable back to the river. This was surveyed and turned down by Mr. Loving on the score of cost, probably correctly. If however a light reinforced concrete pipe line could be run on a suitable small slope for most of the distance, up to a surge tower or elevated reservoir of sufficient capacity—and it would have to be very large indeed—the proposition is a possible one. There is however another alternative which Mr. Loving adopted in preference to this. He proposes to run a canal as far as the ground allows, to between Pipalsat and Aritha, near where the 140 ft. fall would otherwise be obtainable by pipes and the dam head; but with the canal the head available would only be 80 or 90 ft. From here however a sandy valley, with small nullahs, runs down to the Orsang some 6 miles further down. The slope is quite gradual, but Mr. Loving's examination satisfies him that this valley could be deepened by hydraulic sluicing from the canal. In this way a tail race channel could be made to carve itself out, and the power station could then be placed at the termination of the canal. The idea is a bold one, but hills have before now been bodily removed in this way. (The writer saw such a work in progress in Seattle a few years ago.) No doubt many difficulties would be met with, but if trial pits prove the ground favourable the process would be automatic and rapid. A continuous discharge of 550 cusecs or more down a steep slope would unquestionably remove anything it met with, and as the banks collapsed the channel would widen out until stable slopes were obtained. In this way a head of 110 ft. would be obtainable. Mr. Loving estimates that, except in the most abnormal years, he can obtain $550 \times 110/15$ or 4,000 kWs. continuously.

A point in favour of this scheme is that stone, sand, kunkar and suitable earth are available at the various sites, while the railway runs within 1½ miles of the three dams. Mr. Loving's provisional report is on record with the Survey.

80. Bengal ; sites examined.—Hitherto the only sites in Bengal of which the examination has been definite are in the Duars tea planting districts, in the Jaldaka and neighbouring streams. The possibility of development here turns almost entirely on the question of firing the tea leaf electrically, as to which para. 48 of the Report may be consulted. This proposition was first seriously mooted by Mr. A. H. Abbott of Octavius Steel & Co., whose interests in this district are considerable ; it is also receiving attention in Ceylon. The following summary shows the main data of these schemes :—

TABLE 22.—*Bengal ; summary of sites examined.*

Serial.	River.	Nature of supply.	Minimum constant flow assumed, cusecs.	Head, ft.	Minimum continuous power, kW.
(1)	Jaldaka . .	Flow.	189	1,000	12,500
(2)	Moorteo . .	,,	70	150	700
(3)	Ne Chu or Thodi .	,,	32	500	1,050
	TOTAL .	..	..	..	14,250

(1) *Jaldaka River, Duars District.*—(See also Ne Chu River.) The results of a preliminary reconnaissance by the present writer were given on page 69 of the Preliminary Report and in the Second Report, page 61, it was stated that further examination had been made by the General Electric Co. (India) Ltd., to whom a "Grant" has been made. The 1-inch map 78 A/16 shows the ground.

A report was prepared for the company by Mr. T. L. Mathews, M.Inst.C.E., Consulting Engineer, who traversed the ground with Mr. J. D. Allan, Chief Engineer to the Company. It was decided that the best position for the headworks would be in the main river at Godak (or Gotau) immediately below its junction with the Bindu Chu (or Bia Chu), half a mile below the junction of the Jaldaka and Ne Chu (or Thodi Nala). The elevation here, as determined by careful levelling with two aneroids, both ascending and descending, after applying all corrections, appears to be 2,100 ft. within 50 ft. For the power station Mr. Mathews considered that it would not be worth while to go lower than the junction of the Naksal Nadi (or Ma Chu on the maps). The elevation here, similarly determined by the present writer, was 1,130 ft. at a point ½ mile above the junction, or say 1,100 ft. at the junction, with the same probable error. Although these figures may be incorrect as reduced levels (being based on Domohani station) the *difference* is likely to be correct within 20 ft. or so. The gross fall is therefore about 1,000 ft. Mr. Mathews checked the levels with a single aneroid, but it was not clear from his report whether the corrections (often amounting to well over 100 ft.) were applied ; he took the gross fall as probably *not less* than 850 ft., which is certainly too low ; subsequently he raised his estimate to 1,000 ft.

As regards the minimum discharge of the river, M. King, Executive Engineer, Duars Roads, made careful measurements in the lower reaches near the railway in March, 1919, and found only 231 cusecs there. The season was an exceptionally dry one. A month later the present writer and Mr. King gauged the Jaldaka, the Ne Chu and the Bia Chu and found 137, 32 and 20 cusecs respectively, or 189 cusecs in all. The probable error is considerable, as there was no satisfactory site for the work ; but the result accords well with the earlier determination some 15 miles down stream. In December 1919 Messrs. Mathews and Allan measured the 3 streams and found 357, 251 and 184 cusecs in them or 792 in all ; but this larger result would be expected so soon after the rains. The actual minimum discharge is of less importance than usual on this project, as the greatest demand for power would not come until the rains bring on both the tea leaf and the discharge. Mr. Mathews considers that during the tea season the 50,000 kWs., estimated to be required, could be obtained. The expected load factor is between 30 and 40 per cent., so that for the purposes of this report the continuous 24-hour power available may be taken as 15,000 to 20,000 kWs. The absolute minimum may not be more than 12,000 kWs. in exceptional years ; but, as stated, this is immaterial for tea garden purposes.

The intake headworks offer great difficulty, as floods of at least 50,000 cusecs have to be provided for, carrying boulders of 50 tons weight and more down the river ; Mr. Mathews proposes to design so that the floods can carry the boulders over the intake dam, while the flume would take off from a comparatively still water area at the side, properly protected. The flood waters of the Bia Chu, coming into the Jaldaka at the headworks site, and flowing at right angles to that river directly towards the channel entry, will tend to cause all debris to collect near the screens; this will need consideration.

The flume has been designed to be in duplicate, with a combined capacity of 1,200 cusecs, of reinforced concrete on the R. or British Bank; thus on the assumed net head of 850—30=820 ft. net each channel would serve 32,000 kWs., while if survey shows the head to be 1,000 ft. gross each will serve nearly 40,000 kWs. A tunnel some 16,000 ft. in length (out of 40,000 ft. of channel) is involved, for crossing behind and under the Jal Ung (Jal Chu) and Rongo Chu tributaries. It appears that only a very small regulating storage is possible at the forebay, where arrangements must be made for surplussing 900 cusecs for an hour or so in case of a shut-down. Clearly it would be preferable to have a forebay or regulating storage of some 3½ m. c. ft. (an hour's supply at 900 cusecs) if a site could be found; in order to conserve the 24-hour supply for use mainly in 8 working hours far more storage would be necessary; on the minimum recorded discharge of 189 cusecs this would come to 11 m. c. ft. The advantage of this would be the great reduction in the size and cost of the long flumes and tunnel, which might not only balance out in capital expenditure but give the storage in hand into the bargain.

The minimum power available continously is 189× 1,000/15 or 12,500 kWs.

(2) *Moortee River, Duars District.*—A small project was drawn up by Mr. J. Gordon of Sam Sing for his company's tea factories in Chulsa district. It was to develop 1,000 b. h. p. or say 700 kWs. under a head of 150 ft. The scheme has so far not been proceeded with, probably in view of the Jaldaka project; but this latter (q. v.) is also held up now.

(3) *Ne Chu (or Thodi) River, Duars District.*—This river joins the Jaldaka at the point where the latter enters British territory, and during the investigation of the main river (see preceding entry) by the General Electric Co. (India), Limited, it was found that the Ne Chu would provide a good site for preliminary operations on a much smaller scale than would be essential on the Jaldaka. The power could also be used for construction purposes on the Jaldaka scheme. The Company estimates that the Ne Chu will give about 5,000 kWs. during the cold weather and 15,000 kWs. during the tea manufacturing season. This, if substantiated, would suffice, they consider, to electrify about 50 tea gardens and also to produce 5,000 tons of nitrate of lime per annum; the latter being required on the gardens.

The headworks will be situated about 2 miles above the river junction; thence an open flume of 800 ft. and a tunnel of 6,500 ft. will lead to a surge tower on the hill side above the power station site, which is on the banks of the Jaldaka opposite where the Bindu (Bia) Chu joins it. With a pipe line of 1,000 ft. a nett head of 500 ft. is obtainable. The tail race will discharge into the Jaldaka above the site fixed for the headworks on that river, so that the water will again be available for that development. The discharge found in the Ne Chu by Messrs. Allan and Mathews was 250 cusecs in December 1919, and in March 1920 they judged it to be similar, after "considerable rain in the Duars." On the other hand, in March 1919, the present writer found 32 cusecs by careful float measurement, so that the discharge cannot conceivably have been above about 40 cusecs then. The scheme drawn up however ignores this definite minimum and assumes a minimum of 150 cusecs. The minimum power available without storage may definitely be taken as 32×500/15 or say 1,050 kWs. as against 5,050 kWs. continuous assumed by Mr. Mathews. The capital cost of the hydraulic development up to but excluding the power house is estimated to be 7 lakhs for 7,500 kWs. of working plant capacity. To get this output requires 225 cusecs either from flow or storage. Such an amount will probably be available most of the time when it is required, but on this scale the hot weather load will almost certainly *average* more than the 1,050 kWs. minimum. Furthermore, some storage would be essential to meet the *peak* load at such seasons. It is very doubtful whether the project is sound in the absence of considerable storage, for which however a site is believed to exist.

81. Bihar and Orissa; sites examined.—Hitherto no projects in this Province can be said to have been *fully* investigated. Mr. Stevens, the Executive Engineer in charge of the Survey there, began operations; but he proceeded on long leave preparatory to retirement, and hitherto it has not been found possible to spare another whole-time officer. The work has been carried on by the Superintending Engineer, Western Circle, in addition to his ordinary duties, but a whole-time officer will probably be put on to the Survey in the autumn.

Most of the information available is given under the head of "Sites for detailed investigation" and "Sites not investigated" in this Report; but the examination of the Burhabalong and Subarnarekha Rivers has proceeded far enough to show definitely that considerable power is available. Further work remains to be done however on both projects.

TABLE 23.—*Bihar and Orissa; summary of sites examined.*

Serial	River.	Nature of supply.	Minimum constant flow assumed, cusecs.	Head, ft.	Minimum continuous power, kW.
(1)	Burhabalong .	Flow and storage.	170	900	10,000
(2)	Subarnarekha .	Ditto .	90	425	2,550
	TOTAL .	....	..	..	12,550

(1) *Burhabalong River, Mayurbhanj.*—In the Preliminary Report, page 71, such information as was then available was given. On page 66 of the Second Report the difficulties likely to be encountered were noted, as the result of a preliminary reconnaissance. The site is on map 73 J/8 and K/5. The natural fall is 730 ft. which can be increased to 930 ft. by going some distance upstream and dropping a channel, some 2,500 ft. long, from the hill on the R. bank. The rains generally begin in April. The minimum discharge is believed to be about 15 cusecs, and the annual rainfall is nearer 80 inches than 60 inches. Earthen dams of 120 to 150 ft. in height would be required to store about 2,200 m. c. ft. at the two sites referred to in the Preliminary Report (*loc. cit.*). The storage sites are flat open valleys, through which the streams have cut channels 15 to 30 ft deep. They are cultivated, and a good deal of good land would be submerged. The power station would be in a deep rocky valley, difficult to get at, and involving a new road at least 20 miles long. The possibility of cutting through the ridge to the great fall on the East or West (instead of using the natural fall) was considered and ruled out, as the cost would be out of all proportion to the gain. It may safely be assumed that from May to October (six months) the rains would provide far more than the constant available power, and that the storage reservoirs would always be full at the end of the rains (probably till the end of November). The minimum flow being about 15 cusecs it may be taken that 50 cusecs will be below the average flow for the 6 comparatively dry months. The 2,000 m. c. ft. of stored water will give 120 cusecs for 6 months. The lowest constant discharge may therefore be taken as 170 cusecs which on a net fall of about 900 ft. will give 10,000 kWs., continuously. The project is therefore by no means an unfavourable one even though the original estimate was over the mark. No doubt Mr. Douglas' 40,000 e. h. p. (30,000 kWs.) was an estimate of plant installed. It is not far wrong on the usual load factors found in India. The project will repay detailed investigation.

(2) *Subarnarekha River, Ranchi.*—Some information regarding this river was given in the Preliminary Report, page 72, and was supplemented in the Second Report, page 66. The project appears to be a promising one and has now been further examined. The bauxite deposits in the neighbourhood make the project of value, and enquiries have been made as to the power available. Two alternatives were suggested (i) to use the Hundru Ghagh falls, with storage higher up, and (ii) to turn the water from the lower dam through the ridge to near Gola. The latter alternative was found impracticable and has been dropped in favour of the former. It is proposed to utilize the waters of the main river and its tributary the Jumar, joining 7 miles N.-E. of Ranchi on map 73 E/7, at the Hundru Ghagh falls on map 73 E/11. The falls are 28 miles from Ranchi, *viâ* Angara. As stated in the Preliminary Report, the river runs dry and storage is essential. Two earthen dams (with puddle cores) are proposed, both on map 73 E/7. One is on the main river, above the junction, 1 mile from Tatisilwai and 10 miles from Ranchi; the second is on the Jumar, 1 mile below where the Ranchi-Hazaribagh road crosses, and 9 miles from Ranchi. The Subarnarekha dam at Tatisilwai (bed level 427 ft.) will be 4,390 ft. long and 62 ft. high; the Jumar dam at Kadilots will be 5,084 ft. long and 61 ft. high. The ground at these sites is laterite soil mixed with gravel, overlying rock at a depth of 10 to 20 ft. Surplus flood water will have to be escaped through waste weir channels, which will be very costly, as they must be lined with heavy pitching throughout and must be capable of discharging 16,000 to 18,000 cusecs each. The reservoir capacities are estimated to be of 1,064 and 1,070 m. c. ft. respectively, or 2,134 m. c. ft. in all. The submerged land is mostly culturable, and will be expensive to acquire. One village of $\frac{1}{3}$ acre will also be submerged. The water carries much silt in the rains, and the reservoirs will silt up somewhat rapidly unless arrangements can be made higher up for its deposition in part. The power house below the falls will be 8 miles direct from Johna station, B. N. R. The project is a high head one, with the natural waterfall of 312 ft. increased to 425 ft. by means of an open channel. According to the basis adopted in this circle the flood discharges of the two streams probably amount to not less than 19,000 and 17,000 cusecs respectively, so that some 36,000 cusecs may go over the falls at times. No flood discharges have so far

been taken, but 2,100 cusecs were observed after rain in January 1919. The catchment areas are 117 and 103 square miles above the two dams, or 221 square miles in all. The average annual rainfall at Ranchi is 57·6 inches of which 7·6 falls in the 7 dry months, November to May. The lowest year's record is 38·7 inches and 5½ inches have fallen in one day (8th August 1919). The annual run-off is estimated to average 5,900 m. c. ft., with a minimum of 3,980 m. c. ft. Very long open channels are required to reach the falls ; the routes have not yet been surveyed and the existing maps are not contoured, but the distance from Hundru falls to each dam site is about 17 miles. Probably a common channel will serve about 11 or 12 miles of this. With channels of this length the water will take about 3 hours to traverse the distance, so that 4 hours full load regulating storage is essential at or near the forebay and 6 to 12 hours would be preferable. The ground has not yet been surveyed for this, but inspection shows that there is not too much room ; it may be necessary to widen out the channel for the last half mile, so as to get a contour forebay reservoir. The channel and forebay will be on the left bank. The pipe line has not been surveyed, but it will not be unduly long ; Mr. Stevens roughly examined it but failed to record the length. Rough project estimates indicate that the cost of the dams, reservoirs, waste weirs and waste weir channel will amount to about 11⅓ lakhs, including compensation for submerged land. No estimates have yet been prepared for open channels, settling tanks, forebay or power house.

The site provisionally chosen for the forebay (near Maldiha village) is about 437 ft. above the power station site. Several other reservoir sites have been tentatively examined, and further storage may be possible if required. In view of the heavy silting (for which a considerable depth in the reservoirs has been allowed) it may be found desirable to build low dams above the two reservoirs, to catch the heavier debris for some years to come ; this is a matter of cost. There should not be much silt in the outlet water to the channel, as the capacity is considerable and all but the lightest particles will settle far above the dam. On the most conservative estimate flow will provide all the water required for power for 4 months. Taking 2,000 m. c. ft. of effective storage, there will certainly be enough flow during the remaining 8 months (even though the rivers run dry for 3 months) to make up all losses. The constant (12 months) discharge from the storage may therefore be taken as 60 cusecs, or 90 cusecs for the 8 dry months, and the power as 90× 425/15 or 2,550 kWs. continuously as a minimum. The project is therefore well worth completing.

82. Bombay ; sites examined.—Under General Order No. C. W. 12193 P. W. D., dated 8th August 1921, the Governor of Bombay in Council "is pleased to direct that all survey work should cease and that the Executive Engineer on Special Duty, Hydro-Electric Surveys, should ...... collate all data now in his possession in regard to (certain specified) schemes which, together with the information available from the preliminary investigation of (certain other) projects, should be embodied in a report suitable for publication." Certain rain and river gauges however are to be kept on by the Public Works Department and Forest Department "as the data to be obtained from them will be very valuable." So ends one chapter of the Survey. Abstracts of the Report to be locally published are printed in this and the following chapters. Of schemes which have been investigated in considerable detail, although not in all cases completely, the following table gives an abstract ; details are given in the alphabetical abstracts which follow :—

TABLE 24.—*Bombay ; summary of sites examined.*

River or site.	Nature of supply.	Site number.	Constant flow assumed, cusecs.	Head, ft.	Continuous power, kW.	REMARKS.
Kalinadi River	Storage.	...	650	800	35,000	
Karjan River	,,	...	260	125	2,150	Power and irrigation.
Koyna River	,,	...	...	1,600	225,000	Mr. Arnall and Tatas.
Panam River	,,	...	200	90	1,200	Power and irrigation.
Pravara River (Bhandardara)	,,	(i)	400	180	4,800	,,
	,,	(ii)	400	160	4,260	,,
Urmodi River (Satara)	,,	...	4	577	150	
TOTAL					272,560	

It will be observed that 4 sites out of the 6 give promise of combined power and irrigation projects, where neither by itself would probably pay. The Bhandardara dam, however, is under construction for irrigation.

The Koyna project is by far the most promising of all the possible ones in Bombay, and is among the largest continuous power sites in the world. Most of the important schemes so far examined in Bombay lie in the North Kanara District, where industrial enterprise is now practically non-existent. Storage is the essential feature of practically all projects, and illustrations will be found below of possible cases where a project may pay when irrigation and power are combined though neither would pay by itself.

Mr. Bowers has been ably assisted in the enquiry by two temporary engineers, Messrs. Pickmere and Richards, who were recruited in England for this work and appointed on three years' agreements by the Secretary of State. Both, however, have received 6 months' notice on the closing down of the Survey in Bombay.

Kalinadi River Hydro-Electric Project, North Kanara.—Map 48 I/7, 8, 11, 12. The dam site is reached from Londa Station (Madras and Southern Mahratta Railway) by the main road to Supa (16 miles) and thence some 3 miles by foot-path. The site is near Kheda village and in map square No. A3 of map 48 I/11, Lat. 15°-16′ N. and Long. 74°-31′ E., and is about 3 miles above the junction of the Kalinadi River with the Pandri River. The catchment, which is partly in the ghat district, is 107 square miles in area above the dam site, and is mostly rocky or covered with thick jungle. Both the Pandri and Kalinadi are perennial streams and as a preliminary the scheme might be developed on minimum flow alone. Gauging made near the proposed pick-up weir site during 1921 showed a minimum discharge of 69 cusecs. For full development the scheme would depend on storage and flow, the Pandri supplying the monsoon requirements and the Kalinadi, by the storage dam at Kheda, the water for power during the hot weather. A rain-gauge has been maintained at Supa and records for 30 years are available. During the monsoon of 1920 a rain-gauge was put out at Diggi on the ghat edge and further gauges were put out in June 1921 on the catchment. To arrive at an approximate estimate of the average rainfall over the catchment the following procedure was adopted. Areas were allotted to each of the new gauges. The total rain during July 1921 at each gauge was tabulated and, taking the rainfall at Diggi for this period as unity, the rain at each station during 1920 is estimated by proportion. The product of rainfall in 1920 and gauge area is then found for each gauge. Dividing the total of these products by the whole catchment area the average rainfall over the area for 1920 is found. Comparing this with the corresponding rainfall at Supa a factor is found by which Supa rainfall in every year can be reduced to average rainfall over the catchment (*see* table No. 25). The method is of course very approximate but in the absence of any records it is the only means of arriving at the probable rainfall on the catchment. This method indicates that the average rainfall on the catchment for 30 years is 127 inches ; the maximum 183 inches ; while that the worst year gave 73 inches, and the worst two consecutive years 76 inches and 100 inches (1905 and 1906). (*See* table No. 25.)

The area of ghat catchment is steep and rocky and in the absence of any records a run-off of 70 per cent. with 180 inches rain diminishing to 40 per cent. with 70 inches rain has been assumed. Generally the Kalinadi is in deep gorge and the ground does not widen out until some height is reached. The dam at Kheda is therefore designed to be 280 ft. high and 1,100 ft. long and contains about 18 million cubic feet of masonry. A dam of these dimensions gives a storage of 36,300 m. c. ft. at a cost of Rs. 297 per m. c. ft. stored. An annual deplenishment of 17,500 m. c. ft. is possible (*see* balance table No. 26) and allowing 3 ft. evaporation and soakage losses a draw-off of 16,830 m. c. ft. is available. For safety's sake it is assumed that the Pandri supplies power for only two months of the year and hence a continuous draw-off of 650 cusecs can safely be relied on. The pipe line survey was not completed but the head will be about 800 ft., so that the continuous power available will be of the order of 35,000 kW.

The project may be briefly described as follows :—A masonry storage dam at ½ mile W. of Kheda, 280 ft. high and 1,100 ft. long. Waste water could be surplussed over a ridge on the L. H. flank, where an escape cut would have to be excavated, or alternatively by a waste water tunnel. By means of sluices in the dam, water would be drawn off the lake and run down the river some 24 miles to near Bomanhalli (map 48 I/12 and 16; Lat. 15°-10′ North and Long. 74°-45′ East) where a pick-up weir sited near mile 6 on the Kegdal-Kulgi road will divert it into the canal. This pick-up weir should be of the barrage type, with undersluices to dispose of the monsoon floods. The canal will run in a southerly direction some 4·9 miles to the forebay site, in a nala at Lat. 15°-6′-20″ North and Long. 74°-43′-40″ East. By means of a forebay dam 60 ft. high and 500 ft. long some 8 m. c. ft. will be stored, or sufficient for nearly 3½ hours supply. The canal passes through difficult country and deep cuttings and tunnels will be necessary. From the forebay a short canal and tunnel will lead to the head of the pipes at a point about ¾ miles South West of the forebay. The pipe line, which is approximately 1,650 ft. long, runs in a South West direction to the power house site on the R. H. bank of the Kalinadi giving a head of some 800 ft. This includes both the Vincholi and Lalguli falls mentioned in the Preliminary Report. A probable market for the power is Hubli, 40 miles North East of the power house. The surveys are in somewhat incomplete state. Further cross-sections should be taken of the lake area to ascertain more accurately its contents. The line of the canal is open to improvement and may thereby be lengthened. The pipe line survey has yet to be made and also the survey for the power house site. It seems probable that a considerable length of light pipe line, terminating in a surge tower, would decrease the cost and improve the working of the project. By making the canal approximately three miles longer the pipes could be brought down to a power house sited at the junction of the Nagjhiri Nala with the Kalinadi (Lat. 15°-5′ North and Long. 74°-41′ East) with an increase of about 180 ft. in the head. This seems advisable. Rain and river gaugings are very scanty and should be continued.

A very rough estimate has been made of the probable cost of the project and the assumptions made are outlined below. The *dam* site is somewhat inaccessible and a siding would probably have to be run from Dandoli about 20 miles in length to supply materials. In all probability only stone would be available at the site. A through rate of Rs. 60 per brass (100 c. ft.) has therefore been assumed for the dam. The *pick-up weir* would be of the barrage type. As a rough approximation of its cost it has been treated as a solid block of masonry of width equal to its base dimensions, to cover extras on sluice gates, ashlar, etc., and a rate of Rs. 70 per brass has been assumed. The *canal* will involve heavy cuttings, tunnelling and aqueducts, and would resemble the canal of the Tata Hydro-Electric works at Lonavla, though it would probably be somewhat cheaper. This canal cost approximately $4\frac{1}{4}$ lakhs per mile. The proposed Kalinadi canal would be for the same discharge. To cover increases in rates since the Tata canal was constructed the same rate per mile is assumed. To avoid the leakages of the earlier work, due mainly to boring crabs, concrete rather than masonry is advisable. For the *forebay* a rate of Rs. 65 per brass has been assumed to cover cost of ashlar, sluices, etc. A rate per ton for the pipes, etc., slightly in excess of that on the Tata Hydro-Electric pipe line is assumed, to cover enhanced rates and carriage to a somewhat inaccessible site. Excavation and masonry in anchorages and bearer is estimated at Rs. 40 per ton of pipes which is slightly in excess of the cost on the Tata Hydro-Electric pipe line. An estimate of the cost of the *transmission line, receiving station and power house* has been arrived at by comparison with the estimates prepared for the Koyna River project, by Mr. A. T. Arnall, A.M.Inst.C.E. The cost per kilowatt for each item has been calculated for the Koyna project and applied to the Kalinadi Project. A load factor of 40 per cent. has been assumed and this means the installation of plant for 86,500 kW. Table 27 shows a summary of the probable cost of the project; but it must be remembered that the estimate is only very approximate.

TABLE 25.—*Estimate of Rainfall on Kalinadi Catchment.*

	Name of gauges.											
	Supa.	Kheda No. 29.	Palli No. 14.	Kunbhar Wada No. 13.	Guravadi No. 12.	Kalpa No. 11.	Kusaoli No. 21.	Bamula No. 22.	Dudmala No. 23.	Diggi No. 15.	Soliya No. 25.	Totals.
Applied area of gauges square miles.	..	12·40	10·60	14·3	15·8	17·5	3·3	7·9	8·1	1·3	15·8	107·0
Total rain July 1921. Inches.	..	55	33	44	32	34	75	78	78	78	82	..
Total rain 1920. Inches.	90	..	..	..	..	..	..	..	..	190	..	..
Estimated total rain 1920. Inches.	90	134	80	107	78	83	183	100	190	190	200	..
Product of rain and applied area.	..	1660	848	1530	1232	1455	604	1502	1540	247	3160	13778

Average rainfall for catchment area $= \frac{13778}{107} = 128{\cdot}7''$

Therefore Supa factor for catchment area $= \frac{128{\cdot}7}{90} = 1{\cdot}43$

TABLE 26.—*Kalinadi Project. Kheda Lake Balance Table.*

F. S. L. 280 ft. above bed at Dam Site. Capacity 36,300 m. c. ft.

Year.	Rain at Supa.	Average rain or catchment.	Run-on in m. c. ft.	Run-off in m. c. ft.	Stored m. c. ft.	10 months dry weather draw off m. c. ft.	2 months monsoon draw off m. c. ft.	Waste m. c. ft.	Balance m. c. ft.
		R'=R. × 1·43	107 × 2·33 × R'				Supplied by Pandari River.		
1891 . .	82	117	29,169	15,400	15,400	15,000		...	400
1892 . .	105	150	37,396	23,120	23,520	16,000		...	7,520
1893 . .	79	113	28,172	14,560	22,080	17,500		...	4,580
1894 . .	81	116	28,920	15,200	19,780	17,500		...	2,280
1895 . .	83	119	29,668	15,820	18,100	17,500		...	600
1896 . .	*123*	176	43,878	30,280	30,880	17,500		...	13,380
1897 . .	94	134	33,407	19,200	32,580	17,500		...	15,080
1898 . .	92	131	32,659	18,510	33,590	17,500		...	16,090
1899 . .	*51*	73	18,199	7,420	23,510	17,500		...	6,010
1900 . .	*128*	183	45,624	32,250	36,300	17,500		1,960	18,800
1901 . .	95	136	33,906	19,660	36,300	17,500		*2,160*	18,800
1902 . .	88	126	31,413	17,400	36,200	17,500		...	18,700
1903 . .	80	114	28,421	14,780	33,480	17,500		...	15,980
1904 . .	91	130	32,410	18,300	34,280	17,500		...	16,780
1905 . .	*53*	76	18,947	7,900	24,680	17,500		...	7,180
1906 . .	70	100	24,931	11,950	19,130	17,500		...	1,630
1907 . .	119	170	42,383	28,590	30,220	17,500		...	12,720
1908 . .	102	146	36,399	22,080	34,800	17,500		...	17,300
1909 . .	79	113	28,172	14,560	31,860	17,500		...	14,360
1910 . .	76	109	27.175	13,730	28,090	17,500		...	10,590
1911 . .	79	113	28,172	14,560	25,150	17,500		...	7,650
1912 . .	109	156	38,892	24,680	32,330	17,500		...	14,830
1913 . .	81	116	28,920	15,200	30,030	17,500		...	12,530
1914 . .	*127*	182	45,374	31,980	36,300	17,500		8,210	18,800
1915 . .	72	103	25,679	12,540	31,340	17,500		...	13,840
1916 . .	92	131	32,659	18,510	32,350	17,500		...	14,850
1917 . .	105	150	37,396	23,120	36,300	17,500		1,670	18,800
1918 . .	*53*	76	18,947	7,900	26,700	17,500		...	9,200
1919 . .	92	131	32,659	18,510	27,710	17,500		...	10,210
1920 . .	90	129	32,161	18,080	28,290	17,500		...	10,790

TABLE 27.—*Kalinadi River Hydro-Electric Project. Rough estimate of cost.*

Description.	Approximate cost. Lakhs.
Kheda Storage Dam	108·00
Pick-up-weir	5·89
Canal	23·37
Forebay	2·29
Pipe line including anchorages, pipes, bearers, etc.	3·41
Power House installed for 86,500 kWs.	60·55
Transmission line to Hubli 40 miles	17·30
Receiving station	25·95
Distributing lines	2·59
TOTAL	249·35
Add 10 per cent for contingencies	24·93
TOTAL	274·28
Revenue—	
34,600 kWh. for 8760 hours at $\frac{1}{8}$ anna per unit	37·89
Annual expenditure, say	10·00
TOTAL REVENUE	27·89
or 10 per cent on capital cost.	

NOTE.—These figures do not allow for interest payable on subscribed loan.

Karjan River, a tributary of the Narbada, Rajpipla State, Rewa Kantha Agency, combined irrigation and hydro-electric project.—Map 1″ Topo Sheet No. 46 G/9, 10, 13 and 14. The site for the storage work is situated in Lat. 21°-47′-20″ North by Long. 73°-34′ 15″ East, below and close to the junction of the Terav Nala and Karjan River, about 7½ miles from Nandod in the state of Rajpipla. It can be reached in the dry season from Nandod on horseback or in a bullock tonga, in the wet season about two miles would have to be done on foot. The catchment area is about 520 square miles mainly rocky hills and jungle. From February to June there is no flow in the river. In the last 30 years the lowest rainfall on this catchment area was 12·2 inches in 1899, giving an estimated run-off of 1·7 in. The ten years of lowest aggregate rainfall were from 1899 to 1908 when 354·02 inches fell giving an estimated total run-off of 125·2 inches in that period. At the suggested full supply level of 385 R. L. (that is with a dam 215 ft. high) the lake would cover about 16 square miles of the Terav Nala and Karjan River valleys. As suggested the dam would be 215 ft. high (170 ft. R. L. at base and 385 ft. R. L. at crest) and 2,725 ft. long at the crest. There would be needed also, in a saddle of the hill, a few hundred feet to the West of the main dam, a subsidiary dam about 20 ft. high and 170 ft. long. These would contain about 16·6 m. c. ft. of masonry which at Rs. 50 per brass of 100 cu. ft. would cost Rs. 84,00,000. The dam would impound altogether about 28,800 m. c. ft. of water or between full supply level (385 ft. R. L.) and minimum working level (305 ft. R. L.), about 22,800 m. c. ft. at a cost of Rs. 368 per m. c. ft. There would be available after allowing for evaporation, absorption, etc., a yearly supply of 10,962 m. c. ft. at a cost of Rs. 766 per m. c. ft. The power house might be built close to the dam, the tail waters from the turbine returning to the river bed and being picked up again for irrigation purposes by a weir some distance below; or, alternatively, a canal might be taken from the dam at R. L. 305 ft. along a falling contour on the West of the river to a forebay on the hill marked 740 about ¾ mile North West of Zampa, from whence a pipe line would lead to the power house, situated at a convenient point on the left bank of the river, the tail water returning to the river bed. Whether the latter alternative would give an appreciable greater head depends on the necessary height of the pick-up weir, which in this scheme also is necessary. A third suggestion is to take the canal round to the North side of the hill 740, locating the forebay there, and, using a longer pipe line than that of scheme No. 2, to place the power house at the foot of the hills somewhere between the 4th and 5th mile post from Nandod. It might then be possible to deliver the tail waters direct to the irrigation canal, thereby cutting out the necessity of a pick-up weir. If a pick-up weir is found necessary the probable site will be at a point about 21°-49′-35″ North by 73°-34′-30″ East, about 4½ miles from Nandod. The irrigation canal would start either from the pick-up weir or from the power house, and would lead in a North West direction to near Limat Vada Nana, and thence towards the Nandod Railway line. If a pick-up weir is not found necessary a balancing tank will have to be constructed in some convenient nala near the power house and on the course of the irrigation canal, capable of storing half a day's summer irrigation supply with a small variation of surface level. Calculated on three driest years of the last 30, *viz.*, 1899, 1900 and 1901, it is probable that 44·92 m. c. ft. of water per day can be supplied from October 16th to February 15th and 22·46 m. c. ft. per day from February 16th to October 15th. Assuming the reservoir to be full—that is water surface at R. L. 385 ft.—at the end of September 1898 it would probably be full again during the monsoon of 1903. The surface would be at its lowest in July 1899 at about R. L. 305 ft.

The aforesaid quantity of 44·92 m. c. ft per day is equal to 520 cusecs. Taking the duty of the water in the cold weather at 120 acres per cusec there would be enough to irrigate 62,400 acres of mixed crops. The hot weather discharge of 22·46 m. c. ft.=260 cusecs would irrigate 15,600 acres of hot weather or perennial crops. The total area that can be irrigated in one year would therefore be 46,800 acres of cold weather crops and 15,600 acres of perennial crops or a total of 62,400 acres. The discharge adopted for power will be the minimum irrigation discharge, *i.e.*, 260 cusecs. If the surface of the tail water is at R. L. 180 ft. and if it may be assumed that the lowest water level in the lake will be at R. L. 305 ft., then the continuous power available will be 260 ×125/15= 2,150 kWs. or a maximum of possibly 6,500 kWs. under working conditions. During the monsoon, the water used for power purposes would be wasted as regards irrigation; while, during the winter, half of the water used for irrigation would be wasted as regards power. From the middle of February to the beginning of the monsoon all the water used for irrigation could be used for power also. Probable markets for the power are :—

(1) at Nandod, about 7½ miles from the dam site, for mills, lighting, etc.

(2) at Ankleshwar and Broach, about 40 miles away, for the same purposes. Also power might possibly be used for the electrification of the Ankleshwar-Nandod Railway.

The following is an estimate of the difference between the cost of damming the Karjan River for a combined irrigation and hydro-electric project and for an irrigation project only. To supply, for irrigation only, the monthly quantity of water which is proposed in the original project, but supplying none during the months of July, August and September, a lower dam could be used; first, because, having no power to consider, the minimum height of the water in the lake could be lower, and, secondly, because, by drawing off no water for three months of the year, a smaller reservoir capacity would be adequate. For such a reservoir a dam 196 ft. high (crest at R. L. 366 ft.) as against 215 ft. (crest at R. L. 385 ft.) for the combined project would be required. The quantity of land submerged would be about 11·5 square miles as against 17·2 square miles. The estimated additional cost of the combined project is as follows :—

Additional cost of dam.

	Rs.
4 m. c. ft. at Rs 0·5 per cu. ft.	20,00,000
Cost of balancing tank	1,00,000
Additional land 5·7 square miles at Rs. 20,000 per square mile	1,14,000
TOTAL ADDITIONAL COST .	22,14,000

Admissibility of combined project.

The continuous power available is 260 ×125/11=2,955 e. h. p., while with a power factor of 40 per cent. the maximum output= $\frac{2955\times10}{4}$=7388 e. h. p.

Referring to the table on page 23 of the Preliminary Report on the Water Power Resources of India, 1919, assuming the cost of coal to be Rs. 24 per ton, a power factor of 40 per cent and 50 mile transmission line, it will be seen that the probable admissible cost per e. h. p. installed is some Rs. 511. Therefore the total admissible cost =511×7388=Rs. 37,75,268. Comparing the figure of estimated extra cost on the dam, etc., of the combined project over the simple irrigation projects, *viz.*, Rs. 22 lakhs, and the admissible cost of a simple H. E. project, *viz.*, Rs. 37 lakhs, it would seem that this scheme is worth further investigation.

NOTE.—A good deal of survey work is still necessary. More cross-sections of the valleys above the dam site are needed in order to determine the area and capacity of the lake and the surveys for siting canals and power house have hardly been begun. River gaugings also are needed.

NOTE BY CHIEF ENGINEER.—From the maps it appears likely that from the dam a light pipe line could be taken over the intervening nala on an aqueduct or suspension bridge (possibly a syphon) across the bend of the main river, to the hill marked spot level 740 ft. Here a surge tower could be placed, thus utilizing the mean head at the dam. The head assumed above is 125 ft., but in this way it would vary from 125 up to 205 ft. Tailing direct into the canal at about R. L. 175 ft. also seems feasible.

Koyna River Project.—This great project was drawn up by Mr. A. T. Arnall for Messrs. Tata Sons and Co., who have applied for a "Grant" to develop it. It has not therefore been examined by the Hydro-Electric Survey. The catchment area is 346 square miles in the Western ghats, map 47 G/10, 11, 14, 15, with a mean rainfall of about 150 inches. The proposed Helwak Lake would have a draw-off capacity of 120,000 m. c. ft. By tunnelling through the watershed a head of 1,600 feet is obtainable on the Western side. It is estimated that 225,000 kWs. can be obtained continuously.

Panam River, a tributary of the Mahi, Lunavada State, Rewa Kantha Agency. Combined Irrigation and Hydro-Electric Project.—Map 1″ Topo Sheets Nos. 46E/12 and 16, and 46F/9 and 13. The dam site is situated at point about 23°-3′ North by 73°-45′-30″ East on boundary between the States of Lunavada and Sunth Rampur, about 9 miles from the town of Lunavada. It can be reached, in the dry season, from Lunavada Railway Station on horseback or in a bullock tonga. In the wet season it will be necessary to leave the train at the signal station just before reaching the Panam River, south of Lunavada. The catchment area above the dam site is 896 square miles. During the months of February to June there is practically no flow in the river, so that a storage work is necessary, both for irrigation and power. The site is at a configuration similar to that of the famous Chappar Rift in Baluchistan, *i.e.*, the river has cut through a range of hills, across a valley, and out again through a further range. In the last 30 years the lowest rainfall on this catchment area was 12·31 inches in 1899, giving an estimated run-off of 1·64 inches, equivalent to a volume of 3413·8 m. c. ft. The ten years of lowest aggregate rainfall were from 1899 to 1908, when 305·28 inches fell altogether giving an estimated run-off of 54·65 inches. At the proposed full supply level of 440 R. L. (that is with a dam 160 ft. high) the lake would cover an area of 27·2 square miles in the Ghodra Taluka of the Panch Mahal District, and in the States of Lunavada and Sunth Rampur. The following figures are a very rough approximate to the waterspread and contents at various levels :—

R. L.	Surface area at level.		Cubic contents below level in m. c. ft.
	M. s. ft.	Square miles.	
390 feet	285·8	10·2	9,091
400 „	358·7	12·9	12,307
410 „	434·8	15·6	16,268
420 „	517·0	18·5	21,021
430 „	613·0	22·0	26,664
440 „	757·7	27·2	33,505

The dam as proposed would be 160 ft. high and 840 ft. long on the top. This is an exceedingly favourable site. The dam would contain about 6 m. c. ft. of masonry which at Rs. 60 per 100 cu. ft. would cost Rs. 36,00,000. It would impound between Full Supply level and minimum level (that is between R. L. 440 and R. L. 400) 21,200 m. c. ft. at a cost of Rs. 170 per m. c. feet. There would be available, after allowing for evaporation, absorption, etc., a yearly supply of 8,435 m. c. feet at a cost of Rs. 432 per m. c. ft. The storage capacity (21,200 m. c. ft.) is large compared with the yearly draw-off of 8,435 m.c.ft. but this balance is necessary as a carry-over, in order to maintain the full draw-off in a series of bad years (see table 28). The power house would be in a convenient place on the left bank of the river and as near as possible to the dam. The supply pipe would be taken through the dam at a convenient level to supply the turbines. A second pipe through the dam, discharging to the irrigation canal close below the power house, would be installed in order to provide the extra quantity of irrigation water required during the winter months. In order to convey the tail water from the turbines for irrigation purposes a canal starting with F. S. L. at about 310 ft. R. L. would lead from the power house along the left bank of the river to near the village of Mor where it is proposed to use, if possible, a convenient nala for the purpose of a balancing tank. The canal would run thence in a South West direction to Chari then round by Khuntkhar and towards the north to the foot of the hills due east of Sattalao. From there, it is proposed to run underground for the distance of about a mile, partly in tunnel, partly in cut and cover, to somewhere near the "M" in Barot Muwada; thence by Merji Muwada, Bhanpur, Sutaria Muwada, Dokela, Verama, Bamanwad Khalaspur to Palla near Kothamba, beyond which point the canal has not been sited. The balancing tank would be situated on the canal line near the village of Mor and would be designed to store half a day's summer irrigation supply with a variation of surface level of two or three feet. Taking the ten driest years of the last thirty as before mentioned (1899-1908) it is found, on working out an analytical monthly table of estimated run off, absorption, evaporation, etc., that 34·56 m. c. ft. of water per day can be supplied from October 16th to February 15th and 17·28 m. c. ft. per day February 16th to October 15th. Assuming that the reservoir was full, that is, water surface at 440 R. L., at the end of the September 1898, it can be shown by this method that, given the draw-off above mentioned, the reservoir would not fill again until the monsoon of 1909 and that the water would be lowest at the beginning of July 1902 when it would be at approximately R. L. 402. The above mentioned quantity of 34·56 m. c. ft. of water per day is equal to 400 cusecs. Taking the duty in winter at 120 acres per cusec, the cultivable area as 360 acres per cusec, and the commanded area as 450 acres per cusec; there would be enough water to irrigate 48,000 acres and to command 180,000 acres or 281 square miles. This area can be obtained by taking the canal through the Taluka of Ghodra, the State of Pandu Mehwas into the State of Baroda.

The discharge adopted for power will be the minimum irrigation discharge, *i.e.*, 200 cusecs. If the surface of the canal at the power house is at R. L. 310, and if it may be assumed that the lowest water level in the lake is R. L. 400, then the continuous power available will be 200 $\times 90/15 = 1,200$ kWs. for which, on a commercial basis, plant developing some 3,600 kWs. could probably be installed. During the monsoon, the water used for power purposes would be wasted as regards irrigation; during the winter, half of the water used for irrigation would be wasted as regards power.

From the middle of February to the beginning of the monsoon all the water used for irrigation could be used for power also.

The following is an estimate of difference between the cost of damming the Panam River for a combined irrigation and hydro-electric project and for an irrigation project only. To supply, for irrigation only, the monthly quantity of water, which is proposed in the original project, but supplying none during the months of July, August and September, a lower dam could be used ; first because, having no power to consider, the minimum height of the water could be lower, and secondly because, by drawing off no water for three months of the year, a smaller reservoir capacity would be adequate. For such a reservoir a dam 135 ft. high, as against 160 ft. for combined project, would be required and the land submerged about 17 square miles as against 27 square miles. The estimated extra cost of combined project over simple irrigation project is as follows :—

	Rs.
Extra cost of dam	10,00,000
Cost of balancing tank	1,00,000
Cost of extra land (10 square miles) . .	6,00,000
	17,00,000

Referring to the table on page 23 of the Preliminary Report on the Water Power Resources of India, assuming the cost of coal at Rs. 24 per ton, a power factor of 40 per cent. and 50 miles transmission line, it will be seen that the probable admissible cost is as follows :—

Continuous power = 1,200 kWs. = 1,600 h. p.
With power factor of 40 per cent the maximum output = 1,600 × 10·4 = 4,000 h. p.

	Rs.
From table, admissible cost per e.h.p. = . .	511
Therefore total admissible cost = ...	511 × 4,000
. . .	= 20,44,000

Comparing the figure of estimated extra cost on dam, etc., of combined hydro-electric and irrigation project over simple irrigation project, *viz.*, Rs. 17 lakhs and admissible cost of a simple hydro-electric project *viz.* Rs. 20·4 lakhs it seems likely that it would be worth while to make a further examination of this scheme and to get out detailed estimates. There are probable markets for the power at Ghodra about 30 miles from dam site, for mill lighting and at Lunavada for the same purpose. Also for the electrification of the Ghodra-Lunavada Railway.

NOTE BY CHIEF ENGINEER.—While the head is taken as 90 ft. to R. L. 400 the mean will be nearer R. L. 430 ft. For 9 months in the year 400 cusecs would be available.

TABLE 28.—*Proposed Panam lake Monthly statement showing probable replenishment and deplenishment.*

Year and Month.	Contents, etc., at beginning of month.			Draw-off inclusive of evaporation and absorption, etc.				Monthly replenishment	Contents, etc., at the end of the month.		
	R.L.	Contents in m. c. ft.	Surface area in m. s. ft. at different contours.	Depth on top surface in feet.	Quantity evaporated and absorbed as per depth of top surface m. c.ft.	Draw-off during month.	Total deplenishment.		R. L.	Surface area in m. s. ft.	Content in m. c. ft.
1898—											
September .	440	33,505	757·7	·25	180·4	518·4	707·82	2,706·00	440	757·7	33,505
October .	440	33,505	757·7	50·	378·8	812·10	1,190·06	..	438·4	728·5	32,314
November .	438·4	32,314	728·5	·50	364·3	1,036·8	1,401·12	..	436·5	697·0	30013
December .	436·5	30,913	697·0	·50	348·5	1,071·36	1,419·86	..	434·4	667·0	29,493
1899—											
January .	434·4	29,493	067·0	·50	333·5	1,071·36	1,404·86	..	432·25	630·0	28,088
February .	432·25	28,088	630·0	·75	470·2	743·04	1,222·24	..	430·3	610·5	26,866
March . .	430·3	26,866	610·5	·75	462·4	535·08	998·08	..	428·7	599·0	25,868
April . .	428·7	25,868	599·0	·75	449·2	518·4	967·6	..	427·1	582·0	24,900
May . .	427·1	24,900	582·0	·75	436·5	636·08	972·18	..	425·4	566	23,928
June . .	425·4	23,928	566	·25	141·5	518·4	659·9	2,685·25	428·8	600	25,953
July . .	428·8	25,953	600	·25	150·0	535·08	685·08	520·4	428·5	597·5	25,788
August . .	428·5	25,788	597·5	·25	149·4	535·08	685·08	..	427·4	586	25,103
September .	427·4	25,103	586	·25	146·5	518·4	664·9	208·16	426·6	578·5	24·646
October .	426·6	24,646	578·5	·50	289·2	812·16	1,101·36	..	424·7	550·5	23,545
November .	424·7	23,545	550·5	·50	270·7	1,036·8	1,316·5	..	422·3	538·0	22,228
December .	422·3	22,228	538·0	·50	269·0	1,071·36	1,340·36	..	419·7	515·0	20,888

Year and month.	Contents, etc., at beginning of the month.			Draw-off inclusive of evaporation and absorption, etc.				Monthly replenishment.	Contents, etc., at the end of the month.		
	R.L.	Contents in m. c. ft.	Surface area in m. s. ft. at different contours.	Depth on top surface in feet.	Quantity evaporated and absorbed as per depth of top surface m.c.ft.	Draw-off during month.	Total depletion.		R. L.	Surface area in m. s. ft.	Content in m. c. ft.
1900—											
January . .	419·7	20,888	515·0	·50	257·5	1,071·36	1,328·86	..	417·1	492·0	10,569
February . .	417·1	19,559	402·0	·75	369·0	743·04	1,112·04	..	414·8	473·0	18,447
March . .	414·8	18,447	473	·75	354·7	535·68	890·38	..	412·0	457·0	17,557
April . .	412·0	17,557	457·0	·75	342·7	518·4	861·1	..	411·0	442·5	16,006
May . .	411·0	16,696	442·5	·75	331·9	535·68	867·58	..	409·0	427·0	15,828
June . .	409·0	15,828	427·0	·25	106·7	518·4	625·1	..	407·5	415·5	15,203
July . .	407·5	15,203	415·5	·25	103·9	535·08	639·58	1,457·11	409·4	430·5	16,021
August . .	409·4	16,021	430·5	·25	107·6	535·08	649·28	8,320·35	425·0	563·0	23,704
September .	425·0	23,704	563·0	·25	140·8	518·4	659·2	1,077·51	427·2	582·5	25,022
October .	427·2	25,022	582·5	·50	291·2	812·16	1,103,36	..	425·4	566·0	23,910
November .	425·4	23,910	566·0	·50	283·0	1,036·80	1,319·8	..	422·9	544·0	22,599
December .	422·9	22,599	544·0	·50	272·0	1,071·36	1,343·36	..	420·4	521·0	21,256
1901—											
January .	420·4	21,256	521·0	·50	260·5	1,071·36	1,331·86	..	417·7	498·5	19,924
February .	417·7	19,924	498·5	·75	373·9	743·04	1,116·04	..	415·2	473·0	18,807
March . .	415·2	18,807	473·0	·75	354·7	535·68	890·38	..	413·7	464·0	17,917
April . .	413·7	17,917	464·0	·75	348·0	518·4	866·4	..	411·8	449·0	17,051
May . .	411·8	17,051	449·0	·75	336·7	535·68	872·38	..	409·8	433·0	16,179
June . .	409·8	16,179	433·0	·25	108·2	518·4	626·6	208·16	408·7	425·0	15,761
July . .	408·7	15,761	425·0	·25	106·2	535·68	641·88	2,959·04	414·0	466·5	18,072
August . .	414·0	18,072	466·5	·25	116·6	535·68	652·28	5,203·97	423·0	544·5	22,624
September .	423·0	22,624	544·5	·25	136·1	518·4	654·5	416·3	422·5	540·0	22,386
October .	422·5	22,386	540·0	·50	270·0	812·2	1,082·2	..	420·5	522·0	21,304
November .	420·5	21,304	522·0	·50	261·0	1,036·8	1,297·8	..	418·0	500·0	20,006
December .	418·0	20,006	500·0	·50	250	1,071·4	1,321·4	..	415·3	477·0	18,685
1902—											
January .	415·3	18,685	477·0	·50	238·5	1,071·4	1,309·9	..	412·5	454·5	17,375
February .	412·5	17,375	454·5	·75	340·0	743·0	1,083·0	..	410·1	435·0	16,291
March . .	410·1	16,291	435·0	·75	326·2	535·7	861·9	..	408·1	419·5	15,420
April . .	408·1	15,420	419·5	·75	314·6	518·4	833·0	..	406·0	404·0	14,596
May . .	406·0	14,596	404·0	·75	303·0	535·7	838·7	..	403·8	387·5	13,757
June . .	403·8	13,757	387·5	·25	96·9	518·4	615·3	..	402·3	375·0	13,142
July . .	402·3	13,142	375·0	·25	93·7	535·7	629·4	2,393·8	406·8	410·0	14,905
August . .	406·8	14,905	410·0	·25	102·5	535·7	638·2	4,579·5	415·7	480·0	18,848
September .	415·7	18,848	480·0	·25	120·0	518·4	638·4	5,620·3	425·2	564·5	23,830
October .	425·2	23,830	564·5	50	282·2	812·2	1,094·4	..	423·2	546·0	22,730
November .	423·2	22,736	546·0	·50	273·0	1,036·8	1,309·8	..	420·8	524·0	2 1,420
December .	420·8	21,426	524·0	·50	262·0	1,071·4	1,333·4	..	418·0	500·0	20,093
1903—											
January .	418·0	20,093	500	·50	250	1,071·4	1,321·4	..	415·5	479·0	18,772
February .	415·5	18,772	479·0	·75	359·2	743·0	1,102·2	..	413·2	460·0	17,670
March . .	413·2	17,670	450·0	·75	344·2	535·7	879·9	..	411·2	444·0	16,790
April . .	411·2	16,790	444·0	·75	333	518·4	851·4	..	409·2	429·0	15,939

Year and month.	Contents, etc., at beginning of the month.			Draw-off inclusive of evaporation and absorption, etc.				Monthly replenishment.	Contents, etc., at the end of the month.		
	R.L.	Contents in m. c. ft.	Surface area in m. s. ft. at different contours.	Depth on top surface in feet.	Quantity evaporated and absorbed as per depth of top surface m.c.ft.	Draw-off during month.	Total depletion.		R. L.	Surface area in m. s. ft.	Content in m. c. ft.
1903—											
May	409·2	15,930	420·0	·75	321·7	535·7	857·4	..	407·0	412·0	15,082
June	407·0	15,082	412·0	·25	103·0	518·4	021·4	208·2	406·2	405·0	14,669
July	406·2	14,669	405·0	·25	101·2	535·7	636·0	6,452·9	418·9	508·0	20,485
August	418·9	20,485	508·0	·25	127·0	535·7	662·7	2,872·6	423·2	545·5	22,695
September	423·2	22,695	545·5	·25	130·4	518·4	654·8	3,268·1	427·8	580·5	25,308
October	427·8	25,308	580·5	·50	294·7	812·2	1,106·0	..	425·8	570·5	24,201
November	425·8	24,201	570·5	·50	285·2	1,036·8	1,322·0	..	423·5	548·0	22,870
December	423·5	22,870	548·0	·50	274·0	1,071·4	1,345·4	..	421·0	526·0	21,534
1904—											
January	421·0	21,534	526·0	·50	263·0	1,071·4	1,334·4	..	418·4	503·0	20,200
February	418·4	20,200	503·0	·75	377·2	743·0	1,120·2	..	416·2	484·0	19,080
March	416·2	19,080	484·0	·75	363·0	535·7	898·7	..	414·2	468·0	18,181
April	414·2	18,181	468·0	·75	351·0	518·4	869·4	..	412·3	453·0	17,312
May	412·3	17,312	453·0	·75	339·7	535·7	875·4	..	410·4	438·0	16,437
June	410·4	16,437	438·0	·25	109·5	518·4	627·9	874·3	410·7	442·0	16,683
July	410·7	16,683	442·0	·25	110·5	535·7	646·2	3,746·0	417·6	496·0	19,784
August	417·6	19,784	496·0	·25	124·0	535·7	659·7	832·0	417·9	499·0	19,957
September	417·9	19,957	499·0	·25	124·7	518·4	643·1	3,122·4	..	..	22,436

Continuation as a yearly statement.

	Contents at beginning (October) of the year.			Draw-off inclusive of evaporation, absorption, etc.				Yearly replenishment	Contents at end (September 30th) of the year.		
	R. L.	Contents in m. c. ft.	Surface area in m. s. ft.	Depth of top surface in feet.	Quantity evaporated and absorbed as per depth of top surface m. c. ft.	Draw-off during the year.	Total depletion.		R. L.	Surface area in m. s. ft.	Contents in m. c. ft.
1st October 1904.	422·6	22,436	541	5·1	2,759	8,435	11,194	14,090	427·8	590	25,332
1st October 1905.	427·8	25,332	590	5·1	3,009	8,435	11,444	16,930	436·4	695	30,818
1st October 1906	436·4	30,818	695	5·1	3,545	8,435	11,980	10,590	434·3	665	29,428
1st October 1907.	434·3	29,428	665	5·1	3,392	8,435	11,827	14,300	437·9	719	31,901
1st October 1908.	437·9	31,901	719	5·1	3,667	8,435	12,102	15,330	overflows in 1909 monsoon	..	35,129

The aggregate of the monthly absorptions as estimated in the monthly table is equal to about 5·1 ft. on the area at the end of the monsoon.

Pravara River, tributary of the Godavari, Ahmednagar District.—Map 47 E/10. (i) A storage work for irrigation purposes is under construction at Bhandardara to the west of the Ghoti-Rajpur road. This work is situated 22 miles from Ghoti Station (Great Indian Peninsula Railway) and is connected to the Ghoti-Rajpur road by a service road. The catchment area is 47·35 square miles and the minimum run-off gauged is 13,000 m. c. ft. The dam when completed will be 270 ft. high with 3 ft. diameter sluices arranged in pairs at 50, 100, 150 and 200 ft. above the river bed. The full supply capacity of the lake when completed will be 12,690 m. c. ft. The flood water will be surplussed over a waste weir situated on the right bank of the river and will discharge into a nala which joins the river about 1½ miles down stream of the dam site. Table 29 gives the irrigation requirements during the period 16th October to 15th June from which it is seen that the lowest average daily discharge required is 400 cusecs. This figure has been adopted as the figure of average daily discharge for power purposes throughout the year. In order to avoid injury to the dam by discharging under the maximum head, it is proposed to connect the pipe line with the sluices situated at 150 ft. above the river bed level, at R. L. 2327·63. As the storage work is required for irrigation purposes, the discharge from the lake during the period 16th October to 15th June is regulated by irrigation requirements, and so it will not be possible to make use of the varying head in the lake to save water during these months, that is, although with the lake full, *i.e.*, with 257·5 ft. head, only 279 cusecs are required to give the required kilowatts, the full discharge of 800 cusecs must be drawn off. During the monsoon months when irrigation requires no water the varying head could have been made use of, if it were not for the second part of project at Rhonda where the fixed head requires a constant discharge. Table 30 shows the amount of additional storage which will have to be provided for irrigation to compensate for the volume drawn off during the monsoon, and the volume rendered unavailable for irrigation to provide the head required for power. This has been worked out for various heads and discharges, and shows that the best arrangement is to keep the level for power purposes in the lake up to 2,370·13 ft. With a power station at R. L. 2,290·13 or 12½ ft. above the river bed level, to allow for flooding back from the spill channel, the economical head comes to 180 ft. The volume of additional storage required to compensate irrigation, on the 400 cusecs constant draw-off basis, is 2641·233 m. c. ft. The pipe line as stated above will take off direct from the sluices through the dam, and will run down the side of the ridge on which the right flank of the dam abuts to a power station, which can be constructed in the river bed just below the dam. The length of the pipe line will be 450 ft. The available head is 180 ft. and with a constant discharge of 400 cusecs 180 ×400/15= 4,800 kWs. can be obtained, so that on commercial load factors a plant of from 12,000 to 14,000 kWs. could be installed.

(ii) After being discharged from the lake at Bhandardara the water passes over the Rhonda Falls situated some 5 miles below the dam, and ½ mile below the Ghoti-Rajpur road causeway. By means of a pick-up weir and a short length of open canal, a fall of 112 ft. to 160 ft. can be obtained, depending on the height of pick-up weir and length of canal adopted; the lower head being obtained with a pick-up weir 18 ft. high and a canal 1,900 ft. in length (which might be replaced by a pipe to save the cost of a forebay) and the larger head being obtained by a pick-up weir or barrage 46 ft. high and a canal 6500 ft. long. For the former scheme the power house would be situated about ¼ mile below the falls, 5 ft. above H. F. L. and 28 ft. above the river bed. The forebay, if an open canal is adopted, would be on the cliffs immediately above the power house. The length of the pipe line would be 150 ft. For the latter scheme the power house would be situated ¾ mile east of the village of Koduni, 5 ft. above H. F. L. and 28 ft. above the river bed. The pipe lines for this scheme would be 500 ft. long. With the discharge of 400 cusecs available from Bhandardara and a head of 112 or 160 ft., as the case may be, power of the order of 2,980 kWs. or 4,260 kWs. could be obtained, enabling a plant from 7,500 to 9,000 kWs. or 10,000 to 12,000 kWs. to be installed on a commercial load factor.

The total units that can be generated by the combined Pravara schemes are 68 million units or 79 million units, depending on which of the Rhonda schemes is adopted. The site for the additional storage required to safeguard irrigation interests is on the Ardala Nala, map 47 I/2, a tributary of the Pravara River, which joins the main stream 4 miles above the town of Sangamner. The proposed dam site is just below the village of Sawargaon. The catchment area is 55·08 square miles over half of which lies between the 200 inches and 100 inches rainfall areas and the remainder between 100 inches and 40 inches rainfall areas. There are no rain or river gauges at present in the area, but, comparing the area with similar areas in this Presidency, a worst year's run-off 40 inches equivalent to 5,115 m. c. ft. can be relied on. There is practically no appreciable flow in bad years after the monsoon. The dam to store the additional storage of 2,641

m. c. ft. would be 3,251 ft. long and 175 ft. high. The flood waters would be surplussed over the dam.

At a very liberal estimate the possible cost of the Pravara River Scheme, including the additional storage and assuming that the larger of the two Rhonda Schemes is selected, is Rs. 1,20,00,000 or Rs. 1,333 per kilowatt of *continuous* power. Assuming that the through rate charged for power averages 0·33 anna per unit, and that a market exists for the power, the gross revenue would be 16½ lakhs or 13·75 per cent. on the capital cost. The most likely uses for power in this area are :—

(1) The electrification of the Great Indian Peninsula Railway from Kalyan to Igatpuri and possibly on to Nasik.

(2) Industries and lighting in Igatpuri, Deolali and Nasik.

The transmission distance would be Kalyan 48 miles, Igatpuri 32 miles, Deolali 20 miles, and Nasik 25 miles. Detailed surveys have been made for the pipe line and power station at Bhandardara, and for the pick-up weir, canal lines, forebays and power stations at Rhonda. The surveys for the additional storage on the Ardala Nala were about half completed, when work was stopped.

TABLE 29.—*Pravara River Irrigation figures.*

I. *Period 16th October to 15th February = 123 days (rabi)*—

	cusecs.	
(*a*) Rabi discharge (average)	583	
Add losses in canals at 1 cusec per mile for 80 miles (aggregate length of Pravara canals)	80	
Add losses in river from Bhandardara to Ojhar	37 roughly	
	700 cusecs for 123 days —8 days	

for a closure = 115 days which is equivalent to—

Volume consumed 700 × 115 × 86,400 =		6955·200 m. c. ft.
(*b*) Area at F. S. L. (270′ contour) where capacity of the tank is	12690·358 m. c. ft. =	219·770 m. sq. ft.
Deduct—Volume consumed (*see* above)	6955·200 m. c. ft.	
Area at approximate 228′ contour where capacity of the tank is	5735·158 m. c. ft. =	118·139 m. s. ft.
	Total area	337·909 m. s. ft.
	Mean area	168·952 m. s. ft.
Deduct loss by evaporation at 2′ on mean area (2′ × 168·952 m. s. ft.)	337·905 m. c. ft.	
Nett balance	5397·253 m. c. ft.	

II. *Period 16th February to 15th June = 121 days (hot weather)*—

	cusecs.	
(*a*) Hot weather discharge (average)	283	
Add losses in canals at 1 cusec per mile for 80 miles (aggregate length of Pravara canals)	80	
Add losses in river from Bhandardara to Ojhar	37 roughly.	
	400 cusecs for 121 days—8 days	

for a closure = 113 days which is equivalent to—

Volume consumed = 400 × 113 × 86400		3905·280 m. c. ft.
(*b*) Area at 225′ contour approximate where nett balance (*see* above) in the tank is	5397·253 m. c. ft. =	111·957 m. s. ft.
Deduct Volume consumed (*see* above)	3905·280 m. c. ft.	
Area at approximate 169′ contour where capacity of the tank is	1491·973 m. c. ft. =	39·062 m. s. ft.
		151·019 m. s. ft. total area and 75·509 m. s. ft. mean area.
Deduct loss by evaporation at 3′ on mean area (3′ × 75·509)	226·527 m. c. ft.	
Nett balance	1265·446 m. c. ft.	

Thus irrigation requirements from 16th October to 15th June are 12,690·358—1,265·446 = 11,424·912 m. c. ft. but in addition to this a reserve has to be kept for a late start of the monsoon and shortage in the river discharge during the period 16th June to 15th October. For these purposes 1,265·446 m. c. ft. may be taken to suffice, in addition to which volume there are 40·530 m. c. ft. available below 50′ level sluice if required in case of necessity. (Supplied by W. N. Cartland, Executive Engineer, Pravara Canal.)

TABLE 30.—*Pravara River, balance Statement at Bhandardara.*

1. Discharge taken for power	100 cusecs.	100 cusecs.	100 cusecs	200 cusecs.	200 cusecs.	200 cusecs	300 cusecs.	300 cusecs.	300 cusecs,	400 cusecs.	400 cusecs	400 cusecs.
2. Lowest level to which the lake is to be emptied.	R. L. 2340·63	R.L. 2360·63	R.L. 2370·13	R.L. 2340·63	R. L. 2360·63	R. L. 2370·63	R. L. 2340·63	R. L. 2360·63	R. L. 2370·13	R. L. 2340·63	R. L. 2360·63	R. L. 2370·13
3. Volume of water in the lake rendered unavailable for irrigation.	1282·371 m. c. ft.	2129·680 m. c. ft.	2641·228 m. c. ft.	1282·371 m. c. ft.	2129·680 m. c. ft.	2641·228 m. c. ft.	1282·371 m. c. ft.	2120·680 m. c. ft.	2641·228 m. c. ft.	1282·371 m. c. ft.	2129·680 m. c. ft.	2641·228 m. c. ft.
4. Volume of water which irrigation requires to be left in the lake on the 16th June to safeguard against a late monsoon.	1265·450 m. c. ft.	1265·450 m. c.ft.	1265·450 m. c. ft.	1265·450 m. c. ft.	1265·450 m. c. ft.	1265·450 m. c. ft.	1265·450 m. c. ft.	1265·450 m. c. ft.	1265·450 m. c. ft.	1265·450 m. c. ft.	1265·450 m. c. ft.	1265·450 m. c. ft.
5. Total contents of the lake on 16th June. Column 3+Column 4.	2547·820 m. c. ft.	3395·130 m. c. ft.	3906·678 m. c. ft.	2547·820 m. c. ft.	3395·130 m. c. ft.	3906·678 m. c. ft.	2847·820 m. c. ft.	3305·130 m. c. ft.	3906·178 m. c. ft.	2547·820 m. c. ft.	3305·130 m. c. ft.	3906·678 m. c. ft.
6. Volume required to fill the lake up to full supply level. 12690·358 m. c. ft.—column 5.	10142·537 m. c. ft.	9295·228 m. c. ft.	8783·680 m. c. ft.	10142·537 m. c. ft.	9295·228 m. c. ft.	8783·680, m. c. ft.	10142·537 m. c. ft.	9205·228 m. c. ft.	8783·680 m. c. ft.	10142·537 m. c. ft.	9205·228 m. c. ft.	8783·680 m. c. ft.
7. Balance of supply during year of estimated lowest run off 13,000 m. c. ft.—column 6.	2857·463 m. c. ft.	3704·772 m. c. ft.	4216·320 m. c. ft.	2857·463 m. c. ft.	3704·772 m. c. ft.	4216·320 m. c. ft.	2857·463 m. c. ft.	3704·772 m. c. ft.	4216·330 m. c. ft.	2857·463 m. c. ft.	3704·772 m. c. ft.	4216·320 m. c. ft.
8. Volume required from lake for power during the period 16th June to 15th October. Discharge×122×86,400	1054·080 m. c. ft.	1054·080 m. c. ft.	1054·080 m. c. ft.	2108·160 m. c. ft.	2108·160 m. c. ft.	2108·160 m. c. ft.	3162·240 m. c. ft.	3162·240 m. c. ft.	3162·240 m. c. ft.	4216·320 m. c. ft.	4216·320 m. c. ft.	4216·320 m. c. ft.
9. Surplus over or deficiency below power requirements which will be discharged over waste weir. Column 7—column 8.	plus1803·383 m. c. ft.	plus 2650·692 m. c. ft.	plus 3162·240 m. c. ft.	plus 749·30[illegible] m. c. ft.	Plus 1596·612 m. c. ft.	Plus 2108·160 m. c. ft.	Min. 304·777 m. c. ft.	Plus 542·533 m. c. ft.	Plus 945·920 m. c. ft.	Min. 1358·857 m. c. ft.	Min. 511·548 m. c. ft.	Nil.
10. Actual draw off from storage during the period 16th June to 15th October.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	304·777 m. c. ft.	Nil.	Nil.	1358·857 m. c. ft.	511·548 m. c. ft.	Nil.
11. Volume available for irrigation between 16th October and 15th June. Column 6—column 10	10142·537	9295·228	8783·680	10142·537	9295·228	8783·080	9837·760	9205·228	8783·080	8783·080	8783·080	8783·080
12. Additional storage required in order to meet full irrigation requirements. 11,424·913 m. c. ft.—column 11.	1282·376 m. c. ft.	2129·685 m. c. ft.	2641·233 m. c. ft.	1282·376 m. c. ft.	2129·685 m. c. ft.	2641·233 m. c. ft.	1587·153 m. c. ft.	2129·685 m. c. ft.	2041·233 m. c. ft.	2641·233 m. c. ft.	2041·233 m. c. ft.	2641·233 m. c. ft.

Urmodi River, Satara District.—Map 47G/14 and 47K/2. The Urmodi River has a catchment area of 2·63 square miles on a high plateau above the town of Satara. A storage tank formed by an earthen dam is in existence near the village of Kas on the Plateau, which is the main source of water supply for the town and cantonment. From this tank the water is carried partly in open canal and partly in a covered duct to the settling tanks, a distance of 15 miles. There is a scheme on foot to place these settling tanks at a higher level, so as to command all parts of the town. When this is done the total fall from the outlet level of the lake to the F. S. L. of the wash-out tank will be 3659·66—2746=913·66 ft. As will be shown later only a portion of this fall is available for power purposes. The average rainfall in the catchment area is 135·79 inches and the lowest recorded rainfall is 66·29 inches. As the catchment area is very rocky it will be safe to take 50 per cent of this or 33·15 inches as the minimum run-off; this figure would yield 202·5 m. c. ft. The gross storage of the present tank is 98·283 m. c. ft. and the net storage available for Satara Water Supply is 66·686 m. c. ft. The total requirements of Satara City and Cantonment is 60,000 gallons a day=a continuous discharge of 1·115 cusecs. From experiments made in 1913, the losses in the canal amounted to 39 per cent. of the discharge from the tank. Thus, to obtain a discharge of 1·115 cusecs at Satara, 1·83 cusecs must be drawn off from the tank. This is equivalent to a volume of 57·710 m. c. ft. If the dam at Kas was raised 15 ft. it would be possible to store the 202·5 m. c. ft. available in the worst year's rainfall, of which 170·904 m. c. ft. would be available for use. The subsidiary storage tanks at Yeoteshwar on the canal line are capable of supplying 2 cusecs continuously for the 3 monsoon months, which is equivalent to 15·897 m. c. ft., making the total volume available 170·904+15·897=186·8 m. c. ft. The full supply capacity of the channel from Kas is only 5 cusecs, and this could not be increased without interfering with the water supply of Satara. A constant discharge of 5 cusecs throughout the year is equivalent to a volume of 157·7 m. c. ft., so that it will only be necessary to raise the dam at Kas to give this net storage. Assuming that the same losses of 39 per cent. in the canal continue, the 5 cusecs at the head of the canal will be reduced to about 3 cusecs at the point where it is proposed to construct a forebay site. It is, however, possible to reduce these losses at a small cost; so the above discharge will probably be increased to 4 cusecs. The forebay site is situated on the plateau above Satara at a point where the water level in the canal is R. L. 3,333. From this it is proposed to run a pipe line to a power house situated at such a level that it is possible to fill the proposed new wash-out tank from the tail waters by gravity, say, at R. L. 2,756 or 10 ft. above the F. S. L. of the wash-out tank, giving a fall of 577 ft. The length of this pipe line would be 1,250 ft. The power station site would be in rather side-long ground, but no good flat piece of ground can be found at the required level. The power which it is possible to develop amounts only to 150 kWs. continuously, with which a plant of some 300-400 kWs. could be installed on a commercial basis. The permissible cost of the hydraulic development of this project is about 385 × 636×15/12=Rs. 3,06,000, as there would be a very short transmission line. As the hydraulic development would only consist in adding some 12 ft. to the height of an earthen dam, the staunching of leaks in a canal line, the provision of a small forebay and a pipe line 1,250 ft. long, this small project is well worth considering. Power would be used for lights and fans in Satara city and cantonment and possibly for the electrification of the proposed tramway to connect Satara with the Madras and Southern Mahratta Railway.

83. Burma ; sites examined.—Burma will probably prove ultimately (if this investigation is completed) to have more available power than any other province in India. But the country is wild and scattered and communications are bad, so that progress is necessarily rather slow. Commenting on the Administration Report of the Burma Public Works Department for 1919-20 " Indian Engineering " remarks (Vol. LXX, No. 12, page 166) :

" The greatest section covers less than half a page of the report, the Burma Hydro-Electrical Survey. A hundred useful sites have been selected for detailed report, but the survey has been greatly hampered by their situation, for the most part, in remote and fever-stricken jungles. The staff generally has suffered from acute malaria, and two very promising subordinates have unhappily died. It is hoped that most of the projects will be taken up commercially, since owing to the dearth of coal except of the poorest quality, and the large existing demands on the timber supply of the Province, the adoption of hydro-electrical power is an economic necessity. It would seem that the provision of a sanitary board, as for the Panama Canal, is essential to the success of these schemes, and no doubt the Local Government is considering the matter. Indeed, the scarcity of labour, and the slow progress in Burma cannot be overcome without first arranging for the elimination of the mosquito. Nobody acquainted with the Province can doubt this."

The following table gives a summary of the sites so far examined in some detail, regarding which further particulars follow. As the regular reconnaissance form does not appear to have been used the data are somewhat meagre. Most of the Burma schemes can be developed on flow alone.

NOTE.—As only 1·115 cusecs are required to be discharged into the settling tanks, the balance of the tail water, *viz.*, 2·885 cusecs would be passed into the Mahardara Tank which supplies the lower portion of Satara town. This tank is situated at R. L. 2,454 or 302 ft. below the proposed power station. This surplus water could, therefore, be utilised to give additional power of 58 kWs. continuously. The total power which can be derived from the project is therefore 212 kWs. continuous or some 500 kWs. on a commercial load factor. This would probably suffice for the town. There seems a possibility of bringing in some of the small neighbouring hill-top catchments, through the watershed, but the maps are uncontoured. If so, earthen bunds would similarly be used for storing the water of these. Otherwise the possibilities are very small.

TABLE 31.—*Burma ; Summary of sites examined.*

Serial.	River or site.	Nature of supply.	Site number.	Constant flow assumed, cusecs.	Head, ft.	Continuous power, kWs.	REMARKS.
(1)	Anisakan River . . .	Flow and Storage .	...	3	750	150	
(2)	Heho River . . .	Flow . .	...	57	777	2,950	
(3)	Hpaungaw Chaung . .	" . .	...	70	480	2,250	
(4)	Nam Pang River . .	" . .	(*i*)	2,200	75	11,000	
	Ditto . .	" . .	(*ii*)	2,000	30	4,000	
	Ditto . .	" . .	(*iii*)	2,500	210	30,000	
(5)	Nam Teng River . .	" . .	...	500	396	13,000	
(6)	Nam Tu River . . .	" . .	...	3,000	145	29,000	One of many sites.
(7)	Panlaung River . . .	" . .	...	180	2,000	24,000	
(8)	Saingdaing River . .	" . .	...	200	65	...	
		Flow and Storage Same	...	...	65	5,000?	Doubtful.
(9)	Talainga Chaung . .	Flow . .	...	7	1,000	450	
(10)	Yunzalin River . . .	......	...	250	1,578	26,000	Doubtful.
(11)	Zawgyi River . . .	......	...	300	400	8,000	Probably more.
	TOTAL .					155,800	

(1) *Anisakan River, Maymyo.*—This tributary of the Myitnge has a sheer drop of 750 ft. at Deitdawgyi falls, which have been investigated for supplying Maymyo with power. The catchment is about 20 square miles and the discharge has been gauged down to 5 cusecs in May 1919 and is believed to fall lower, even down to 2 cusecs. There are storage possibilities just above the falls and the pipe line would take off directly from the reservoir. With storage the small project is probably good for at least 200 kWs. continuously, and any reasonable peak load could be met. (Map 93 C/5.)

(2) *Heho River, Yawnghwe, Southern Shan States.*—The natural waterfall on this river is situated close to the road from Kalaw to Yawnghwe and near the new terminus of the Southern Shan States Railway. The river flows to a considerable extent from a very large perennial spring or tunnel in the limestone rock at the head of a large flat valley, evidently an old lake bed. The catchment area is about 20 square miles, to some extent cultivated in this valley, surrounded by hills so as to form a basin. The lowest discharge hitherto recorded is 57 cusecs in March 1920, and it is improbable that it falls much lower. The soil is of a peaty nature and appeared likely to afford a large storage; it has since however been found that, as all over Burma, there are " ye-ngoks," or disappearing stream channels, in the rock. In fact, just as the river is fed largely from one such, so, if a reservoir were constructed, it would similarly disappear. If the stream rises 5 or 6 ft. this happens even now, though ordinarily the discharge goes over the fine falls. The stream discharges by these falls, which total 777 ft. in 4,000 ft. horizontal, into the valley above Inle Lake (map 93 D/10, 14). The site was originally examined by Mr. R. T. D. Alexander on behalf of the Railway Board, in connection with the railway referred to, but he considered that there would be insufficient power. Subsequently Messrs. Barlow and Meares examined the site and appraised it at some 3,800 e. h. p. minimum. A detailed survey was undertaken in the cold weather of 1919-20 and, as recorded above, it was found that no large storage could be relied on. Even during the dry weather it is uncertain whether the entire drainage of the valley finds its way to the falls. An open channel of 3,500 ft. would be needed to reach the forebay site, but a tunnel 1,200 ft. long could be used instead and would almost certainly be preferable. The pipe line will be 4,150 ft. long to give 777 ft. head. Good forebay and power house sites are available. The continuous power is 57×777/15 or 2,950 kWs. which is far more than would have been required for working the ghat section of the railway. The line now runs to the site.

(3) *Hpaungaw Chaung, tributary of Namtu River, Southern Shan States.*—The head waters of this stream are used for local irrigation in the vicinity of Hsumhsai (map 93 B/12, 16) and not much water is available for power in the dry season. Some 70 cusecs might be obtained without interfering with irrigation and a fall of 480 ft. (known as the " Whispering Devil fall " in the vernacular) can be obtained not far from Nawnglan. The minimum power available is therefore 2,250 kWs. continuous, and more if the water rights were acquired. The site has been fully examined, but no further information has reached the compiler of this Report. It is possible that 120 cusecs could be obtained.

(4) *Nam Pang River, tributary of Salween, Southern Shan States.*—Three sites have been examined on this river, all about 150 miles from the nearest railway at Heho.

(*i*) *Kunkha falls*, situated 2 miles south of Keng Kham, map 93 K/12, 16; L/9, 13. A dam of 15 ft. in height and 200 ft. in length is proposed, presumably for regulation only, but the approximate storage capacity is not stated. With a pipe line 200 ft. long a fall of 75 ft. is obtainable. The minimum discharge is reckoned to be 2,200 cusecs, giving 11,000 kWs. continuously.

(*ii*) *Naung Wo falls*, about 5 miles north of Keng Kham, map 93 K/12, 16. A head of 30 ft. can be obtained with a pipe line 350 ft. long, without any open channel. The minimum discharge here is taken as 2,000 cusecs, as there are places where water can escape. (See remarks under Heho River, *supra.*) The continuous power available is 4,000 kWs.

(*iii*) *Loi Ha falls*, about 1½ miles south of Hoyan, map 93 K/12, 16. Here the probable discharge is assumed to be 2,500 cusecs, but as 2,997 cusecs were recorded in April 1920 and there are no regular gaugings it will be safer to take 2,200 cusecs as in site (*i*). A small dam of about 300 ft. in length and 20 ft. in height is required and the available head is 210 ft. No open channel is required and the pipe line is 2,700 ft. long. The continuous power will be some 30,000 kWs.

(5) *Nam Teng River, tributary of Salween River, Southern Shan States.*—A survey has been completed of the falls on this large river, about 4 miles below Wan Kun Long, 85 miles due east of Taungyi, and 150 miles by road from Heho station on the Southern Shan States railway (map 93 L/2, 6.) The discharge in June 1919 was 792 cusecs and in May 1921 1,400 cusecs; the minimum is not known but may be taken

as of the order of 500 cusecs. With an open channel of 1,000 ft. and a pipe line 2,000 ft. long a head of 396 ft. can be obtained, as against 359 ft. recorded in an earlier reconnaissance. The site is rather inaccessible but a road could easily be made to it. The power available is some 13,000 kWs. continuously, though locally assessed at 45,000 turbine h. p. on a discharge much above that recorded above.

(6) *Nam-Tu River.*—This is a tributary of the Irrawaddy River, known as the Myitnge in its lower reaches. The site is on map 93 C/9, 13, but is not easy to distinguish. There are many rapids all along the river, which has a large perennial discharge from an immense catchment. It has been examined in a considerable number of places but so far only the Pyaungohoo rapids have materialized as worth detailed examination. This site is 32 miles due south of Nawnghkio station on the Lashio-Mandalay railway. The gorge has steep sites and might be costly to develop as there would have to be a diversion tunnel; also the power house site would offer difficulties owing to the heavy floods encountered. On the other hand, there is great power even at this one site, and if flood regulation higher up were possible the whole river could be developed on lifting dams, giving vast power. The fall at the rapids in question is 145 ft. The discharge in March 1921 was over 3,800 cusecs, but the minimum is not known. It is taken locally at the above figure, but 3,000 is probably nearer the mark, giving continuous power of 29,000 kWs.

(7) *Panlaung River.*—The minimum flow of this river is about 180 cusecs and there is a natural lake reservoir, capable no doubt of being increased and regulated, 1 mile north-west of Kanbyin village (map 93 C/12, 16). There is a total fall of 2,200 ft. in about 17 miles and four alternative projects have been examined. The value of the site may be taken as 24,000 kWs. over the whole fall, whether developed in stages or as a whole.

(*i*) The useful fall of 800 ft. from the lake to the plain below at Indwet village could be developed with a short channel and a pipe line of 1,550 ft. in length. There is a good power station site, but the ground for channel, reservoir, forebay and pipe track is much fissured and may prove difficult.

(*ii*) An extension of (*i*) by running the channel further along to a total length of 12,560 ft. thereby getting a fall of 1,100 ft. instead of 800 ft. The pipe line would be 2,500 ft. long.

(*iii*) This utilizes the water from the lake *after* the first fall of 800 ft. and adds the stream joining below the lake, these two streams forming the Panlaung proper. The fall is that between a point 1½ miles north of Moubin village (map 93 D/9, 13) and a point ¾ mile upstream from Songyi village (map 93 D/1, 5). The fall is apparently in series with No. (*i*); its amount is not stated, but it may be 2,200—800 or 1,400 ft. The scheme is stated to be a promising one, but is not completely examined.

(*iv*) This utilizes the water of No. (*i*) with about 12 cusecs from other small streams. It is hoped to make use of the full fall from the upper section of the river above Kanbyin village (map 93 C/12, 16) to the river near Dalcin village (map 93 C/4, 8). The channel would be about 17 miles long, with some tunnels, and the pipe line 4,500 ft. or so to give 2,200 ft. head. The discharge here is reckoned to be 212 cusecs minimum.

Of these No. (*i*) has been more fully investigated than the others and would give continuous power of some 10,000 kWs. But in all probability the whole fall could be developed in stages so the site may be taken as worth $180 \times 2,000/15$ or 24,000 kWs. The site is some 30 miles east of the Rangoon-Mandalay railway (Thedaw section, mile 322) and within 15 or 20 miles of the Thazi-Kalaw road.

On the adjoining map 93 D/9, 13, the Panlaunge Bend is also listed, but apparently this is embraced in No. (*ii*) of the full scheme preceding, as the assumed discharge is the same and the head is 1,000 ft.

(8) *Saingdaing River, tributary of Mayo, Akyab District.*—(Map 84 D and 84 C.) This is the only known site near Akyab. There are natural falls of 65 ft. named after the river, and they are accessible by launch from the town. The minimum discharge is assumed to be 200 cusecs, so that on flow alone some 800 kWs. only could be depended upon continuously. Alternatively a dam 800 ft. long and 135 ft. high would give "considerable" storage, but even the order of magnitude is not noted. As the site with this storage is assessed at 8,000 turbine b. h. p. or say 5,000 kWs., the storage must be fairly large or the normal discharge far greater. The site is below Buthidaung, and in the Preliminary Report a minimum discharge of about 1,000 cusecs was believed to be probable. The flood discharges are of the order of 100,000 cusecs, so the reservoir would be filled without difficulty.

(9) *Talainga Chaung and Kyaung Pyu.*—These two streams were investigated in 1919 for supplying power to the proposed Cinchona Plantation in Tavoy. The site is in Lat. 14°20, Long. 98°15. A minimum discharge of about 7 cusecs is available with a fall of 950 ft. so that 450 kWs. are obtainable continuously. It appears probable that a regulating reservoir can be constructed to impound the flow during

the non-working hours, in which case any *peak* load could be met up to about 1,500 kWs.

(10) *Yunzalin River, tributary of Salween.*—Investigations are in progress along the entire length of this river above Klothuta Zayat, which is 22 miles north of Papun. (map 94 F and G). The discharge was measured during the dry weather of 1920-21 and is locally taken as 250 cusecs minimum. It is however doubtful if one season's discharges give any true indication. The river bed has no falls, but has rapids amounting to some 600 ft. Three schemes for utilizing all or part of this head have been proposed, but no details have been sent in except that 327 ft. gives a possible lay-out. The river is the most promising one for supplying Rangoon, which however at present supplies itself cheaply from rice husk and wood refuse. Preferable to utilizing the rapids appears to be a project for diverting the waters with those of the Thelaw Klo towards the west and nearer the railway, by means of a short tunnel or cutting near Pyagawpu into the Shwegyin stream. A suitable dam site has been found below the junction of the two rivers (maps 94 B/15, 16 and F/2, 3, 4). In this case the head would apparently be 1,578 ft. There would be "good storage," but it is not stated whether this would be of the order of 10 or 100 or 1,000 m. c. ft. However, with a minimum discharge, including help from the storage, of 250 cusecs the continuous power would be of the order of 26,000 kWs.

(11) *Zawgyi River, tributary of Myitnge.*—The Mong Hing falls are two days' march from the hill station of Kalaw, 10 miles from Lawk Sawk, and 50 miles from Kume Road station. The dry weather discharge is reckoned not to fall below 300 cusecs. The available head is 400 ft. and both open channel and pipe line are short. Good sites, cheap to develop, exist for regulating reservoir, forebay and power station. The falls are spread over about a mile, where the river makes two right-angled bends. It is proposed to take off from the apex of the upper bend, on the L. bank and thence to run to the pipe head in open channel 3,350 ft. long. The upper section of the pipe line, some 1,610 ft. long, would run on a small slope to a surge tower, whence the pressure section 700 ft. long would descend at an angle of 40°. The regulating reservoir would hold 15 m. c. ft. and good ground exists for it. The catchment area is 400 square miles with an annual rainfall about 45 inch and the *average* discharge is probably 600 cusecs, much of which is from springs. The minimum continuous power available at this fall is $300 \times 400/15$ or 8,000 kWs.

From the hills to the plains there is a fall of 4,000 ft. in 20 miles with a catchment above Kyaukse of about 2,500 square miles. From 1910 to 1918 the average cold weather flow has been between 515 and 2,200 cusecs in the plains below, with very heavy occasional floods. Taking the total fall the river appears to be worth some 80,000 kWs. continuous. (Map 93 G/3, 7, 10, 11, 14, 15.)

84. Central India ; sites examined.—*Bhopal.* A small supplementary project, for utilizing the upper and lower city lakes at Bhopal (map 55 E), was drawn up by Mr. H. P. Gibbs of Tata Sons & Co. Messrs. Bull and Meares visited Bhopal in January 1920 and reported favourably on the scheme. The upper lake will have a H. F. L. of R. L. 1,660 ft. when the proposed weir and shutter are put in at Bhadhbhada (1,657 ft. now), and the lowest safe draw-off level is fixed at R. L. 1,649. The spillway level of the lower lake, into which the upper one will discharge. is 1,641 feet, giving a fall of 8 to 19 ft. From the spillway of the lower lake there is a fall of 40½ ft. to the tail water level, now utilized by means of an overshot water wheel driving pumps. Mr. Gibbs' proposal is to use the lower lake as a forebay and to utilize the storage of the upper lake for power. The available storage is 1,140 m. c. ft. with a possibility of not more than 940 m. c. ft. in exceptional years. The actual project is based on 700 m. c. ft. During the 8 dry months 33 cusecs can be obtained, and in the monsoon there will generally be a large excess. The net head will be 40 ft. and as the draft on the main lake would cease when the forebay lake was receiving sufficient water from its own catchment the tail waters are not liable to rise appreciably. The constant power available is 85 kWs. which would work in parallel with the existing steam plant and thus save fuel with a cheap development. The *monsoon* power is much greater, about 200 kWs. continuous. The project is now being re-investigated by a Consulting Engineer.

Indore, Kanar River.—A site suggested by Major Traill was examined, on map 46 N/14, not far from Indore. It is almost certainly likely to prove prohibitive in cost as only some 200 kWs. continuous could be obtained from a costly storage.

85. Central Provinces ; sites examined.—The work done so far in the Central Provinces is mostly entered under the head of "Sites worth detailed investigation" but the Silewani Ghat scheme (Pench and Kulbehra Rivers) Chindwara District may perhaps be placed in the category dealt with in this paragraph. With a constant discharge of 230 cusecs and a head of 900 ft. some 13,700 kWs. are available.

This project was suggested by Mr. Batchelor some years ago in a pamphlet, which was referred to at some length in the Preliminary Report, pages 62 and 73 and also in the Second Report, page 62. As the project has created considerable interest it will be dealt with here in some detail, to the extent to which information is now available. A thorough reconnaissance has been made of the site, proving it to be well worth detailed survey, although it is probable that the power obtainable is not more than about half that assumed by the original author of the scheme.

In brief outline, the project depends on monsoon storage in two lakes, formed by damming the Pench and Kulbehra Rivers, tributaries of the Kanhan River. The former is the larger and upper storage, and its regulated flow will be taken in a tunnel through the watershed to the latter river, and on to the second storage. Thence a long canal leads to a smaller regulating storage and eventually to a forebay, from which a pipe line runs to a power house on the banks of the Kanhan River. Localities are indicated below.

The catchment area above the proposed dam on the Pench is 260 square miles and at the Kulbehra dam 115 square miles. There is only one rainfall station, Tamia, on the edge of the former catchment; therefore the records at Pachmarhi and Chindwara have also been used in calculating the yield. This has been worked out by Mr. Barlow's method, from each day's fall in various years, the gauging stations being used for those portions of the catchment to which they apply best. An error was made however in using different minimum years at the different gauging stations; clearly the same two years, giving the probable lowest combined yield, should have been used. In the table sent in this was allowed for by reversing the yields of the two dry years at Pachmarhi and Chhindwara (Pench reservoir) so as to give the lowest probable yield; this would not give correct results, and the table that follows perhaps more nearly represents actual conditions. If the same series of years had been used the results would probably have been slightly higher.

TABLE 32.—*Silewani Ghat, Rainfall and Yield.*

Raingauge station.	Year.	Rainfall.	Year.	Rainfall.	Effective fall in the two years on Barlow's classification inches.		YIELD M. C. FEET		
							Catchment sq. miles.	From col. 6.	From col. 7.
1	2	3	4	5	6	7	8	9	10
Pench Reservoir.	*Two driest consecutive years.*				1st year.	2nd year.		1st year.	2nd year.
Tamia	1907-8	34·97	1908-9	60·42	30·91	57·70	133	3,711	5,110
Pachmarhi	1898-9	70·80	1899-00	38·85	08·12	34·46	29	1,244	410
Chhindwara	1898-9	34·31	1899-00	14·27	31·09	9·45	98	1,839	269
TOTAL							260	6,794	5,795
Kulbehra Reservoir.									
Chhindwara	1898-9	...	1899-00	...	31·09	...	115	1,565	191
Pench Reservoir.	*Normal year.*								
Tamia	1903-4	05·23	...	...	59·7	...	133	6,868	...
Pachmarhi	1010-11	77·08	...	...	75·36	...	29	1,549	...
Chhindwara	1877-8	41·28	...	...	36·57	...	98	1,544	...
TOTAL							260	0,961	...
Kulbehra Reservoir.									
Chhindwara	1877-8	...	...	...	36·57	...	115	1,697	...

The table is the summary from detailed sheets of each day's rainfall tabulated in the manner explained in the Preliminary Report, page 8, and in para. 23 of the present report. The catchments on Barlow's classification are: Tamia, E; Pachmarhi, D; Chhindwara, B for Pench and C for Kulbehra. As the draft allowable depends on the storage and carry-over, an isolated bad year can certainly be neglected if conditions are regulated for the two driest consecutive years. Therefore, on the data in the table, the average yield of the two worst years will be 6,794+5,795/2 or 6,300 m. c. ft. for the Pench and 878 m. c. ft. for the Kulbehra or 7,178 m. c. ft. in all. Normally there will be 9,961 and 1,697 m. c. ft. or 11,658 m. c. ft. in all.

In the absence of a series of gaugings the only check that can be applied to these results is that on page 334 of Buckley's Irrigation Pocket Book, 3rd Edition, where the percentages of run-off for a small tank catchment in this neighbourhood are given. The ratio is 13 per cent. minimum and 23 per cent. average, which gives 3,865 m. c. ft. in each of the two bad years and 10,500 m. c. ft. in a normal year.

On page 333 of "Indian Engineering" for 11th June 1921, Mr. Batchelor assumes yields of 16,100 and 3,640 m. c. ft. or 19,740 m. c. ft. in all, as against 18,400 m. c. ft. in his original pamphlet. There seems little warrant for such high yields in view of the above.

The Pench and Kulbehra Rivers were gauged from June to December 1920, and the following is an abstract of the results, with the rainfall at special gauges in each of the catchments.

Pench River (260 sq. miles).

June 1920—
Rainfall at 3 stations 1·20, 1·91, 3·77 inch.
Total discharge 163 m. c. ft. at Baranga Teli.
Maximum flood 1,297 cusecs.
Minimum flow 4 cusecs.

July 1920—
Rainfall 12·01, 7·30, 4·42 inch.
Total discharge 662 m. c. ft. at Baranga Teli.
Maximum flood 2,050 cusecs.
Minimum flow 4 cusecs (under 100 on 7 days only).

August 1920—
Rainfall 11·39, 5·89, 6·59 inch.
Total discharge 1,017 m. c. ft. at Baranga Teli.
Maximum flood 5,550 cusecs.
Minimum flow 76 cusecs.

September 1920—
Rainfall 4·93, 3·53, 1·44 inch.
Total discharge 1,149 m. c. ft. at Baranga Teli.
Maximum flood 6,307 cusecs.
Minimum flow 106 cusecs.

October 1920—
No records.

November 1920—
Rainfall—*Nil*.
Total discharge 40 m. c. ft. at Baranga Teli.
Minimum flow 12 cusecs.

December 1920—
Total discharge 14 m. c. ft. to 15th.

Kulbehra River (115 sq. miles).

June 1920—
Rainfall at 3 stations 3·83, 1·52, 2·76 inch.
Total discharge 219 m. c. ft. at Khairwara.
Maximum flood 1,196 cusecs.
Minimum flow 2 cusecs.

July 1920—
Rainfall 4·83, 6·95, 6·22 inch.
Total discharge 214 m. c. ft.
Maximum flood 1,621 cusecs.
Minimum flow 6 cusecs.

August 1920—
Rainfall 5·07, 6·63, 7·65 inch.
Total discharge 326 m. c. ft.
Maximum flood 3,250 cusecs.
Minimum flow 3 cusecs.

September 1920—
Rainfall 1·97, 1·23, 2·24 inch.
Total discharge 51 m. c. ft.
Maximum flood—not recorded.
Minimum flow 12 cusecs.

October 1920—
No records.

November 1920—
Rainfall—*Nil*.
Total discharge 18 m. c. ft.
Minimum flow 7 cusecs.

December 1920—
Total discharge 7 m. c. ft. to 15th.

Clearly with such wide differences in the rainfall, and only 3 gauges, any determination of run-off from these readings must be liable to serious error. The run-off from the Kulbehra per square mile is much smaller than that of the Pench. The total yield in the 4 months June-September was 2,991 m. c. ft. for the Pench against 810 m. c. ft. for the Kulbehra; and the former figure is much below the estimated minimum yield. Taking the averages of the rainfall stations the run-off in the 4 months works out to—

Pench 12 per cent., 14 per cent., 20 per cent. and 55 per cent.

Kulbehra 29 per cent., 13 per cent., 18 per cent., 8 per cent.; the abnormal result for June being due to 3 days' heavy rain. Not much dependence can be placed on these figures however.

The site selected for the Pench dam is just below Baranga Teli on square 4 of map 55/J, 16. Twelve villages would be submerged. This dam would be 9,900 ft. long and 147 ft. maximum height and would impound 8,500 m. c. ft. of effective storage at a discharge level of R. L. 2,300. This was reckoned to be the yield in the best of the two driest consecutive years; but for reasons given the table shows a lower figure. In further investigating the project it may be desirable to increase this capacity to the average yield of say 10,000 m. c. ft. from this catchment, as the carry-over would substantially increase the possible draft in a bad cycle. The Pench River reservoir, and the data in this paragraph, have been used to illustrate the graphical method of determining storages in para. 30 *supra*.

A tunnel some 5·2 miles long with an open channel would take off direct from the Pench reservoir and would discharge into a tributary of the Kulbehra River, by which the water would be carried down to the Kulbehra reservoir; there would therefore be no difficulty in regulating the main storage exactly to the requirements.

Coming now to the Kulbehra River, the dam would be between Thunia and Khairwara (square 6 *ibid*) and 4 villages would be submerged; the length would be 10,300 ft. and maximum height 94 ft. to impound 1,539 m. c. ft. of effective storage at discharge level 2,190. This is similarly about the yield of the best of the two driest consecutive years of this catchment. The Kulbehra reservoir with this considerable capacity would be refilled as required from the Pench reservoir; an open channel some 19½ miles long would lead from the Kulbehra storage to the smaller regulating reservoir on the Umra Nala (square 5 of map 55 K/13) where some 11 days' supply for the whole project could be stored (if so much is necessary); this again avoids any waste from the upper storages. The catchment area of the Umra Nala at the site near Ekalbehri is 40 square miles with a mean yield of some 588 m. c. ft. which has been fixed as the capacity of the reservoir. It would appear however unnecessary to spend 6 lakhs on this work unless it proves to give substantial additional power, as it is only required as a regulator at the end of the long channel. On the other hand, falls of 10 inch in one day have been recorded, equal to about 1,000 m. c. ft. on a 40 square miles catchment. This matter requires further consideration based on longer periods. From the Umra Nala regulating reservoir a 6 mile open channel would lead to a forebay at Silewani tola on the boundary of squares 3 and 4 of map 55 K/13. Here 36 m. c. ft. effective could be stored, which is far more than ample. The pipe line would be 4·6 mi. long, leading to a power house near Nandudhana above the Kanhan river, where the fall is 900 ft. The power house site however is 69 ft. above bed level in the Kanhan and 48 ft. above high flood level. To use this additional head more than a mile of extra pipe would be required; but it seems practicable to sink the power house and run a tail race tunnel to the river. This is a matter of cost compared with the value of the extra power, as noted below. The pipe line proposed on the plan prepared locally could probably be improved upon; it appears practicable to run it along at a slightly greater slope than the hydraulic gradient, near the 2,000 or 2,050 ft. contour, for some 2 miles; by installing a surge pipe at the termination the long upper section would be greatly decreased in cost and rendered safer in working.

It is reckoned by the investigating officer that on the basis of constant 24-hour working a discharge of 205 cusecs could be maintained throughout the two driest years. With suitable carry-over it seems possible that 230 cusecs could in fact be depended upon. This would be equivalent to $230 \times 900/15$ or 13,700 kWs. continuously. If the extra 48 ft. of head referred to above could be utilized it would be good for an extra 730 kWs. continuously, or over 6 million units a year, taken on any load factor. Valued at ½ anna these give a revenue of 2 lakhs extra, which would justify considerable expenditure. The water could of course be drawn off to meet any peak load and any conditions of load factor, so that on ordinary working conditions a plant of 30,000 to 40,000 kWs. could be installed. The approximate cost of the hydraulic development (up to the forebay) is roughly estimated as 86 lakhs, which is less than Mr. Batchelor's total figure. It is made up as follows :—

	lakhs.	
Pench reservoir	27·5	
Tunnel from same	19·5	
Kulbehra reservoir	15·4	
Open channel to forebay	17·6	
Regulating reservoir	5·9	
TOTAL	85·9	exclusive of forebay.

If a plant of 35,000 kWs. were installed this would be Rs. 240 per kilowatt, so that with the pipe line and power house the total cost would be of the order of Rs. 500 per kilowatt installed; this is distinctly cheap.

The irrigation possibilities have not been fully examined. By throwing a weir across the Kanhan River the substantial perennial discharge of the power house could probably be utilized to great advantage in the commanded areas below; also, if the project materialized, irrigation pumping to uncommanded areas might be feasible where the pumping head was low.

86. Cochin; sites examined; the Chalakudi River.—As noted in the Preliminary Report, page 89, some 19,000 kWs. can, it is said, be obtained under 577 ft. head with a minimum flow of 50 cusecs and a storage of 1,000 m. c. ft. The scheme has been fully investigated by Mr. Forbes, Chief Electrical Engineer, Mysore. Mr. Tate hopes to visit Cochin shortly. On the basis of minimum *continuous* power the value of the site, including the storage, appears to be of the order of 4,000 kWs. only, but data are lacking.

87. Gwalior; sites examined.—In Gwalior State three combined hydro-electric and irrigation projects have been drawn up locally by order of His Highness the Maharaja Scindia, under the direction of Mr. S. K. Gurtu, M.A., M.Inst.C.E., M.I.E. (Ind.), Member of the Board of Revenue for Irrigation, Gwalior. One of these is under construction, and is referred to in another part of this report; the other two, here dealt with, will no doubt have to wait the completion of the Parbatti Project. The two projects which follow are the subject of printed reports, which have received the advantage of publicity and criticism in "Indian Industries and Power" and "Indian Engineering"; and they have also been examined by various irrigation experts. Certain modifications have consequently been made in the original designs. The full Reports cannot for reasons of space be printed here, but through the courtesy of Mr. Gurtu the following abstract is given of a note prepared by him. The total power is stated to be 42,300 kWs. continuously.

Sindh River Project.—It is proposed to dam the Sindh River near Narwar, 40 miles south of Jhansi. The catchment area is 2,000 square miles and the discharge varies from some 300,000 cusecs in the rains down to 10 to 20 in the driest part of the year. There are four reservoir sites which have been investigated, with capacities from 10,000 to 15,000 m. c. ft. The original project was drawn up for a single dam at Narwar, of great height and length, but subsequent investigation has shown the desirability of the subdivision which is practicable, so as to render gradual development possible without crushing capital charges. It is proposed to use the power for ore smelting, and the tail race water for irrigation. As the proposal now stands, the discharge will be regulated from a pick-up weir at Magroni, where a head of 780 ft. can be obtained. The power available is estimated to be some 40,000 kWs. continuous as a maximum.

Kuno project.—The river Kuno has a drainage area of 1,500 square miles and the discharge of the river varies from 268,000 cusecs in the rains down to 5 or 10 cusecs in the driest part of the year. The project is primarily one for irrigating 400,000 acres of land liable to drought and famine; but it is one of those not infrequent cases where it appears likely that neither irrigation nor power alone would justify the heavy expenditure involved (800 lakhs) while the combination *may* prove remunerative. The main storage is to be at the Jangarh Dam, with a capacity of 51,000 m. c. ft., a pick-up weir across the Dorat Nala giving large regulating storage. The scheme is not likely to mature until those previously mentioned have been taken up, but with a head of 55 ft. it will give some 2,300 kWs. continuously.

88. Madras; sites examined.—The following sites in Madras have at one time or another been fairly exhaustively investigated, so that their minimum power capacity is known with certainty; in nearly every case the power for 9, 10 or more months in the year is in excess, and sometimes greatly in excess, of the value here given. The following table is a summary of these sites:—

TABLE 33.—*Madras; Summary of sites examined.*

Serial.	River or site.	Nature of supply.	Site number.	Constant flow assumed (cusecs).	Head (ft.)	Continuous power (kWs.).	REMARKS.
	Ayyar River see Kollamalai Hills.						
(1)	Cauvery River, Mokadatu	Regulated flow	(i)	550	175	6,400	See also para. 65 for developed sites.
	Do. Hogonkal	Ditto	(ii)	550	46 (or 85)	1,700	
(2)	Kolab River, Bagra	Flow and Storage	...	380	600	14,000	See also Tetliguma. Mr. Perry's project.
(3)	Kollaimallai Hills (Ayyar River)	Ditto	...	30	2,000	4,000	
(4)	Kundah River	Ditto	...	21+20	2,000	5,400	
(5)	Periyar Lake	Storage	...	250	1,000	16,500	Provided that a supplementary reservoir is constructed.
(6)	Pykara River	Ditto	...	15	3,000	3,000	Grant applied for.
(7)	Sirumalai project, Aruvi Odai River.	Storage	(i)	9½	1,700	1,000	Mr. Perry's project (i) depends on storage of (ii).
	Ditto	Ditto	(ii)	4	660	175	
	TOTAL					52,175	Kilowatts continuous.

(1) *Cauvery River, (i) at Mekadatu (Goat's leap), Madras and Mysore.*—See Preliminary Report, page 91. These rapids are 26 miles below the existing Mysore plant at Sivasamudram (see para. 65) and 28 miles above the Hogenkal Falls, 67 miles from Salem. With a minimum flow of 550 cusecs and a fall of 175 ft. the continuous power available is 6,400 kWs. The Mysore Government has drawn up projects for utilizing these rapids but no works have been constructed. The river enters British territory 2 miles below this site.

(*ii*) *At Hogenkal Falls (Smoking Rock), Salem and Coimbatore Districts.*—See Preliminary Report, page 90. These falls are 25 miles below the point where the river becomes wholly in Madras territory, and 28 miles below the Mekadatu rapids; 70 miles above Erode and 50 miles from Kanjamalai. The minimum flow, as at Mekadatu, may be taken as 550 cusecs, and the head is 85 feet which may however be reduced to 46 feet if the Metur irrigation reservoir below is constructed. It would not be safe to design on the larger head, so the minimum power may be taken as 1,700 kWs. continuous. An inspection note dated 14th August 1918 on the site by the late Chief Engineer for Irrigation (Mr. W. J. Howley) is on record in the Survey.

(2) *Kolab River, at Bagra Falls, Koraput Agency, Vizagapatam District.*—This was mentioned in the addendum to the Preliminary Report and a short description was given on page 74 of the Second Report. The site has now been further examined by Mr. Tate, who has modified the existing proposals somewhat. This scheme is locally preferred to the neighbouring one on the Machkand River (*q. v.*). It may be noted that the Indravati River also rises on the Jeypur Plateau, but its power possibilities lie at Chitrakot falls in the Central Provinces (*q. v.*).

The Bagra falls are reached by a circuitous route from Salur B. N. R., in many stages. The catchment area is approximately 600 square miles, of which the tributary Dadi River accounts for 150 square miles. The minimum run-off calculated by Strange's tables is :—

	m. c. ft.
Kolab	8,400
Dadi	2,800
TOTAL	11,200

The minimum flow, gauged in May 1919, was 100 cusecs for the combined streams. The rainy season lasts for 5 months and storage would have to be provided for 7 months, though the actual flow would be far in excess of the minimum for a large part of this time even in dry years. Mr. Tate's proposals involve a dam in the first instance in the Kolab only, at a point some 6 miles above Mr. Sneyd's site; if required a dam site has also been examined on the Dadi, but this would not need to be built at first. The storages allowed for are each 7/12 of the run-off given above, or 5,000 and 1,600 m. c. ft. respectively. The constant available discharge is therefore—

	cusecs.
Kolab flow	75
,, storage	210
TOTAL	285
Dadi flow	25
,, storage	70
TOTAL	95

or, eventually, 380 cusecs at the headworks. The site found for the Kolab dam by Mr. Tate has the required capacity with 660 ft. length and 80 ft. in height, whereas neither of the older sites have it even with 100 ft. of height. His Dadi reservoir dam would be only 50 ft. high.

From the dam the water will flow down the natural bed for some 5 miles to a diversion weir close to the original dam site, where the river makes its great right-angled bend. Thence an open channel 2 miles long leads to a regulating reservoir of 60 m. c. ft. From this reservoir a tunnel 3,000 ft. long leads through the ridge to the forebay, where a fall of some 600 ft. can be obtained back to the same river. (The height was originally given as 750 to 800 ft. but presumably the latest figure is right.) The pipe length is about 2,500 ft. only, running on the spur on the left bank of a small stream near Bodligura village. Here the power house site is located, at the foot of the ghat. The constant power available is $380 \times 600/15$ or 14,000 kWs. on the lowest computation. The hydraulic development up to (but excluding) the power house is estimated by Mr. Tate to cost some 140 lakhs. On commercial load factors this would be of the order of Rs. 450 per kilowatt installed (say 30,000).

As in the case of the Machkand, which it joins, there is no doubt that if the floods are regulated at the site examined the river could be developed by means of lifting dams to the extent of a further 15,000 kWs. or more in the course of its rapids to the junction.

Mr. A. C. Duff, I.C.S., at one time Special Assistant Agent at Khoraput, recorded the following note during a tour in this area :—

> "It is lamentable to see these perennial supplies of water power running to waste. With these and with its enormous natural resources in wood, iron, manganese and cultivable rice land Jeypore ought to be one of the richest zamindaris in Madras."

Clearly this is more true than ever now, when the new harbour at Vizagapatam is about to be made; the distance is only 100 miles, a trifle in these days of 300 miles transmissions, and the power requirements of the new port will inevitably be large if cheap power is available. (See also Tetliguma falls on this river; para. 105.)

(3) *Kollamallai Hills, Ayyar River, Salem and Trichinopoly District.*—(Map 58 I/7.) As noted in the Second Report, page 75, Mr. H. W. Perry is responsible for the discovery and preliminary work on this site, which has since been examined by Messrs. Sneyd in 1920 and Tate in 1921. Two rainfall stations have been established in the catchment, as to which little was known before. The run-off has been calculated by Barlow's method (para. 23 *supra*) for the year March 1920—February 1921, and was found to be 18 inches from a total rainfall of 58·4 inch. (This is very probably too low.) By comparison with the records for the 3 driest consecutive years at Yercaud in the Shevaroy hills, 25 miles to the north, the minimum run-off (in the driest year) is calculated to be 6½ inches. From gaugings it is believed that the minimum flow available will be 7 cusecs; this is made up of 4 to 5 cusecs at the dam site with a supplementary 1 cusecs from the tributary joining the Ayyar at the falls below Arupuli temple and a further 2 cusecs from the Kathavadi tributary. Mr. Sneyd considered that in the worst period a storage of 600 m. c. ft. would supplement the flow for the 6 dry months so as to ensure a constant discharge of 30 cusecs. The reservoir site surveyed by Mr. Perry would hold 700 m. c. ft. which should just be obtainable from the catchment, and the ground appears favourable for the dam proposed. Subsequent investigation by Mr. Tate confirms that officer's opinion. Mr. Tate expects a minimum run-off of 6·5 inch from the main catchment above the dam of 19 square miles or 287 m. c. ft. in a bad year. There is however another 16 square miles of catchment between the dam and the intake to the flume, which would give the whole supply assumed for at least the two wettest months, so storage would be required to supplement the flow for 10 months. Mr. Tate takes the minimum constant supply as 7 cusecs flow *plus* 10 from storage or 17 in all. An additional carry-over from normal years of some 400 m. c. ft. net could however apparently be depended upon, equal to a further 15 cusecs, which brings the minimum back to 32 cusecs or say 30 cusecs.

The fall is 2,000 ft. so power of the order of 4,000 kWs. continuous can be expected. In 1920-21 the rainfall was exceptionally high and a run-off of 794 m. c. ft. above the dam was calculated. As during such a season the whole supply would be obtained from the lower catchment the excess of this over the capacity of the tank would probably be lost. In a moderate year there should be no surplus, as the draft would continue concurrently with the inflow whenever the lower catchment could not supply it. One hamlet and 200 acres of dry cultivation would be submerged. There is a suitable escape on a ridge about ¼ mile from the dam site, joining the stream again. From the dam the water would flow in the natural bed to near Arupali Temple (level 2,500 ft.) and thence in a flume 4½ miles long. There are several stream crossings and the ground is very steep. A subsidiary flume 2 miles long would lead from the Kathavadi tributary.

Irrigation considerations enter the problem. The area irrigated under the Ayyar, above its junction with the Cauvery, is :—

	Acres.
Direct irrigation	3,112
Indirect irrigation	4,324
Wet irrigation of dry lands	700
TOTAL .	8,136

With a draft of 30 cusecs the stream bed will always be wetted, and the effect on the tank-filling power of the river will not in Mr. Tate's opinion be appreciable. There may however be difficulties over compensation of the local land-owners. The Kathavadi Ayur is generally dry, so offers no difficulty due to its submerged diversion dam. As regards the main dam, this will act as a flood regulator, giving a constant discharge, while the freshets from the tributaries below will continue to fill the tanks as heretofore. The first irrigation anicut is at Pulianjolai, ½ mile below the tail race, and there are others lower down still. Of the 42 square miles of catchment at this anicut only 19 square miles are behind the main dam. Mr. Sneyd considered that the sole effect of the dam would be to conserve water now escaping unutilized during floods, whereas the 30 cusecs would materially benefit lands under the higher anicuts by giving an unfailing supply of 30 cusecs.

The chief market for power would be Trichinopoly and the district around. The Salem iron district is nearer still.

(4) *Kundah River, Nilgiri Hills.*—See Preliminary Report, page 90. This project has been fully worked out and an agreement entered into with Messrs. Tata Sons & Co., for the use of it. With storage of 800 m. c. ft. and a working head of 2,000 ft. some 5,400 kWs. continuous power can be obtained. The minimum flow assumed is 21 cusecs, supplemented when necessary by a draw-off of 20 cusecs from the

storage reservoir. It is proposed to instal 10,500 kWs. of plant.

(5) *Periyar Lake.*—This has been fully investigated and a grant has been given for the water power rights. There is some 16,500 kWs. continuously available for 240 days in the year, but at present power cannot be *assured* for the rest of the year. See Preliminary Report, page 91. A supplementary reservoir would enable a continuous supply to be maintained, so the site may safely be assessed at its full value. Head 1,000 ft.

(6) *Pykara River, Nilgiris.*—This has been fully investigated, and negotiations are still proceeding as to its utilization; the Kundah River could serve the same area. The power available is not less than 3,000 kWs. continuous and may be more. By passing through the watershed a head of 3,000 ft. is available.

(7) *Sirumalai Project, Aruvi Odai stream, Madura District.*—This project was worked out by Mr. H. W. Perry who published a pamphlet on it in 1917, *vide* Preliminary Report, page 92. A reconnaissance of the site, which is on map 58 J/4, has since been made by Mr. Tate. The hills are close to Kodaikanal Road railway station and are reached from there.

The catchment area of this small tributary of the Vaigai River is only 8 square miles and the project depends mainly upon storage. There are two branch streams, the Ponnuriri and the Sortar, with a number of natural waterfalls; the project prepared by Mr. Tate involves two stages :—

(*i*) A lower dam on the combined stream in the Seravanai Khad, impounding 130 m. c. ft. (eventually taking the tail race discharge from the upper site) with a 7,000 ft. channel at R. L. 2,500 (forebay) and a fall thence of 1,700 ft. to a lower power house at R. L. 800.

(*ii*) An upper dam on the Ponnuriri in the Periya Odai Khad, impounding 150 m. c. ft. with a 4,000 ft. channel at about R. L. 3,350 (forebay) and a fall thence of 660 ft. to a power house at R. L. 2,690 above the lower dam.

If developed, the lower site only would clearly be used in the first instance, supplemented by the upper storage when required and by the upper power station eventually. There are no contoured maps available, so it is not possible to judge whether the two branch streams could be joined up at the upper reservoir level and the whole drop to Aruvior main fall developed in one stage; if this were practicable, it would be preferable to the proposals made.

The discharge will normally be at its lowest in May and, if the south-west monsoon fails, in September. Ordinarily the rains continue from the middle of June till the middle of December. Both branch streams are liable to sudden spates of great intensity, and a flood discharge of 12,500 cusecs was estimated at the lower dam site in 1917, lasting for a few hours. The minimum flow, so far as is known, is about 2 cusecs at the same point. There are no rainfall stations in the catchment; the surrounding plains receive an average of 30 to 35 inches but the hills undoubtedly receive far more. In the absence of information Mr. Perry's estimate of 65 inches average is a probable one; but the minimum is not known. Mr. Tate takes the total run-off as 25 per cent. of the total rainfall, giving 297 m. c. ft. off 8 square miles with a rainfall of 65 inches. The catchment appears to be of class D or possibly E in Barlow's classification (para. 23 *supra*) and even in a deficient year the estimate of 25 per cent. appears very low. Mr. Perry assumed 60 per cent. which is probably far too high.

Lower site (*i*).—The dam site has a sheet rock foundation, and with a dam height of 100 ft. the width would be only 500 ft. at the top, the banks sloping down at 2 to 1. The capacity, as stated above, is 130 m. c. ft. The long lower flume traverses almost precipitous ground in parts, on the river bank. Only a small forebay site holding 12,000 c. ft. is considered practicable, but by running it along the contour as an enlarged flume more capacity may be obtained. The amount mentioned would not provide 15 cusecs for the 40 minutes which it would take the water to traverse the flume, so that security of flow would involve waste of water at the forebay. The lower pipe line will be 4,500 ft. long on a good rock foundation. The lower power house site is favourable in area and nature and well above flood level. The constant power available from this site alone may be taken as 4 cusecs under 1,700 ft. head or roughly 450 kWs. continuous. If however the upper reservoir were also constructed, when required, the continuous flow would then be 9½ cusecs, giving 1,000 kWs. continuous.

Upper site (*ii*).—It is very doubtful if it would pay to develop the upper site for the very small power available; but the building of the dam alone would, as shown above, more than double the power at the lower site. In the absence of the flume the regulated flow would utilize the natural bed. The upper dam would be on rock in a gorge, and with a height of 80 ft. the width would be only 300 ft. at the top. The capacity would be 150 m. c. ft. The flume line would run on very steep rocky ground on the left bank for 4,000 ft. to a forebay site again of too small capacity, *viz.*, 8,000 c. ft. only. The upper pipe line would be 1,500 ft. long, giving 660 ft. head, to a very limited power house site at the side of the gorge. The power available at this upper site would be 4×660/15 or 175 kWs. continuous only. It would scarcely be likely that this would justify the expenditure on the channel and works; on the other hand, if the upper dam were already built to supplement the power at the lower site it is possible that these works might eventually be remunerative. No estimates have been made except those in Mr. Perry's original paper. He estimated the cost of the lower scheme, with both dams, at 15½ lakhs; but this (if correct) would be equivalent to some 17 lakhs or more now. The estimate in any case was little more than guess work as it was stated that "the Pelton wheels are very simple and could be made locally"! Accepting a figure of about 17 lakhs for the whole lower project up to Madura, this would be Rs. 680 per kilowatt installed for a plant of 2,500 kWs. which would be about right on 1,000 kWs. continuous rating. The figure is certainly not prohibitive, and in fact allows a margin. Some 8¾ million units could be generated, and nearly 8 million delivered in Madura; the capital charges at 12 per cent. would then only come to 0·41 annas a unit delivered to the sub-stations in Madura. After allowing for distribution the power could certainly be remuneratively sold as cheaply as it is in Madras City.

The storages would be very valuable for irrigation. During the dry months the flow at site is at present only 1 or 2 cusecs whereas it would become 9½ cusecs. The first tank irrigation is 3 miles below the site.

Canal falls in Madras.—Seventeen canal falls of from 4 to 12 ft. were recorded in the Preliminary Report. None have been developed. There is an annual closure on all the canals in question, and power would only be available for 9½ to 11 months each year. It is possible however that use might be found for this discontinuous power, either by running the plant from two falls closing at different periods, or by using subsidiary plant, or by interconnecting with perennial systems. The minimum power available from all the falls together is some 2,400 kWs. for the period mentioned.

89. Mysore; sites examined; the Gersoppa falls, Sharavati River.—This famous waterfall is on the boundary between North Kanara, Bombay Presidency, and Shimoga, Mysore. The falls are within 20 miles of the sea and near Bhatkal harbour, a port of the future (map 48 J/12). The catchment area is about 150 square miles with a mean annual rainfall between June and September of from 75 to 100 inches and 150 inches in the Ghat portion. The fall is 800 ft. The Chief Electrical Engineer to the Government of Mysore has submitted a report to the Darbar for a project to cost 4½ crores of rupees. If half this sum be taken as the total cost of development at the falls, at the high cost of Rs. 1,000 per kilowatt of continuous *minimum* power, the site would be good for 20,000 kWs. It is probably far more.

90. Punjab; sites examined.—The Punjab undoubtedly has enormous potential power throughout the whole Himalayan area; but so far attention has been mainly concentrated upon one great project with its subsidiary branches. There are some small power schemes working, as noted elsewhere (para. 68), and one project involving several canal falls is the subject of an agreement between the local Government and a promoter (para. 75) and as the specifications have been prepared it may be considered as in the construction stage. When further power is required in the province it can be found, as the notes on areas and sites for detailed examination, or not so far examined at all, will show. In the list which follows the Anu and Nangal projects are subsidiary to the Sutlej River project, but the alphabetical arrangement is retained.

The following is a summary :—

TABLE 34.—*Punjab; summary of sites examined.*

Serial.	River.	Nature of supply.	Minimum constant flow assumed, cusecs.	Head, ft.	Minimum continuous power, kW.
(1)	Anu	Flow and regulating storage.	10	1,913	1,270
(2)	Sutlej at Nangal	Flow	3,300	37	8,000
(3)	Sutlej River project	Flow	3,300	363	80,000
				TOTAL	89,270

(1) *Anu Khad project.*—This tributary of the Sutlej, joining the main river not far below the Simla hydro-electric station, was originally believed to be the most favourable one for development for the further pressing needs of Simla and its neighbourhood, as well as for construction purposes on the main Sutlej River project. Two possible methods of development, on the full available head and lower down stream on a reduced head, were examined by Colonel Battye; only the more complete one need be considered here, as a partial development which would prevent subsequent complete utilization is undesirable. The head available is 1,913 ft. to obtain which two open channels of a total length of 14 miles long are necessary. Comparison of the catchment area and local rainfall with those

of the neighbouring Nauti Khad (the Simla Works) seemed to show that 20 cusecs could be depended upon as a minimum, as the catchment runs up to about 11,000 ft. and snow lies late. With the artificial storage reservoir designed there would then have been enough regulating water in hand to meet any peak load within the projected plant capacity, although not enough to supplement the average flow in dry periods. Unfortunately the exceptionally dry spring of 1921 upset all calculations, and for 33 days in April and May the flow only averaged about 10 cusecs. Although a masonry reservoir could be constructed to spread this flow over any desired load conditions it would require 2·8 m. c. ft. to augment the average supply by a single cusec over that period. The capacity of the Anu Khad cannot therefore be rated higher than 10×1913/15, or 1,270 kWs. continuous on flow. Nevertheless the site may be found useful at a later date. The project actually included two reservoirs with an aggregate capacity of 12·73 m. c. ft. Allowing for sufficient reserve to meet any peak load at the end of the dry period this storage would give just over 4 cusecs for such a period of 33 days as has been experienced; thus with this large artificial storage the continuous power would only amount to 1.800 kWs.

(2) *Nangal project, Sutlej river.*—When it was found that the Anu Khad (previous entry) could not be depended upon, Colonel Battye turned to the main river as an alternative. The site at Nangal had been suggested by Mr. Nicholson, the officer who drew up the Bhakra Dam project, as a suitable source of power for the construction of the dam. There is sufficient power for the whole of the immediate needs of the area within the Simla hills as well as for the construction work on the Sutlej River project; and the latter will, it may be anticipated, be working before the irrigation dam construction begins. Below the dam site, and in the great bend of the river, there are two series of rapids each with a fall of about 30 to 40 ft. The upper rapids lie between Nangal and Dabkhera (1 in. map 53A/7, square 5), while the tail race from these could feed a plant at the lower rapids if it should ever be necessary. Not only is it intended to use the upper Nangal site (here alone referred to) for present needs, but also as a standby plant to the main project. The scheme is therefore drawn up on the basis of a "productive work." The gross head is 37 ft. but the tail waters may rise 8 ft. and reduce the available head to this extent at flood times. A canal some 4 miles long leads from the headworks to the power station site. The record minimum flow is 3,330 cusecs so that the minimum continuous power available is 8,000 kWs. for when the head is reduced there will be a great excess of water. It is proposed to instal four 2,200 kWs. sets (1 spare) and to run a transmission line from Dabkhera to Kalka and on to Simla, at 44,000 volts. Eventually the transmission lines and sub-stations will (with the plant) form part of the main project; but if this does not mature Nangal can stand up alone.

(3) *Sutlej River Hydro-Electric project.*—This great scheme was referred to at length in the Preliminary Report, page 96, where it was somewhat confused with the Bhakra Dam irrigation project which happens to overlap the power scheme; the two however are separate and distinct and in no way antagonistic; in fact the irrigation project will eventually help the power scheme. It would be unfair to Colonel B. C. Battye, D.S.O., R.E., to do more than summarize the conclusions of his detailed Project Report, which was submitted to the Punjab Government in June 1921, as the result of 18 months' special duty. The great loop on the Sutlej where it enters the plains may be seen in any Atlas, but it can best be studied on the 1 in. maps 53A/7, 8, 11 and 12. Here the course of the river was deflected as it cut through the foothills, so that a great bend occurs some 42 miles round and only 5½ miles across at the chosen point, between Malbuna (53A/11, square 6) and Kirthpur (53A/12, square 1). It is proposed to tunnel through the ridge, which rises to 3,400 ft. here, and to develop the greater part of the fall so obtained. The bed level at the head works is about 1,315 ft. while at the return to the river it is about 924 ft.; but the normal difference in level between the pond surface at the tunnel entrance and the tail water at the site selected is 363 ft. giving a net working head of 324 ft.

The lowest recorded discharge of the Sutlej here, during the 20 years of record by the Irrigation Branch, is 3,330 cusecs, as recorded above (Nangal). The minimum flow in a normal year is considerably more, namely about 3,700 cusecs, while the average cold weather discharge (which storage may some day render available) is far greater. The minimum continuous power available is therefore 3,330×363/15 or say 80,000 kWs.

Turning for a moment to irrigation problems, the Sutlej now feeds the Sirhind canal from headworks at Rupar; but further extensions on this canal system are under consideration and in this connection the Bhakra dam project has been drawn up. The dam site is near the north-eastern point of the loop; the dam itself is designed to impound 112,000 m. c. ft. of water with a height of no less than 395 ft. The waters will head up far beyond the gorge

where the tunnel takes off, and will add 150 ft. to the gross and nett head available. With this increase in view, a pressure tunnel has been designed, as otherwise not only would this potential head be lost but the problem of dissipating some 55,000 h. p. at the tunnel entrance would have to be faced. The great reservoir will normally be full in August, and is intended to discharge throughout the winter so as to be emptied by February, thus giving a continuous additional discharge of some 6,000 or 7,000 cusecs. From the time the reservoir empties till the snows begin to melt (in April or May) and augment the normal discharge, this immense additional power could only be made available by a subsidiary storage higher up-stream ; there are however sites which have been examined roughly, and it is reckoned that the scheme can ultimately be developed up to a *minimum* continuous power of about 240,000 kWs. when all storages are laid down.

The proposed tunnels are 20 ft. in diameter and 9,836 ft. long. They run into a surge and distributing chamber from which 5 reinforced concrete tunnels 1,810 ft. long will lead off to the side of the hills where they merge into 10 ft. steel pipes running down to the power house, a distance of 8,701 ft. This makes a total of 20,350 ft. from the tunnel entrance to the power house. The velocities at normal full load are 10·6 and 8·5 ft. per second in tunnel and pipe respectively.

Five 16,000 kWs. sets are provided in the estimates, the generating voltage being 13,200. The usual governing system is provided with in addition a system of bye-passes to take care of both sudden and gradual changes of load. In fact 25 per cent of the flow is to be continuously bye-passed, except at full load. Each set has its own 100 kWs. exciter driven by an induction motor and there is, in addition, a 6th spare exciter set driven by an induction motor and a pelton wheel. All heavy switchgear is to be remote controlled from the transformer station located (owing to the nature of the ground) some 400 yards away from the power house. The generating and E. H. T. switchgear controls are located in a building, but the transformers and E. H. T. switchgear are embodied in an outdoor type steel structure station, two sets of bus-bars being provided.

Four banks of transformers are contemplated, two for the Delhi trunk and two for the Lahore trunk, the capacity of each single phase transformer being 7,500 kva.

There are two main trunks at 132,000 volts, one going to Delhi (with a spur from Amritsar to Patiala) and one to Chuharkana—about 30 miles beyond Lahore. In addition there are branch lines at 44,000 volts as follows :—

(i) Sonepat to Bhiwani.
(ii) Patiala to Dhuri and Rajpura.
(iii) Kalka to Simla.
(iv) Jullundur to Ludhiana.
(v) Amritsar to Tarn Taran.
(vi) Lahore to Ferozepore.
(vii) Chuharkana to Lyallpore.

All the larger towns covered by this network are to be tapped by outdoor substations (standardized as far as possible), the distributing voltage being 3,300 or in certain special cases 6,600. The constant voltage system has been adopted owing to the length of the lines and the size of the load. This involves the installation of about 50,000 kva. of synchronous condensers, divided up between Delhi, Sonepat, Ambala, Kalka, Jullundur, Amritsar, Lahore, Chuharkana and Lyallpore.

A 250,000 circular mil aluminium-steel cable has been selected for the main 132 kv. lines, strung on 80 ft. steel towers spaced 1,000 ft. apart in the plains (*i.e.*, when clear of the Siwalik range). Two circuits are provided, one on each side of the tower, the 3 phases being spaced vertically one above the other. The 44 kv. towers are 50 ft. high, with an average spacing of 500 ft. ; the cable sizes vary with each spur.

With regard to the demand for power in the province a census has been made which shows that there are some 22,000 kWs. actually in existence (1919) in the area covered by the project. Data for rate of growth have been obtained from all over India and collated, and a reasonable yearly increase in demand arrived at. The net result of the investigation shows that, assuming that the existence of cheap power has a moderate effect on the rate of growth, the plant will be loaded to its full capacity of 80,000 kWs. in about the year 1942, assuming 1929 to be the first year of operation.

The rates to be charged for power are on a sliding scale and vary from ·65 to 1·00 anna per unit for all consumers taking more than 20 kWs., the larger consumers of course paying less. Provision is made for the conversion of factories to electric drive by the promoters of the scheme, the cost being recovered in a few years by means of a small conversion tariff. The scheme when completed, is expected to cost about $9\frac{1}{2}$ crores and to pay about 9 per cent in the 14th year of operation.

91. Punjab ; canal falls.—A full list of the canal falls in the Punjab was given in the Preliminary Report, page 97, and it is unnecessary to repeat it here. In every case periodic closures for inspection and repairs are made when possible and emergent closures when necessary, but for the purposes of this report the closure may be ignored. The following summary shows what power is available on normal (not minimum) discharges.

TABLE 35.—*Punjab ; canal falls.*

—	No. of falls.	Kilowatts.
Upper Jhelum Canal	5	3,000
Lower „ „	6	2,500
Upper Chenab „	2	11,000
Lower „ „	4	600
Upper Bari Doab (Ravi) Canal	20	44,000
Lower „ „ „ „	2	4,400
Sirhind Canal (Sutlej)	28	25,000
Western Jumna Canal	1	700
TOTAL	68	91,200

On minimum flow this may be reduced to 40,000 kWs.

Four falls, included in the above summary, are those earmarked by the Punjab Hydro-Electric and Industries Development Association, as noted under the head of "plants under construction" (para. 75). Should the Woolar Lake barrage in Kashmir be built, the present system of rotational closures between the two Jhelum canals will be much modified.

A grant for development of the falls of the Upper Bari Doab Canal, where it takes off from the Ravi at Madhupur, has been applied for by the Subera Hydro-Electric and Agricultural Development Association ; an older concession to Sir Thomas Higham and others for the same falls has lapsed. There is a fall of 109 ft. in 4·6 miles ; 140 ft. in 7½ miles ; 175 ft. in 9¼ miles ; and 200 ft. in 13 miles. The minimum recorded flow is 1,300 cusecs, while much more water is generally running. By constructing a special power channel, and not using the main line at all, continuous power can be practically assured.

Sir Thomas Ward, late Inspector-General of Irrigation, suggested further possibilities on the Western Jumna Canal, in connection with the rebuilding of the level crossing at Dadupur. As at present designed there are two falls not far below the regulator, and it would not be difficult to get 7 ft. head with a general minimum flow of 2,000 cusecs and 1,200 absolute. If any storage sites should be found higher up a further canal could be constructed at a higher level and lift irrigation could be worked from the fall referred to. There would always be some 900 kWs. available.

Mr. E. S. Lindley, Executive Engineer, also made some useful suggestions regarding these canals, and possible combination of falls, especially for sub-soil pumping and lift irrigation. So far the tube well experimental work near Amritsar has been kept on so small a scale that its full possibilities can hardly be gauged.

92. Sikkim ; sites examined.—In the Preliminary Report, page 37, Messrs. Burn & Co., Sikkim project, the Lagylap scheme was erroneously entered as "under construction." No construction has in fact been begun as yet. The project however has been investigated. The site is at Lagylap Pass, east of Gangtok, at a high elevation near the snow line, and not far from the divide. The project utilizes a perennial tributary of the Tista, flowing from a snow-fed lake, which can be dammed as a regulator. The site is near a gap in the water-parting, through which a diversion can be made. With an open channel, a steep fall of 2,000 ft. can be obtained into the Roro Chu or Tahsouche Nala. The site is capable of giving 5,000 kWs. continuously at a very low cost—about $\frac{1}{10}$ anna per unit on full development.

93. United Provinces ; sites examined.—Before proceeding on leave Mr. T. M. Lyle, Executive Engineer in charge of the Survey, submitted a preliminary note on the season's investigations, 1920-21. The work has since been carried on by Rai Sahib Shanker Das. The various sites examined are summarized in the following table, after which abstracts of the reconnaissance reports are given in alphabetical order.

The results of the reconnaissance of the Ganges and its tributaries in the Himalayan area is given in considerable detail. The Sarda-Kali-Darma-Gori tract is much worse off for communications, and much more difficult of access than the Garhwal Rivers and Western Almora ; the latter are on pilgrim routes.

Rewah offers great possibilities. Mr. F. E. Bull, lately Chief Engineer, inspected the various falls on the Tons group and was much impressed by their possibilities. He pointed out however that in all these Rewah sites the question of carry-over for deficient seasons will require careful handling. So far the "bund" has generally been proportioned to impound the average calculated run-off. If so built, a considerable volume would have to be kept in reserve until required in a deficient season or *series of two deficient seasons.* Alternatively, the storage could be increased by the amount of the carry-over required, seeing that the excess would be obtainable as often as not ; this alternative however will probably prove less favourable financially than the first one. In all these Rewah projects, finding sufficient earth will be a difficulty, Mr. Bull further remarks : "In this matter we are hampered by want of real knowledge about the run-off from any given rainfall, and considering that the amount of power to be anticipated is from 50,000 to 70,000 e. h. p. from the Purwa and Chichai sites together it would be worth while putting up an automatic recording gauge on the Tons, so that the period of floods could be recorded and the total discharge in the season of known rainfall accurately measured." As to this, Chapter 3 of this Report may be read ; the necessity for the work of correlating rainfall and run-off is great.

TABLE 36.—*United Provinces ; summary of sites examined.*

Serial No.	River or site.	Nature of supply.	Site number.	Constant flow assumed (cusecs).	Head (ft.)	Continuous power (kWs.)	REMARKS.
	Alaknanda River } Bhagirathi River }	See Ganges below.					
(1)	Baghi (Baghain) Nadi . .	Storage	...	90	430	2,600	Irrigation will benefit.
(2)	Bakhor Nadi	,, ...	...	158	155	1,600	Ditto.
(3)	Beohar River	,, ...	...	440	380	11,000	130 miles from Cawnpore.
(4)	Belan River	,, ...	...	217	125	1,800	
(5)	Chahla Nala	,, ...	...	22	245	360	
(6)	Chandraprabu River . .	,, ...	...	105	390	2,730	Promising.
(7)	Chaprer Nala	,, ...	...	11	240	175	
	Dhauliganga River—See Ganges.						
(8)	Ganges River and tributaries	Flow and lifting dams .	Multiple	{ 2,000 { 3,000 { 2,000	300 310 300	40,000 } 60,000 } 40,000 }	Dependent on flood regulation.
(9)	Gohna Lake	...	...	...	...	...	Doubtful.
(10)	Goorma River	Storage	...	80	650	3,500	Promising.
(11)	Gumti River	...	...	...	...	...	Doubtful.
(12)	Jumna River	Flow	(i)	750	168	8,000	...
	,, ,, ...	,, ...	(ii)	750	255	13,000	...
	,, ,, ...	Lifting dams . .	Multiple	750	400	20,000	...
(13)	Karamnasa River . .	Storage	(i)	228	232	3,500	Very good and desired by Darbar.
	,, ,, ...	(From i)	(ii)	225	170	2,500	...
(14)	Karnawati Nadi	Storage	...	13	133	120	...
(15)	Kemasin Nala	,, ...	...	10	240	160	...
(16)	Ken River	Flow and Storage . .	(i)	3,000	150	30,000	Irrigation will benefit.
	,, ,, ...	,, . .	(ii)	130	175	1,500	Far more if upper site were developed.
(17)	Kosi River	Flow	(i)	150	400	[4,000]	} Alternatives.
	,, ,, ...	Flow and storage . .	(ii)	300	850	17,000	}
(18)	Kuria	Storage	...	13	310	270	...
(19)	Maha River	,, ...	...	210	350	5,000	...
(20)	Odda River	,, ...	...	145	600	6,000	...
(21)	Paisuni River	,, ...	...	20	180	250	Large power if Itwan reservoir made.
(22)	Patar Nala	,, ...	...	11	240	175	...
(23)	Pindar River	Flow and lifting dams .	Multiple	1,000	1,000	65,000	Dependent on flood regulation.
(24)	Ramganga River . . .	Flow	...	100	100	650	...
(25)	Ranj Nadi	Storage	...	40	280	750	...
(26)	Sarda River	Flow (Lifting dams ?) .	...	?	500 or more.	...	Not determined.
(27)	Sarju River	,, ,, .	...	?	...	...	Ditto.
(28)	Tons River (Rewah) . .	Storage	...	1,440	335	32,000	A fine project.
	Vishnuganga—See Ganges above.						
					TOTAL .	369,640	say 370,000

(1) *Baghi (Baghain) Nadi, Tributary of Jumna.*—This site is 10 miles south of Kalinyar Fort (map 63 C/8), 21 miles North-east of Panna, and ½ mile north-west of the deserted village of Kudakpur, on map 63 D/9, 13. It is 115 miles from Cawnpore. There are two natural falls close together, making up with rapids a gross head of 480 ft. of which about 430 ft. could be utilized (Aneroid levels). The Nadi dries up by April, so storage would be the basis of the project. The catchment area is 110 square miles and the rainfall station nearest is at Panna. The dry weather fall (8 months) average 5 inches and falls to 1·9 inch minimum ; for the monsoon it averages 47 inches and falls to 20½ inches minimum. The highest fall in one day is 14·4 inches on 8th August 1919. The estimated run-off is 5,100 m. c. ft. average and 2,000 m. c. ft. minimum. It is proposed to make a long earthen bund, 3 miles by 60 ft. high, a furlong or so above the upper fall, with a flank escape on the left bank. The capacity would be 3,600 m. c. ft. which would generally be obtained. The submerged land is mostly jungle, but there are 2 or 3 villages in it. No open channel is necessary ; a pipe line ½ mile (?) long would lead directly to the power house site about 1 mile north-west of the upper fall. (A forebay site is mentioned, but it is not clear how it would be fed in the absence of an open channel or a longer pipe.) The tail race water could be used for irrigation lower down in the Banda district. The site is estimated to give 90×430/15 or 2,600 kWs. continuously, and appears to be a very promising one in view of its combined power and irrigation possibilities.

(2) *Bakher Nadi, tributary of Belan and Ganges, Mirzapur District.*—See Preliminary Report, page 100, and Second Report, page 79. This very promising scheme has now been surveyed, and estimates are under preparation. The natural fall of 79 ft. can be brought up to 155 ft. ; it is 1 mile south of Sirsi village, on map 63 L/9, and about 5 miles from the junction with the Belan. The stream dries up in the hot weather. The rainfall at Robertsganj show an average fall in the 8 dry months of 6½ inches with a minimum of 1·6 inch. In the 4 wet months the average is 39¼ inches and the minimum 27¼ inches. The highest fall in one day was 8·69 inches on 21st June 1911.

Catchment is 220 square miles and a run-off of 5,870 m. c. ft. is expected on the average, with a minimum of 4,080 m. c. ft. A storage site has been surveyed ¼ mile above the fall, where an earthen bund 2 miles long and 65 ft. high, with a flank escape, will mpound 5,800 m. c. ft. with a waterspread of 12 square miles. Ten villages and a good deal of agricultural land would be submerged. From the reservoir a pipe line 4,000 ft. long would lead to a power house site 2,000 ft. below the fall. By making an open channel ½ mile long the pipe could be reduced to ¼ mile with a loss of 23 ft. of head. The solution appears to be a light closed pipe leading to a surge tower. The cost of the storage will be about Rs. 303 per m. c. ft., which is cheap. The stored water would also be valuable for the Belan canal, so the whole cost would not fall on the power scheme. Mirzapur is 25 miles off and has considerable power demand. The power available is 158 ×155/15 or say 1,600 kWs. continuous. The Kanchwa and Khabhwa Nadis within 10 miles could possibly supplement this source.

(3) *Bechar River, tributary of Tons, Rewah State.*—This is mentioned, in connection with the Tons Project (q. v. below) in the Second Report, page 81. There is a natural fall of 367 ft. or 380 ft. in all about ½ mile north-east of Chachai village, and not far from the Tons fall (map 63 H/1, 5). In the Preliminary Report this fall was attributed to the Tons. There is a small perennial flow, and 14 cusecs were found so late as the 15th May 1920. The catchment is 639 square miles. The rainfall at Rewah, in the catchment, averages 3·7 inches in the 8 dry months, but drops to *nil* occasionally. In the monsoon the average is 37½ inches, and the minimum 24¼ inches. A run-off of 17,800 m. c. ft. average and 11,800 m. c. ft. minimum is estimated. An earthen bund 4 miles long and 63 ft. in height, with a flank escape, just above the fall, would impound 15,200 m. c. ft. Good land with 40 villages would have to be submerged. An open channel 1 mile long on the left bank would lead to the forebay, which would probably be common to this and the Tons development. The pipe line would be 600 ft. long and the site is capable of giving 440×380/15 or 11,000 kWs. continuously. The distance to Cawnpore is 130 miles and to Allahabad 60 miles. Project estimates are under preparation.

(4) *Belan River, tributary of Tons, Mirzapur District.*—The Preliminary Report (page 100) held out prospects of small power here, while the Second Report (page 79) raised the estimate but pointed out difficulties in the way of submerged land. A survey has now been made. There is a natural fall (old Kote waterfall) of 49 ft. capable of extension to 125 ft. about 1½ mile south of Mukha (Makha) village on map 63L/10, reached from Mirzapore. The river dries up in May and carries very little flow even in March. The catchment is 308 square miles and the rainfall records at Robertsganj (see Bakher Nadi entry) hold good. The run-off is estimated as 8,200 m. c. ft. average and 5,700 m. c. ft. minimum. An earthen bund 1 mile long and 101½ ft. high about a furlong above the fall would

impound 8,200 m. c. ft. with a waterspread of 22½ square miles. As stated in earlier reports, the submerged land is mostly good agricultural, containing 22 villages. Two miles of open channel on the left bank lead to a good forebay site, whence 2,000 ft. of pipe would be required. The power station site would be at the junction with the Bisahi Nala, and would require to be cut out of rocky ground. The power available is 217×125/15 or 1,800 kWs. continuous.

As stated in the Second Report (*loc. cit.*) a fall of 300 feet could be obtained into the Son River, but it would be an expensive development; this however requires to be looked into further.

(5) *Chahla Nala, tributary of Baghi (Baghain) Nadi and of Jumna.*—This site is reached from Panna and is a mile north-east of Jhanda village on Map 63 D. There is a natural fall of 190 ft. and a total fall of 245 ft. with rapids, as found by aneroid. The catchment area is 25 square miles of steep, rocky country, and the rainfall is as given under the Baghi Nala above. The estimated run-off is 1,450 m. c. ft. average and 580 m. c. ft. minimum. A bund or dam 1½ mile long and 80 ft. high is proposed just above the fall; earth is not plentiful, and it is doubtful if the project could bear the cost of a masonry dam. The capacity is 950 m. c. ft., which it is believed could be depended upon. The submerged area is all waste land. A pipe line ¼ mile long would lead from the reservoir to the power house, close below the fall. It is believed that 360 kWs. could be obtained continuously.

(6) *Chandrapraba River, tributary of Karamnasa and Ganges, Benares State.*—This was mentioned in the Preliminary Report, page 100, and further information was given in the Second Report, page 79. The site has been surveyed and estimates are under preparation. The site is reached from Benares (36 miles) and is on map 63 P/1, about 6 furlongs from Dhusaria (Dhoosoorea) village. There are two natural falls aggregating 238 ft. close together which with rapids will give 390 ft. altogether, by levelling. The river dries up in April or May; gaugings are being made at other seasons. The catchment area is 109 square miles, of which only a part is in the hills. The rainfall records (30 years) at Robertsganj, just outside the catchment, are given under the Bakher Nadi above. The probable run-off is known fairly accurately and is taken as 3,844 m. c. ft. average and 2,529 m. c. ft. minimum. A main storage reservoir is proposed about 1 mile above the upper fall, using an earthen bund 5,000 ft. long and 80 ft. high, with flank and saddle escape. The capacity is 3,844 m. c. ft. with a waterspread of 6¼ square miles, and this will be filled almost every year. The submerged land is mostly jungle, with a little agricultural land and two villages. Some 3 miles of channel on the left bank are necessary, including 4,000 ft. of tunnelling and four Nala crossings. The forebay site is 1¼ mile below the lower or Rajdari fall, and provides sufficient regulating storage to save waste. There are difficulties over making a power station site if the shortest length of pipe line (1,000 ft.) is used; but as 3,000 ft. of pipe are required to reach a good natural site the money would probably be better spent on excavation work. A 4-inch to the mile map has been prepared, showing the headworks site, channel alignment, forebay and power house sites. The power available is 105×390/15 =2,730 kWs. continuous. A cost of about Rs. 1,000 per kilowatt is forecasted, but on commercial load factors it will of course be far less. The scheme is a very promising one, especially in connection with the Karamnasa (q. v.).

(7) *Chaprer Nala, tributary of Ken River, Panna State.*—This small nala, 16 miles south-west of Panna City (map 63D/2) has a natural waterfall of about 216 ft. and, with rapids, can be developed (including draft head) for 250 ft. head, by aneroid determination. The nala runs dry in March, so development could only be by storage. The catchment area at the fall is 15 square miles only. The rainfall at Panna (9 miles distant) is given above under the Baghi River. The run-off is estimated to average 696 m. c. ft. with a minimum of 278 m. c. ft. It is proposed to store 480 m. c. ft. and this can be depended upon to fill practically every year. The storage site is about 300 ft. above the fall and 7 miles south-west of Baraur. Here a 50 ft. bund about 1 mile long, with a flank escape, will store the quantity stated at a cost of about Rs. 500 per m. c. ft.; the ground submerged would be jungle. A good forebay site exists, but if this were used there would be some loss of head, while water will also be wasted. It will clearly be preferable to take a pipe from the reservoir direct, using a surge pipe at the forebay site, whence a pressure pipe about ½ mile long leads to the power station site, ¼ mile from the fall. By means of a draft tube the whole fall could be used, though the power station would be 20 ft. above bed level. The continuous power available on the storage alone is 11×240/15 or 175 kWs. only. This is hardly to be worth development, but if small power were needed it would appear to be likely to be moderate in cost. [The remarks as to rainfall and (in proportion to catchment area) run-off, and the method of development would be the same for the Kemasin, Kuria and Patar Nalas entered below.]

(8) *Ganges River, in Himalayan area, with its tributaries the Bhagirathi and the Alaknanda, the latter including the Vishnuganga and Dhauliganga.*—The following extracts are from Mr. Lyle's inspection note of 4th March 1921, relating to his reconnaissance in November and December 1920 :—

" The object of this inspection was to gain a general idea at first hand of the general conditions of this tract of Garhwal and to see if there were any really obvious sites for developing hydro-electric power on a large scale. It is useless going into detail in small schemes until we have a general idea as to the main possibilities of the larger rivers.

" There is no use in describing in any great detail the valleys at innumerable points. My object in this report is to give the main aspects of the river with a view to power development, and I shall state these as briefly as possible.

" The whole Ganges valley is rather disappointing in respect of power possibilities. The volume of water is undoubtedly large but the formation of the valley is on the whole unsuitable. The valleys are narrow in the stretches that have a flat slope and where the valley looks fairly wide and likely to give useful storage the bed slope is so great that no considerable length of reservoir would be possible without an enormously high dam. The question of impounding water seems therefore impracticable. In the second place, the valley sides in reasonably accessible localities are not sufficiently canyon-like nor is the rock generally sufficiently sound to allow of the construction of high dams for the straight forward purpose of constructing artificial falls to give the requisite head for power. In the third place the valley sides are too steep and unstable as a rule, in such tracts as have a fair bed slope, to enable the water to be extracted from the river and be carried along the hillside in a canal or flume in order to accumulate sufficient head.

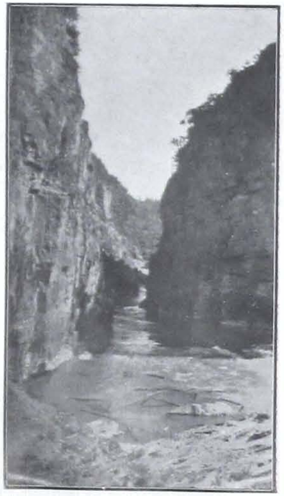
" Where high dams are being considered with a view to storage it must be remembered that these would generally entail the submersion of a large proportion of cultivated land, as where the hillside is at all flattened out the villagers have taken advantage of this to construct their terraced fields. Every scrap of such ground is most valuable in Garhwal, where the proportion of culturable land is so small, and more especially as these low lying patches of cultivation are generally the most fruitful, as they can often be irrigated from either the main river or a subsidiary stream. Garhwal is very subject to famine and the lessening of the cultivated area would be a serious matter. On the other hand the very fact that it is so liable to famine is a cogent argument for the development of any local industries that it might be possible to foster by the supply of cheap power. The railway that is projected from Rikikesh Road to Karnprayag would be an immense advance in many ways, and the possibility of this being constructed in the near future was borne in mind in these investigations. Karnprayag is 116 miles from Hardwar by the pilgrim route (to Badrinath), and it is just within this stretch of river that power, if available cheaply, would be within transmittable distance of the plains, along an alignment that would be easily accessible for erection and maintenance.

" The Ganges River proper only extends up to Deoprayag, where it is formed from the confluence of the Alaknanda and Bhagirathi Rivers. The former of these is the main stream and, in continuance of the Ganges, forms the boundary between British Garhwal and the Native State of Tehri Garhwal. The Alaknanda extends right up to Vishnuprayag near Joshimath, where it in turn is formed by the junction of the Vishnuganga and Dhauliganga Rivers. The former comes from Badrinath and the latter from the Niti Valley. Up to Karnprayag, in what might be termed the 'accessible' portion of the Ganges system, the slope of the bed ranges from about 10 ft. a mile to 20 ft. a mile. The surveyors of the Hardwar-Karnprayag Railway found that the average slope in this reach was 14 ft. a mile, which agrees very closely with my barometer observations. Above this the river has a steadily increasing bed slope, soon developing into 30 ft. and eventually towards Badrinath 300 ft. a mile. The main valley has the appearance of a trough scoured out by a strong velocity of water, which would necessitate a rapid bed slope. The bed of the river is also as a rule down on solid rock. It is possible that in recent times, speaking geologically, the lower or outer end of the valley has been gradually raised until the bed slope has been flattened out to its present state. It will thus be understood that the very portion in which it is most desirable to have facilities for development of power is just the portion in which the natural conditions are most unfavourable. Higher up there is much more power, if we think of power as a product of 'volume' and 'gravity,' though the difficulties of utilizing it even here are also great owing to the narrowness of the valley and the steepness of the hillsides.

" Considering the 'accessible' portion of the river, it is evident that any project for power must be dependent on an artificial fall, which means the construction of a masonry dam. The actual construction of such a dam would entail as the most troublesome feature the temporary diversion of the river, in order to

Alaknanda River at Deoprayag (Mile, 58 of District Road) looking west, showing flood spill channel to south of main river bed. Bhagirati River joins the Alaknanda from north at point X.

Gohna Tal looking east showing in foreground the continual heavy erosion of the old slip debris. Slip debris also seen on far bank with breach in the centre.



Alaknanda River at Koteswar (Mile 98, of District Road). Looking east into kakar's leap Gorge.

Alaknanda River at Koteswar (Mile 98 of District Road) Looking east into kakar's leap Gorge but from further downstream on left bank.

Alaknanda River from Hat Girder Bridge near Pipalkoti at Mile 144, of District Road. Looking up the Gorge at possible site for a dam.

get in solid foundations. This diversion would require heavy works as the minimum flow of the Ganges proper up as far as Deoprayag cannot be less than 5,000 cusecs, and the Alaknanda between Deoprayag and Rudraprayag would be in the region of 3,000 and from Rudraprayag to Karnprayag 2,000 cusecs. This would also only hold for about 4 to 5 months in the winter, as during the hot weather the melting of the snows swells the volume of all these main rivers enormously. This is further augmented when the monsoon breaks.

" There are three points on the river where a diversion of the water is reasonably possible. These are (1) mile 37 of the Hardwar-Badrinath District Road, three miles below Kotlibhel Public Works Department Inspection Bungalow, (2) at Deoprayag, mile 58 of the Road, and (3) at Koteswar, mile 98 of the road, 3 miles above Rudraprayag.

" (1) The Kotlibhel site is at a quick bend of the river, which has formed a very decided ' loop ' at this place. The river which has been running in a westerly direction suddenly turns north and changes quickly after a mile into a loop, flowing south. At the point where the road crosses the ' saddle ' it would be possible to tunnel the one limb of the river into the other, and the tunnel would probably not be longer than a quarter of a mile. Below this tunnel a temporary dam might be put as soon as the tunnel was ready, and the river diverted through to the other side. *The permanent dam might then be built on the downstream limb at a point upstream of the exit of the tunnel where there is a narrow gorge for a short length.*

" This is only a brief outline of the idea, which would entail many difficult problems of actual construction. The strata at the site proposed for the dam are dipping towards a southerly direction of about 140° and their vertical angle is about 70°, so that the dam would be built at right angles to their bedding planes. This would require careful geological investigation. The band of rock that forms the gorge stands well out into the river on both sides of the loop and is of harder material than the other rocks in the vicinity A dam of about 300 ft. high would be possible. If it were feasible to utilise a flow of 4,000 cusecs with a net head of 450 ft. this would give about 160,000 e. h. p.

" (2) The river at Deoprayag had originally another channel on its southern bank just above the junction with the Bhagirathi. The bed of this is about 40 ft. above the present river surface, and the two are separated by a bluff some 80 ft. high above the dry bed. The flood waters use the second channel occasionally as a spill channel. It would be possible to build a dam here to give a head of about 80 ft., but as this would submerge a portion of the town of Deoprayag, it does not appear to be a workable proposition. The sacred meeting of the waters of the Alaknanda and Bhagirathi would not be interfered with, as the dam would be upstream of this place. However I do not think it is worth thinking about in present circumstances.

" (3) The river just above Koteswar narrows into a very tight gorge, with practically vertical limestone cliffs on either side. This limestone is of good hard quality and lies nearly horizontal with a slight dip towards the upstream side, so that the conditions for foundations are favourable. The river in the gorge takes a curve and it would be possible to divert the cold weather waters through a tunnel drilled in the rock on the left bank, to discharge just opposite the little temple downstream of the gorge, which would not be interfered with in any way. With a dam 300 ft. high, there should be power of about 45,000 e. h. p. available, assuming a net head of 250 ft. and a flow of 2,000 cusecs. The main difficulty about this scheme is that the river runs in a narrow valley below the site and there is no very good position for a power house, but probably this could be overcome. There is a possible site just below the dam site on the left bank, and another about a mile down on the right bank. Both banks are here British territory.

" I think both schemes Nos. 1 and 3 should be surveyed in detail early next season, in October-November. And I am of opinion that scheme No. 3 will probably prove worth carrying out. It would not be so ambitious as No. 1 but it would be a ' safer ' engineering feat, and would be a first stage in an endeavour to harness rivers of this kind well inside the Himalayan tract. If successful it would open up big prospects for Garhwal. If the project can be shown to be reasonably sound financially it would surely be possible to use it in the scheme for opening up the country by light railways.

" In the higher stretches of the Ganges river system there are many tight gorges, more especially in the portion from Pipalkoti to Joshimath. This is in fact more or less one long gorge (20 miles) the whole way. The only place that seems suitable for a power site is at the lower end of this series of gorges, that is just where the ' Hat ' girder bridge spans the Alaknanda near Pipalkoti P. W. D. Inspection House. The gorge here is only about 40 ft. wide and extends vertically to a height of 190 ft. There is good flat ground half a mile downstream and lots of room for both a settling tank and the power house. Assuming a head of 150 ft. and a flow of 1,000 cusecs we could probably get about 13,000 e. h. p. A diversion tunnel could probably be made through the rock in the right bank, though it would have to be on a curve.

"*All the diversion tunnels suggested in these schemes could be finally utilized as sluices to help in the control of floods.* Being at a low level they would have the effect of keeping silt from depositing near the dam. In the Koteswar scheme it might be possible to make a settling tank on top of the present saddle on the left bank by controlling the flood level by means of heavy sluicing through the dam at various heights (this being necessitated by the narrowness of the dam), but in the Kotlibhel scheme there does not appear to be a good site for a settling tank. The silt laden water in the hot weather and rains will involve problems of this sort, though a certain amount of clarification should take place in the reservoirs themselves.

"There are no other sites on the Ganges that should, I think, be considered at present.

"The rivers flowing into the main central valley, while of smaller volume have considerably greater bed slopes. Thus the Bhagirathi has a slope of about 30 ft. a mile above the junction at Deoprayag. The Mandakini has a slope of about 70 ft. a mile above the junction at Rudraprayag. With the exception of the Bhagirathi, which has not been examined for more than 3 miles above Deoprayag and which is wholly in the Native State of Tehri Garhwal, none of these other streams seem suitable for power development as they are inaccessible at present and have not, so far as was seen, any very suitable sites. If however it were desired to build a number of comparatively small power stations at scattered sites, I think that the smaller side streams would be much more cheaply developed than would be possible by endeavouring to take flumes off the main rivers. For example, the Patalganga and the nala at Helang village, two miles above Gulabkoti, would be easily developed. The latter is a small stream carrying about 10 cusecs in December, and never carrying less according to local inhabitants. It has a very steep fall into the Alaknanda, and the site is very favourable for development, were it not so remote (157 miles from Hardwar). A head of 1,100 ft. can be obtained, using a flume of about half a mile and a pipe line of about 1,500 ft. The power would be about 1,000 e. h. p. There is a very good site for a settling tank and forebay at the head of the pipe line, and a first class site for the power house 100 ft. above the river. This is a rather favourable sample of what these smaller streams are capable. Unfortunately most of them are in remote localities. Those which are in more accessible places have nothing like the same amount of head available, combined with a fairly favourable discharge.

"In passing it might be mentioned that there is one spot on the Ganges where the river widens out considerably. This is at the town of Srinagar, where the valley is about a mile wide for a distance of 3 miles. It would be impossible to impound water here to any great height without submerging a lot of very valuable land and endangering the town. Much damage was done here by the great flood from the Gohna lake in 1894, and the town was largely rebuilt at a higher level than the original one, which suffered so much from the flood.

"The Gohna lake itself was examined in December with the double object of seeing if power could be obtained and also if the water could be utilized in the months of low discharge in the Ganges to augment the supply for canal irrigation. A special note has been written about this and submitted separately to the Chief Engineer, as desired by him. (*See* Gohna Lake.) It is sufficient to say here that the prospect of utilizing it in either direction does not appear to be very promising.

"In all projects for development of the Ganges, and in fact of all these Himalayan rivers of the United Provinces, special attention must be paid to the possibility of floods on a scale comparable with that roused by the Gohna lake disaster in 1894, when the flood rose to enormous heights and did immense damage although it had been foreseen and elaborately prepared for during the previous 12 months. Any obstructions in the river in the nature of dams must be able to withstand such heavy action, and works such as flumes and power houses must be well protected. In ordinary years the river rises about 30 ft. to 40 ft. in the narrow valleys in flood time, and the Gohna flood rose in places in the Alaknanda valley as much as 200 ft. At Deoprayag it rose 70 ft. and at Byansghat 80 ft. above ordinary H. F. L. There are places where the hillside might slip at any moment and cause a similar catastrophe.

"Before passing on I would remark that the hopes entertained from a previous study of the map that a tunnel through the big loop of 4 miles of river length at Byansghat, where the Nayar River joins the main stream, were not realized as the fall accumulated by the slope of the river is too small to be of use."

It will be seen from the above note that the Ganges and its tributaries cannot easily be developed on ordinary lines, and within reach of the plains. The whole note shows that in order to render development practicable *flood regulation is essential* in the Bhagirathi and the Alaknanda or in both. This would be of the utmost value for the irrigation canals also. But it is entirely impracticable *on any ordinary lines of* masonry dams. The only *possible* method appears to be that suggested in para. 33 of this Report. Mr. Lyle's note indicates some places where he contemplated the possibility of diverting the waters through a tunnel during the construction of a masonry dam; this however would leave the main problem untouched. The flood waters would pass at an unknown height over such a dam, and there would be no head at such times. It would be absurd to write of the Ganges as having no available power for the reason that present methods of developing that power are useless. If the floods could be regulated in the manner suggested the whole course of the rivers could be harnessed by lifting dams; and one such lake would suffice for the whole stretch up to the meeting of the next great river. The "accessible" part of the Alaknanda is taken as that up to Karnprayag, where the Pindar River comes in.

This gives:

(i) Some 15 miles from Karnprayag to Rudraprayag with 2,000 cusecs minimum.

(ii) Some 31 miles from Rudraprayag to Devaprayag with 3,000 cusecs minimum.

If, however, full scale flood regulation were possible, without which these discharges will remain for ever unharnessed, the minimum flow would be greatly raised. If the bed slope on (i) be taken at 20 ft. a mile, as indicated by Mr. Lyle, the power available in that stretch is 2,000×300/15 or 40,000 kWs. on the minimum flow. If the slope of (ii) is 10 ft. a mile the power in the lower stretch is 3,000×310/15 or 60,000 kWs. The last 20 miles of the Bhagirati, before it joins the Alaknanda, in the like conditions of regulation may safely be assessed at 2,000×300/15 or 40,000 kWs. There is therefore available, on minimum flow, and above the sacred junction where the Ganges begins, a clear 140,000 kWs. of continuous power.

(9) *Gohna Lake, Garhwal District.*—The following is Mr. Lyle's inspection note, dated December 1920, of this lake; *vide* "Gauna Lake" in Preliminary Report, page 101:—

"I visited the lake on the 17th December, having arrived at Gohna village the evening before. I again visited the lake and its surroundings on the morning of the 18th, and left that day, travelling down the Birchi Ganga bed taking levels with my aneroid barometer.

"As far as could be ascertained from the District Engineer of Garhwal, there are no observations made or records kept by the local authorities of the state of the slip each year, nor is any attempt made to ascertain at what rate the lake is filling up or how much the surface level alters after heavy floods. There is also no information about discharges.

"As a full description of the history of the slip, which occurred in the monsoon of 1893, is recorded in the special 'Narrative Report' by the Superintending Engineer, Second Circle, Provincial Works, United Provinces, dated 14th November 1894, it is unnecessary to go into this again.

"The level of the lake surface is approximately R. L. 5,500. The lake is now about 1½ mile long and ¼ mile broad. The volume of water impounded after the bursting of the dam in 1894 was approximately 1,800 m. c. ft., and I estimate roughly that it contains about 1,000 m. c. ft. now. It appears to be rapidly silting up from the top end, and as there is a large catchment behind it there must also be a considerable amount of the finer silt carried well into the body of the lake. I had no means of taking soundings to test this.

"The discharge from the lower end of the lake was about 100 cusecs, but accurate gauging is difficult as the bed of the outfall is so uneven and the flow is so turbulent.

"The slope of the river bed was originally about 250 ft. per mile according to the record in the flood report. It is now about 500 ft. per mile for the first two miles and thereafter flattens out. This is due to the fact that the debris from the dam was washed down the river bed for many miles, resulting in a very large deposit of boulders and shingle in the valley. The river is now cutting into this and appears to have eroded out its new bed to a depth of about 25 ft. opposite Gohna village. The deposit must still be a considerable depth.

"Although there was about 100 cusecs flowing over the outfall of the lake, I gauged it as about 10 cusecs some 4 miles lower down. This is explained by the fact that the water sinks into the thick deposit of detritus in the bed. Lower down the volume again increases and eventually becomes about 150 cusecs where it empties into the Alaknanda.

"As will have been understood from the foregoing there is nothing like a defined dam in the river as looked at from the downstream side. From the end of the lake the river bed simply slopes steeply away over the broad shingle-strewn valley, though for the first half mile it is running between the sloping sides of the original breach.

"On account of the enormous amount of debris still downstream of the lake it seems to me impracticable to think of tunnelling a duct out of the lake for the purpose of utilizing the water for irrigation. Any such tunnel would have to be made in the solid rock hillside on the left or south bank of the river, and it would be a long tunnel—at least a mile—and the question as to whether the rock would be suitable would have to be carefully considered. Personally I think making a tunnel in this unstable material, which is lying at a very high angle of dip, would be a dangerous proceeding in the first instance, and its upkeep, if successfully completed, would be an expensive item.

"Further, the question of raising the dam again in order to impound more water seems to me also impracticable. There is nothing solid to found a dam on, and filling the present wide breach with shingle or similar material would not be satisfactory nor, I think, feasible.

"There is also no apparent prospect of utilizing the lake for the hydro-electric power. The reasons will be obvious from the foregoing description. Owing to the steep and unstable nature of the hillsides a flume would not be possible, and a tunnel would also be too risky. The head available is also not so great as would have been the case if the river downstream had not been so much filled up with the debris of the dam washed down in the flood of 1894.

"As a means of obtaining information about the rate of silting up of such lakes, and of cognate matters such as the life of the boulder dam formed by the slip, I think that yearly observations of the lake level after the rains, soundings taken systematically every 5 years or so, and general observations on the state of the dam and river below might, with great advantage to Government, be maintained by some one, such as the District Engineer. Monthly discharges would also be useful."

It will be seen that Mr. Lyle here considers the possibility of tunnelling the lake and of raising the old landslip dam, and dismisses both as impracticable. It may be so in this instance, but nevertheless the suggestions on the subject made in paragraph 33* of this Report are worth serious consideration.

(10) *Goorma River, tributary of Belan and Ganges, Rewah State.*—See Second Report, page 80. There is a waterfall of 402 ft. which can be increased to 650 ft., ¾ mile north of Belonhi village, on map 63 L/1, 2, ten miles from Mauganj. The stream dries up in April and has little discharge in dry weather. The catchment is 120 square miles. The rain-fall records at Mauganj show a dry weather fall (8 months) of 5¾ inches average and 1 inch minimum. The normal fall is 39½ inches in the monsoon, falling to 24 inches minimum, while 6½ inches have fallen in one day (24th June 1916). It is estimated that the run-off will be 3,340 m. c. ft. average and 2,230 m. c. ft. minimum. About ½ mile above the fall an earthen bund 2 miles long and 63 ft. high, with flank escape on left bank, will impound 3,140 m. c. ft. Some good land with 10 villages would be submerged. A channel 3½ miles long in difficult ground leads to the forebay site. The pipe line would be ¼ mile long and the power house would be 2 miles below the fall. The ground has been partly surveyed. The power available is estimated at $80 \times 650/15$ or 3,500 kWs. continuous. Cawnpore is 160 miles distant. The scheme is a decidedly promising one.

(11) *Gumti River, tributary of Sarda.*—Mr. Lyle reports a possible reservoir site on this river near Baijnath, which will be examined. No information is at present available, but the remarks on the Ganges may be read. Gaugings in the plains, near Sitapur, after junction with various tributaries showed :—

15 April 1919	226 cusecs.
15 May „	214 „
7 June „	193 „

The minimum in the hills will be far less.

(12) *Jumna River.*—The agreement, granting the right to develop this river to the United Provinces Power Association, is still in force but nothing whatever has been done towards development. Government is now looking into the projects independently. They involve short-circuiting two bends, at Jalanta (upper) and Binahar (lower) respectively (map 53 F/14). At the Jalanta site there is a double loop, to utilize which too short tunnels would be driven through the spur, giving a fall from R. L. 2,362 to 2,194 or 168 ft. gross. The Binahar site has a single loop, involving a 2 miles tunnel, giving a fall from R. L. 1,953 to 1,698 or 255 ft. Part of the land is in Tehri State, which is a party to the agreement. The minimum recorded discharge of the Jumna at Paonta is 2,264 cusecs, and the maximum 300,000 cusecs. At these sites higher up, however, the minimum is reckoned at 750 cusecs. The above heads do not include any extra received from the diversion weir; this would certainly more than compensate for losses and might greatly increase the head. The promoters reckon to obtain 20,000 kWs. at Binahar and 9,000 kWs. at Jalanta or 29,000 kWs. in all. On the basis of continuous power the sites may be assessed at 13,000 and 8,000 kWs. or 21,000 in all.

Further power from lifting dams is unquestionably capable of development. In the absence of information it seems probable that of the fall from about 1,500 ft. (below the two loops referred to above) to the canal headworks not less than 400 ft. could be utilised by means of lifting dams, giving an additional 20,000 kWs. continuous.

*The proposals in para. 33 were formulated before Mr. Lyle's report was received; see p. 105 "Kotlibel site" and first para. on p. 106.

(13) *Karamnasa River, tributary of Ganges, Benares State.*—This was favourably mentioned, and in some detail, on page 101 of the Preliminary Report; the Second Report, page 79, showed it in an even better light. It has now been surveyed in some detail, and project estimates are being prepared. There are two separate natural waterfalls 6½ miles apart, so that it will clearly be better to develop them separately; the upper or Deodari fall is 5 furlongs south-east of Aunratand village on square 5 of 1-inch map 63 P/5, just *above* the junction of the Gurwat Nala and its many branches, while the lower or Chandpattiar fall is 1½ mile east of Pandi on square 4 of that map.

(i) *Upper fall.*—The Deodari fall is 176 ft. which can be made up to 230 ft. with rapids. Storage will be necessary, as the river practically dries up in March. There would eventually be two reservoirs, one at the falls with a catchment of 350 square miles total and 50 square miles when the upper reservoir is constructed, and the other at Naugarh 7 miles higher up, with a catchment of 300 square miles. The rainfall at Robertsganj is as given for the Bakher Nadi above, but a gauge is now fixed at Naugarh also. The available run-off at Deodari is estimated to be 8,440 m. c. feet average and 5,230 m. c. ft. minimum: of this 6,680 and 4,070 m. c. ft. respectively would be above the Naugarh reservoir. The above figures are nett, after deducting the requirements of the Ghaghar canal (3,900 m. c. ft.). The Deodari earthen bund will be 15,600 ft. long and 69 ft. high and will hold 1,763 m. c. ft.; Naugarh 14,300 ft. and 101 ft. high with a capacity of 6,680 m. c. ft. In the calculations one month's carry-over has been allowed for. There are flank and saddle escapes at Deodari and a flank escape at Naugarh. Some good land and six villages would be submerged. From the Deodari reservoir 3,000 ft. of reinforced concrete pipe would run on a gentle slope to a surge tower, where pressure pipes 1,500 ft. (?) long would lead to the power house, on the left bank, near the junction with the Gurwat Nadi. The tail waters would carry on to the lower site, and would eventually be invaluable for irrigation both in Benares State and in Bihar and Orissa. The Benares Darbar is anxious that this site shall be developed, as it is within easy reach of the City and its industrial needs. The power available is estimated to be 228×232/15 or 3,500 kWs. continuous, so that there are great possibilities for this combined power and irrigation project.

(ii) *Lower fall.*—The Chandpattiar fall is 143 ft. and with its rapids 170 ft. It would naturally only be developed after the upper site, the regulated discharge of which would feed it. The water would be taken off by a pick-up weir on the left bank into an open channel 2 miles long, involving some bridging and tunnelling, up to a forebay 2 miles below the fall. The regulating capacity of the forebay would be sufficient. A pipe line of 1,000 ft. would lead to the power house site. The power available, when the upper site reservoirs are made, will be 225×170/15 or 2,500 kWs. continuous. Between the two sites the district should be able to get most of the power required for some time to come.

(14) *Karnawati Nadi, tributary of Anjhal N. and Ganges.*—A small scheme is possible on this Nadi, which has a natural fall (called Tanda Dari) and rapids amounting to 133 ft. a mile south of Tanrh village, on map 63 K/12, 16. The catchment is 27 square miles and it is believed that a run-off (based on Robertsganj rainfall—see Bakher Nadi) of 627 m. c. ft. average and 438 m. c. ft. minimum can be obtained. For impounding the average run-off an earthen bund 42 ft. high at the highest point and 8,450 ft. long would be needed. An open channel 5 furlongs in length on left bank would lead to a forebay and the pipe line would be ¼ mile long. The site is only 10 miles from Mirzapur City, but the power available, some 120 kWs. continuous only, would be insufficient. An additional 40 kWs. could be obtained by raising the Tanda water works dam, but it would hardly be worth the extra cost of about a lakh of rupees.

(15) *Kemasin Nala, tributary of Ken, Panna State.*—This is exactly similar to the neighbouring Chaprer Nala (q. v. *supra*). The natural fall and rapids, with draft head, give some 240 ft. head. The catchment (map 63 D/2) is 10 sq. mi. The storage site is immediately above the fall and 1½ mile from Baraur. The capacity with a 40 ft. bund 1 mile long would be 320 m. c. ft. which it is believed could be obtained annually. The power available is about 10×240/15 or say 160 kWs. continuously.

(16) *Ken River, tributary of Jumna.* (*i*) *Upper site.*—This site is on map 54 P/15, below the junction of the Sonar River, and about 6 furlongs north-east of Udla village; it is locally called Pandwan Ghat—see entry on pages 101-2 of Preliminary Report. Access is from Rewah *viâ* Maihar and Jukehi. Here there is a natural fall of 55 ft. which can be increased to 150 ft. by the rapids. Flood discharges are believed to rise over 300,000 cusecs (*loc. cit.*) while the minimum in June is believed to fall to 5 cusecs; on 7th March 1921, there were 28 cusecs flowing. The catchment area is about 6,000 square miles. The nearest rainfall stations are Panna (28 miles) and Gangao (17 miles), and the figures are as stated above for the Baghi Nadi. The estimated run-off is 140,000 m. c. ft. (= 10 inches)

in an average year and 70,000 m. c. ft. in a minimum year. The storage site is ¼ mile above Pandwan Ghat, near Udla and Mahwadanda villages. An earthen bund 6 miles long and 150 ft. at the deepest point is contemplated, with a flank escape on the left bank. It is suggested that, as there is difficulty over earth, the centre and deeper portion of the dam may be of masonry. The capacity would be 100,000 m. c. ft., but it is very unlikely that this could be worked to as the ground is "mostly good agricultural land, with many villages and temples," and in Native States. An open channel of 7 miles would be required to utilize the total head, though it could be avoided by developing the site in two stages. The ground is not favourable for the channel, which would be expensive. The pipe line is likely to be 1,000 ft. long. There is a good power house site and the tail race would discharge above the two Ken Canal reservoirs, so that irrigation would greatly benefit by the regulation afforded by the storage; this is the best point about the project. The continuous discharge would be 3,000 cusecs on the above storage, giving 30,000 kWs. continuously.

(ii) *Lower site at Korai falls.*—This site is on map 63 D/1, at the Korai falls, 3 miles below Bariarpur where the headworks of the Ken Canal are situated. The natural fall is 125 ft. which rapids would bring up to 175 ft. The flow of the river would only operate the plant for 3 months in the year—July to September. The maximum flood discharge is about 500,000 cusecs, while the minimum discharge is about 5 cusecs, all the available water being taken by the Ken Canal when required for irrigation. It is proposed however to construct a storage reservoir on the Banna Nadi, a tributary entering some 25 miles above the Korai falls. The catchment is given as 250 square miles, which is presumably that of the Banna. The rainfall is as given at the upper site (*supra*) and the run-off is estimated as 11,600 m. c. ft. average and 4,600 m. c. ft. minimum. The storage site is 2 miles west of Rangna village, and it involves a 2-mile bund 50 ft. high, with a saddle escape on the right bank. The capacity is 5,000 m. c. ft. and most of the submerged area will be jungle in Bijawar State. The supply from the reservoir will run in the main stream bed to Bariarpur and thence by open channel to the fall, some 3½ miles. A pipe line of 500 ft. length is required, and the tail waters can be used for irrigation. Apart from power, the storage site in the Banna Nadi is worth detailed survey, as the Irrigation Department is in search of a reservoir site to store water for the Ken canal; a combined scheme is therefore hopeful. The power available is estimated to be 1,500 kWs. continuous, from a constant discharge of 130 cusecs with a fall of 175 ft. This head assumes that the power station can be placed at such a height above bed level that the whole draft head can be used; the site actually suggested was 75 ft. above bed level. The effect of the development of the upper site (q. v.) would be a huge increase in the power available; but as it is unlikely this may be left out of account for the present.

(17) *Kosi River, tributary of Ramganga, Almora District.*—Power is required in this area for ropeways, and an enquiry was made from the Government of the United Provinces, on the 9th June 1921, as to whether any good sites had been found. Mr. Lyle notes that a small reservoir site was surveyed at Someswar, but it offered little power. The sub-overseer who was dealing with this river and the Ramganga in 1920 unfortunately had to proceed on sick leave; and by the time the enquiry referred to above was received the monsoon had broken, so that the exceptionally low discharge of 1921 could not be determined. The Preliminary Report stated that the minimum recorded at Ramnagar was 152 cusecs, and that 200 cusecs are generally running in the dry weather. This is one of many cases that show how essential it is to have regular gaugings made of all rivers, if information is to be available when required.

Major Cairns, who was temporarily employed on the Survey, submitted a reconnaissance report in 1920, regarding the Kumeria site on map 53 O/2, 3, 6, 7, shown also in the 4-inch Forest maps 37 and 38 (Ramnagar Division) near the Ranikhet cart road. The river here makes a ten-mile hair-pin bend (*vide* Atlas sheets) and the proposal is to tunnel through the intervening spur. In this way a drop of 400 ft. is obtainable in about 3½ miles, but the actual length of tunnel depends on the height of the headworks dam. As the minimum discharge is about 150 cusecs the continuous power available *without* storage is some 4,000 kWs. Major Cairns (whose report was only received when this Report was ready for the press) makes the identical suggestion put forward in para. 33 of this Report, and the river seems to be an ideal one for the purpose. The main stream at the dam site is only about 350 ft. across, the site being a few hundred feet above the temporary bridge over the Kosi near Kumeria rest-house. Instead of building a masonry dam Major Cairns suggested that the gorge might be filled in with material from the cut and the river taken over a natural saddle escape, over the spur, and down a nala on the other side. The gross height of the spur over bed level upstream is 575 ft. This could be cut down 75 to 100 ft. or so to form an escape capable of dealing with the maximum flood when coupled with, and regulated by, the storage capacity. The pressure tunnel could be constructed about 100 ft. above bed level, to allow for silting up. The minimum flow during construction could be passed down by a diversion tunnel near the base (20 or 30 ft. above bed level) or by a pipe under the bund. It would be essential to complete the bund in one season unless a large enough waste tunnel were built to carry the wet season's discharge. The storage capacity would be about 2½ m. c. ft. per foot of dam, and if the bund were 500 ft. high to the saddle escape there would be some 400 ft. of storage above the tunnel, or 1,000 m. c. ft. at least. Of this about half could be used without excessive variation of head and allowing a margin of 50 ft. for regulation the normal head would now be some 850 ft. There would probably be an excess of water surplussed for at least 6 months in the year. During the remainder of the year the normal mean discharge will be at least 300 cusecs (probably far more), and the storage will enable this to be used as required; the allowable draw-off from the storage may be considered in the light of an emergency reserve. The power available will then be 300×850/15 or 17,000 kWs. continuously instead of 4,000 kWs. The extra 13,000 kWs. (if there should be a demand for it) would justify an expenditure of some 60 or 70 lakhs at 12 per cent with a load factor of 50 per cent. and a selling price of ¼ anna. Failing the practicability of this proposal, or the boldness to carry it out, a masonry spillway lifting dam of some 50 ft. or 75 ft. would increase the head and power and reduce the tunnel length. An advantage of the larger proposal is that the minimum discharge at the Ramnagar canal headworks below would be about doubled.

(18) *Kuria (or Kilkila) Nala, tributary of Ken, Panna State.*—This again is exactly similar to the neighbouring Chaprer Nala (q. v.). The natural fall and rapid with draft head give some 310 ft. head. The catchment (map 63D/2) is 23 square miles of steep and rocky country, with some cultivation, and the Panna rainfall (see Baghi Nadi) has been used. The storage site is immediately above the fall and 2 miles North of Panna City. There would be difficulty over obtaining sufficient earth for the bund, which would be 1½ mile long and 100 ft. high to store 400 to 600 m. c. ft. It is very doubtful if any dam other than an earthen one will prove feasible for such small power; nevertheless the site seems the best of the group of similar schemes. The power would be some 13×310/15 or 270 kWs. continuous on the lowest estimated storage, and 50 per cent. higher if the full estimated run-off can be impounded.

(19) *Maha River, tributary of Tons, Rewah State.*—The Keonti falls on this river correspond to those on the Beehar and Tons near by, and all were inspected by Mr. F. E. Bull, the late Chief Engineer, in February 1921. The catchment area is 380 square miles, and the natural fall of 275 ft. can be brought up to 350 ft. The river runs in a canyon below the falls, and an open channel in rock cutting would lead to a forebay above the power house site. There is stated to be a fair discharge even in May. Mr. Bull considered that 8,000 m. c. ft. could be stored by an earthen bund of 60 to 70 ft. in height; but valuable land would be submerged. The power available is about 210×350/15 or 5,000 kWs. continuously.

(20) *Odda River, tributary of Belan River and Ganges.*—(See Second Report, page 80.) By combining this stream with its tributary the Kanjas Nadi, 2 miles east of Niagarhi village and 9 miles North of Mauganj, a promising scheme has been surveyed. (Map 63H/13, 14.) There is a natural fall (Behooti fall, not Babuti as given *loc. cit.*) of 415 ft. which can be increased to 605 ft. as determined by levelling. The river falls to about 2 cusecs, but the average discharge during the dry months of 1921 (an exceptionally dry year) was about 15 cusecs to which 5 more can be added from the Kanjas Nadi. The catchment areas are Odda 213 square miles and Kanjas 65 square miles. The rainfall records at Mauganj have been given above, for the Goorma River. It is estimated that an average run-off of 7,260 m. c. ft. will be obtained, with a minimum of 5,100 m. c. ft. The main storage would be a mile above the Odda fall with a subsidiary storage close above the corresponding fall on the Kanjas N. The maximum height would be 73 ft. with an earthen dam some 6 miles in length and a flank escape. The estimated capacity is 7,260 m. c. ft. which would almost always be obtainable; unfortunately the submerged land is mostly agricultural, containing also 25 villages, including Niagarhi. On this account it is doubtful if the combined scheme can mature, but the Odda by itself accounts for 5,560 m. c. ft. of storage. The continuous power is estimated at 145×600/15 or practically 6,000 kWs. *without the Kanjas N.* The site is 150 miles from Cawnpore, 50 miles from Allahabad and 40 miles from Rewah. The Magardha and Amdaha Nalas could, if required, be brought in to give an extra 1,000 kWs. The site was inspected by Mr. F. E. Bull, late Chief Engineer, in February 1921.

(21) *Paisuni River, tributary of Jumna.*—For various reasons this river is not very promising, although it has considerable possibilities. There is a natural fall of 139 ft. which could be made up to 180 ft. with

rapids, 5 furlongs east of Jurania village. The catchment is on map 63 D/9, 13 and 63 C/16. This was mentioned in the Preliminary Report, page 102. It is proposed to make a storage reservoir on the Surbhanga Nadi, a tributary stream, about 1½ mile above its junction. The rainfall at Rewah (see Beehar entry above) during the dry 8 months averages 3·7 inches and sometimes fails altogether; during the monsoon it averages 37½ inches and falls as low as 24·3 inches. The catchment area of the Nadi is 18 square miles of steep, hilly country, and a run-off of 580 m. c. ft. average and 420 m. c. ft. minimum is expected. With an earthen bund 1 mile long and 30 ft. high a capacity of 580 m. c. ft. would be obtained, and this would almost always be filled. A pick-up weir below the bund would feed a channel 1 mile long on the left bank and lead to a forebay site, from which the pipe line would be some 500 ft. long. The power station would be a mile below the falls.

It may also be mentioned that a site for a reservoir was surveyed by the Irrigation Department near Itwan village, 3 miles above the Paisuni falls, for storing 3,350 m. c. ft. from a catchment area of 87 square miles. That site lies partly in Banda District and partly in Baraundha State, C. I. Opposition from the Darbar however caused this to be dropped. An even better site, so far as storage is concerned, exists just above the falls, with a catchment of 113 square miles, but the railway would then have to be diverted.

It appears that the scheme outlined above can only be fully carried out if the Irrigation Department is able to build the reservoir at Itwan, which is unlikely. In that event, however, it will supply 447 cusecs for 285 days. So far as the Surbhanga site is concerned the power is limited to 20×180/15 or 250 kWs. continuously.

(22) *Patar Nala (Samua Nala on old maps?), tributary of Ken, Panna State.*—This nala has a natural waterfall near Baraur (map 63 D/2) of 210 ft. The conditions are similar to those of the Chaprer Nala close by—see entry *supra*. A 40 ft. bund 1 mile long will store 350 m. c. ft. which it is considered that the 11 square miles of catchment area can fill annually. The pressure pipe would run directly from the reservoir, with a surge pipe. The continuous power available is 11×240/15 or 175 kWs. only.

(23) *Pindar River, tributary of Alaknanda and Ganges.*—(See Preliminary Report, page 102.) This river, joining the Alaknanda at Karnprayag in Garhwal runs parallel with the foot of the hills within easy transmission distance. Mr. Lyle went over the lower portion of it up to Gwaldam, about 30 miles from Karnprayag. The bed slope is about 50 ft. per mile increasing to 70 ft. in the higher reaches of this stretch. No suitable site was found. The possibility of tunnelling from the Pindar into the Gumti at Gwaldam (near Baijnath) was examined and found unfavourable. There is a possibility of tunnelling, from a point higher up, into the Sarju valley by way of the Lahor River or the Kanal Gadh. The notes on the Ganges (*supra*) may be read; the Pindar would appear to be the most favourable tributary to begin on, if ever development on the lines there suggested is carried out. The power available in stages, by lifting dams, taking 1,000 ft. of the head only, is 1,000×1,000/15 or 65,000 kWs.

(24) *Ramganga River, tributary of Ganges, Almora District.*—(Preliminary Report, page 102.) The remarks as to power required and information available on the Kosi apply also here. Such storage sites as have been suggested are unsatisfactory. The river rises in Garhwal, at high elevations, though not in the perpetual snows. Mr. Lyle reports that the most promising scheme in this locality was obtained from an old project of the Irrigation Department, in which it was proposed to tunnel the Ramganga from a point near Marchula into the Kosi valley by way of the Paniala Sot, which joins the Kosi at Mohan, 14 miles above Ramnagar station. The difference in bed level is 125 ft. here so that a working head of 100 ft. should be obtainable.

The minimum discharge in the hills is believed to fall as low as 100 cusecs; the following gaugings have been forwarded by the Chief Engineer, R. & B., U. P.; they were taken 100 ft. above ferry ghat on the Hardoi-Farukhabad road, *i. e.*, in the plains and including many large tributaries :—

	Cusecs.
15 April 1919	403
15 May ,, ...	382
7 June ,, ...	309

It is possible that the river may be capable of flood regulation—*vide* remarks on the Ganges. The minimum power at the site named above is 660 kWs. continuous.

(*Note.*—There is another Ramganga River, a tributary of the Sarda, to the East of the above.)

(25) *Ravj Nadi (Dalsagar Nadi), tributary of Baghi (Baghain) Nadi, and of Jumna.*—This site is reached from Panna and is on map 63 D/5. There is a waterfall of 244 ft. which can be increased to 280 ft. by rapids; it is locally named Lakhanpur Ka Seha. The stream is dry by April. Its catchment area is 50 square miles of steep rocky country with very little cultivation. The rainfall at Panna is given under the Baghi Nadi above, and the run-off is estimated as 2,320 m. c. ft. average and 930 m. c. ft. minimum.

The site for the bund is a furlong above the fall, it would be 2 miles long and 70 ft. high, with a flank escape. There are difficulties as to earth for the bund. The estimated capacity is 1,600 m. c. ft. which can generally be depended upon. A short channel 700 ft., on easy ground, is required on the left bank, ending at a good forebay site. The pipe line is stated to be 300 ft., but if the fall is 280 ft. this is unlikely to be correct. The power house site is ¼ mile below the fall. It is believed that 750 kWs. continuous can be obtained.

There is another fall of about 250 ft. with a catchment of 12 square miles on a tributary of the Ranj Nadi, a mile to the west of the above site.

(26) *Sarda River, tributary of Gogra River and Ganges.*—In view of the beginning of work on the great Sarda Canal Project this river, rising in Tibet and flowing between British territory and Nepal, takes on new interest. It was mentioned in the Preliminary Report, page 103, where the information was not altogether correct. The river is generally very similar to the Ganges, and a reconnaissance was made by Mr. Lyle in 1920. Beyond the junction of the Ladhia and Kali Rivers, which make up the Sarda proper, it is out of reach. The snow-fed Kali is the main river; the Sarju (q. v.) is not permanently snow-fed, though it rises at high altitudes. The most hopeful point on the river seems to be the double bend at the junction with the Ladhia, but any works here in the way of a dam or a tunnel through the lower bend would involve co-operation between Nepal and India; short-circuiting the upper bend would place the tunnel in British territory. The absence of maps has prevented the identification of these loops, referred to by Mr. Lyle. It appears, however, from the Atlas sheet (scale one-millionth) that there is a fall between 500 ft. and 1,000 ft. at the bend at Uparkoti, 11 miles north-east of Tanakpur station. For the present no estimate of power on this river is possible; discharge curves are, however, available in connection with the canal works.

(27) *Sarju River, tributary of Sarda.*—See entry regarding Sarda River in Preliminary Report, page 103. Mr. Lyle inspected the Sarju for 5 miles above Bageswar; there is a gorge just above where the Lahor River comes in, but the prospects were not very favourable. See however remarks on the Ganges, which apply here also. There is no information as to discharges.

(28) *Tons River, tributary of Ganges, Rewah State.*—The noted falls on the Tons River were mentioned on page 103 of the Preliminary Report and on pages 80, 81 of the Second Report, to which an old print of the falls formed the Frontispiece. The site has now been surveyed, and the results bear out the earlier forecasts. The waterfall is 1½ miles south-east of Poorwa (or Purwa), and is reached from Rewah. The natural fall is 193 ft. high, but with an open channel it can be increased to 335 ft. as ascertained by levelling. The river is perennial, but falls low in the hot weather; it carried 45 cusecs on the 30th March 1921 and is believed to go up to 400,000 cusecs. The catchment area is 2,075 square miles. The rainfall at Rewah has been given under the Beehar River; a gauge is now fixed at Poorwa also. The run-off is estimated at 57,700 m. c. ft. average and 38,500 m. c. ft. minimum. An ideal reservoir site has been surveyed a mile above the fall (2 miles by river) where a 3½ mile bund 82 ft. high will impound 49,400 m. c. ft. with a waters pread of 92 square miles. The cost per million cubic feet stored will be only about Rs. 183, which is exceptionally low. There is a flank escape on the left bank,. 3,000 ft. long. A good deal of the submerged land is agricultural, and there are 73 villages within it. A channel 4½ miles long on the right bank leads to a forebay site that would need deep excavation. The pipe line would be 600 ft. long leading to a power house site on the Beehar River (q. v.) which would be combined with this scheme. There may be difficulties over the submergence of so much good land, but it is probable that the project for the two rivers can be recast so as to be more favourable from the Darbar's point of view. The continuous power available from the Tons alone is $1{,}440 \times 335/15 = 32{,}000$ kWs. This is within 130 miles of the great industrial area of Cawnpore. Project estimates are under preparation.

(*Note.*—The Tons River in Dehra Dun District, mentioned among the " sites not examined," is a different river.)

94. United Provinces; Canal falls.—The falls on irrigation canals in the United Province were listed in the Preliminary Report, pages 103-105. The available power, as tabulated there, is as follows on minimum discharges (subject to closure):—

TABLE 37.—*U. P. canal falls.*

Upper Ganges Canal—		
Anupshahr Branch (9 falls)	1,200	kWs.
Aligarh Division (3 falls)	900	"
Bulandshahr Division (4 falls)	1,050	"
Meerut Division (4 falls)	1,800	"
Northern Division (5 falls, 1 developed)	2,200	"
Eastern Jumna Canal—		
Upper division (11 falls)	1,800	"
Lower Ganges Canal—		
No information	..	"
TOTAL	8,950	"

Of these, projects are on foot for utilizing the Palra falls, Aligarh Division, Ganges Canal, and the Ghunna and Sarkari combined falls, East Jumna Canal. The former is known as the Khurja hydro-electric project (400 kWs.) and the latter as the Saharanpur hydro-electric project (300 kWs.). Further projects are in preparation for utilizing the Somera falls, Aligarh Division (200 kWs.) and the Bhola falls in the Meerut Division. In the latter case 3 units of 250 kWs. are proposed, worked by double horizontal open type wheels of 375 B. H. P. The cost, including transmission to Meerut, is estimated at about 22 lakhs. Should the Jumna scheme be carried out it would cover much of the above areas.

CHAPTER 13.—KNOWN SITES WORTH DETAILED INVESTIGATION.

95. Summary of known sites.—A number of reconnaissances made, either by the Survey or before this began, have shown power to be available at many sites on a practicable scale, although the type of project has not been finally determined and the ground has not been surveyed. Generally too the available water has only been casually determined, as only in very few instances has regular gauging been carried out. The following pages deal with the Provinces and States in alphabetical order and, under each, give such information as is available. The following table summarises the results.

TABLE 38.—*Summary of known rivers and sites.*

Reference.	Province or State.	Number of sites.	Probable minimum power; kW. continuous.
Paragraph 96 .	Assam	2	5,000?
" 97 .	Bengal	2	5,000?
" 98 .	Bihar and Orissa . . .	3	20,000
" 99 .	Bombay	15	230,350
" 100 .	Burma	16	492,400
" 101 .	Central India (Bhopal) . .	1	400
" 102 .	Central Provinces . . .	18	113,860
" 103 .	Coorg	1	1,500
" 104 .	Jammu and Kashmir . .	2	179,500
" 105 .	Madras	11	53,900
" 106 .	Punjab	..	not known
" 107 .	Rajputana ; Alwar . .	1	160
" 108 .	Travancore	11	not known.
	United Provinces—see Chapters 12 and 14.		
	TOTAL .	83	1,102,070

96. Assam ; known sites.—Further examination and survey is required of the sites already enumerated as "investigated but not developed" and in addition the Sobansiri River and Jatinga River (see Chapter 14) appear worth further examination. There may be others in this latter list, of which little or nothing is known at present. Lack of funds has prevented more being done as yet.

97. Bengal ; known sites.—The following entries relate to sites which have been examined to some extent, but of which the possibilities are not really known.

(1) *Darjeeling District.*—As noted in the Preliminary Report, page 69, the various tributaries of the Little Rungeet River, which joins the Great Rungeet and the Tista, are known to have power available to the extent of over 2,000 kW. ; but as the 25-year old Darjeeling plant (Table 60) has not had to be extended for many years it appears that the district does not demand further power. It is certain however that other local streams than those mentioned (*loc. cit.*) would greatly increase the total available. See also Tista River, para. 111. When tea firing and manufacture is carried out electrically (see para. 48) these sources of power will prove valuable.

(2) *Karnaphuli River, Chittagong.*—The Barkal rapids on this river, some 45 miles from the flourishing port of Chittagong, and 16 miles above Rangamati, were casually reported on by Messrs. Scott-Mackenzie, Dreshler and Bell in 1906-07 ; but no further action was taken as the project was regarded as of questionable value and likely to be too expensive. It is very doubtful if this verdict was correct, and there has been no expert examination. (Map 84 B.) In the course of about 1½ miles in the Barkal gorge (according to the above reports) there is a normal fall of 38 ft., though this goes down to 20 ft. or perhaps less during heavy floods. Discharge readings appear to indicate normal discharges of 700 cusecs or more, though it is believed that the minimum may be as low as 100 cusecs. The average rainfall is of the order of 100 inches. It was realized that with so low and variable a fall a lifting dam would be necessary, together with a channel about a mile long from the dam to the foot of the rapids ; but as the hydraulic development was likely to cost some 10 lakhs the project was dropped. There is a good natural weir at the head of the rapids which would apparently form a foundation for a lifting dam. Either immediately behind this, or further upstream, there appears to be a basin which "would form a dry season storage reservoir," but no guess at the capacity was made. This storage may serve either of two purposes, or both. If it is comparatively small it may still be sufficient for flood regulation ; hat is to say, the discharge of an exceptional flood for a few days might be spread over a week or two so that the fall at the foot of the rapids would not be lost from the rise of tail waters. If the capacity is larger it would serve definitely to augment the flow over the dry period. There

are no rain gauge stations in the catchment, but in the Chittagong district generally there is ordinarily some rain in every month, and no long drought is probable. If the minimum discharge is so low as 100 cusecs average for so long as a month 260 m. c. ft. stored would double this discharge. Let it be assumed however that 150 cusecs could be always depended upon.

As the locality is subject to earthquakes high dams would be inadvisable; but with reinforced concrete moderate dams could safely be built. In the absence of any details let a 40 ft. lifting dam be assumed, either alone or in combination with a storing dam higher up; if the latter were in fact practicable, and offered the storage needed, a much lower lifting dam would suffice as all the natural head would be available. It may be taken that with a channel (apparently in tunnel) about a mile long a net fall of some 70 ft. could be depended upon.

On these somewhat speculative assumptions it is probable that $150 \times 70/15$ or 700 kW. continuous could be be developed. The load factor in Chittagong may safely be estimated at from 35 to 40 per cent. so that a plant of some 2,000 kW. could in all probability be operated; if the site proves favourable the power available may be twice as much. Supposing the whole development, including the transmission to Chittagong, to cost 15 lakhs it would probably be able to compete with fuel at present prices. At any rate the project is worthy of expert examination.

The preliminary edition of the ¼ inch map 84 B is now available, but form-lines only are given, not contours. It appears however very probable that a site can be found within a distance of 10 miles above the rapids where large storage can be impounded; this should be below the junction of the Thega Khal, which flows in from the south and brings a large catchment of hilly country in. If such a reservoir is possible there can be no doubt that a succession of lifting dams (para. 31) could be used to obtain the whole power of the river; no levels however are known at present.

98. Bihar and Orissa; known sites.—In addition to the Burhabalong and Subarnarekha Rivers, entered in a previous paragraph, the three rivers below merit further examination, as well as the whole Hazaribagh-Ranchi plateau. Doubtless some of the "areas and sites not investigated" will also prove, on reconnaissance, to be worth detailed examination.

(1) *Dumragarhi and Gilling Silling, Ranchi District.*—A fall of about 500 ft. can be obtained at Dumragarhi, near Johna. Reservoirs can be constructed in the Raru, Ganga and Dumargarhi streams. An especially good storage site exists in the Raru below Harpabera, but it has not been surveyed. It is believed that a constant discharge of 200 cusecs could be obtained, giving some 6,600 kW. continuously. There may be much more storage available, up to double this power, but the combination with the Subarnarekha (*q.v.*) is reported impracticable. The fall is only 1½ miles from Johna railway station, Bengal-Nagpur Railway, and could be approached by a line running round the foot of the hills from Silli. (Map 73 E/11.)

(2) *Koel, South.*—There are falls of 50 ft. near Nagpeni, which cannot be increased owing to scruples regarding a local fair, the site of which would be submerged by a dam. There are however "plenty of storage sites higher up, and a discharge of 1,000 to 2,000 cusecs could probably be obtained." The catchment is very large. Considerable storage is required in this river also in connection with the projected steel works near Manoharpur, and the Survey has been asked to examine sites. If power on the above scale of say $1{,}000 \times 50/15 =$ 3,300 kW. or perhaps double that could be obtained, and the tail water subsequently utilized for condensation purposes, the prospects would be bright. The site on the map has not been identified, but is on the direct road from Ranchi to Gumla.

(3) *Mahanadi River, Daspala State.*—A Calcutta firm brought to notice the possibilities of the narrow Burnool Gorge, which extends for 12 or 14 miles below Tihaparan in Daspala State (map 73 D/14). Some of the area exists in the 4-inch Forest maps. The site is accessible from Cuttack *viâ* Angul. Discharges are probably known in the local Irrigation Branch. If flood regulating storage is possible, development by lifting dams (para. 31) can be done; otherwise development by open channel from a single lifting dam is likely to prove feasible. No details are at present available. The river is navigable by small craft, for which arrangements would perhaps be essential. As regards the Hasdo, Mand and Tel tributaries of the Mahanadi River see the "Central Provinces—sites not examined." There are large storage possibilities, all of which would tend to reduce the flood discharge of the Mahanadi itself and to increase its dry weather discharge. There are also rapids near Padampur and down to Sambalpur. There is little doubt that the river has great potential power, and it may be hazarded that 10,000 kW. is obtainable from it.

99. Bombay; known sites (partially examined).—The following summary relates to known sites in Bombay which have been partially examined by the Hydro-Electric Survey and which merit complete investigation. As however the Survey has now been closed down in the Presidency (see para. 82), the completion of the work will have to await more favourable times.

TABLE 39.—*Bombay ; summary of known sites.*

Serial No.	River or site.	Source of supply.	Site No.	Constant flow assumed, cusecs.	Head, ft.	Probable continuous power, kWs.	REMARKS.
1	Bedti R.	Storage	...	333	650	14,500	
2	Bene Nala	"	...	92	1,200	7,000	
3	Damanganga R.	"	(i)	132	450	4,000	
	" "	"	(ii)	132	130	1,140	
4	Gira R.	"	...	100	438	2,900	
5	Hiranyakeshi R.	"	(i)	100	1,800	12,000	
	" "	"	(ii)	215	1,400	20,000	
6	Kaneri R.	"	...	600	1,150	46,000	
7	Mahadeo R.	"	...	86?	1,400	8,000	
8	Mahi R.	" and lifting dam	...	?	?	5,000?	Combined power and irrigation scheme.
9	Sonda R.	"	...	540	1,100	39,600	
10	Tattihalli R.	"	...	240	750	12,000	
11	Tadri R.	"	...	550	1,400	51,300	
12	Vaiturna R.	"	...	111	800	6,660	
13	Venna R.	"	...	3½	1,100	250	
	TOTAL	......	...	...	...	230,350	

(1) *Bedti River, tributary of the Gangavali river, North Kanara District.* (Map 48, J/13).—The site is near the village of Magod situated 11 mi. south of Yellapur, on a local fund road which takes off from the main Yellapur-Karwar road 2 mi. out of Yellapur. The falls are situated about 2 mi. S.S.-E. of Magod and are 380 ft. high. There are considerable rapids above and below the falls in a distance of 4 mi., the total fall in this length being 650 ft. There is no possible dam site in the vicinity of the falls as the river for some considerable distance upstream flows in a deep gorge. As there is little or no flow in the hot weather, the project must be developed on monsoon flow aided by storage. The catchment area above the falls is 768 sq. mi.

Six rain gauges are maintained in or near the catchment area, which is "non-ghat," and so the average readings of the stations, which are well distributed, can safely be applied to the whole area. The average rainfall over the catchment area works out at 44·18 in., and the minimum rainfall at 27·14 in. A safe estimate of the run-off in the average and worst years is 21 in. and 9 in. respectively which would yield 37,590 m. c. ft. in an average and 16,110 m. c. ft. in the worst year.

The absence of any good storage site in the vicinity of the falls make this project an ideal one for gradual development, as it is obvious that water will have to be let down from storage (or storages) situated at some distance from the falls to a pick-up weir above the falls. A good site for a pick-up weir is found about 1½ mi. due east of the village of Magod whence a canal line 1½ mi. long, mostly in tunnel, would run to a nala a mile south of Magod, which forms a convenient site for a forebay. From the forebay site a pipe line 6,000 ft. long would lead to a power station on the banks of the Bedti river, ¾ of a mile from its junction with the Sonda river. A site for a small storage work is found 1½ mi. E. of the village of Maradkop, 8½ mi. above the proposed pick-up weir, where it appears likely that a dam 150 ft. high and about 3,500 ft. long with a waste weir on the left bank would store about 8,000 m. c. ft. Other sites probably exist either on the main river or its tributaries but the initial project should be for the abovementioned storage work.

With a storage of less than half the minimum year's run off, monsoon flow could be relied on for 3 months of the year, and the storage would yield a constant discharge of 333 cusecs for the other 9 months. With this discharge power of the order of 14,500 kW. could be developed on a fall of 650 ft.

This project, although one of the least promising of the Kanara Projects on account of its comparatively low fall, is well worth detailed investigation.

(2) *Bene Nala, tributary of the Tadri River, North Kanara District.* (Map 48 J/10.)—The site is situated 1 mi. to the N. of the Sirsi-Kumta Road 18 mi. out of Sirsi or 20 mi. out of Kumta. Sirsi is 54 mi. from Haveri station on the Madras and Southern Mahratta Railway. The catchment area of the nala above the proposed dam site is 23 sq. mi., the whole of which is in Ghat area. No records of river discharge have been kept and no

rain-gauge exists in the catchment area. The nearest rain gauges are :—

Above Ghats.—Sirsi 18 mi., average rainfall 95·89 in.; minimum rainfall 60·49 in.

Below Ghats.—Kumta 20 mi., average rainfall 138·8 in. ; minimum rainfall 94·7 in.

The rainfall in the catchment area will probably be 30 to 40 per cent. in excess of the Kumta figures, and a minimum run-off of 60 in. can safely be allowed—equivalent to a discharge of 3,206 m. c. ft. It will probably be found that the monsoon flow can be relied upon to give the required discharge during the months half June, July, August and half September, but in order to guard against a late commencement or an early stoppage of the monsoon, the storage work should contain 10 months supply. 3,206 m. c. ft. less, say, 300 m. c. ft. for losses in lake is equivalent to a discharge of 92 cusecs throughout the year. The required storage is therefore :—

300 plus (92×86,400×303)=2,678 m. c. ft.

The proposed dam site is situated 1 mi. up stream of the Kumta-Sirsi road crossing and 1 mi. to the W. of the village of Balekop. It appears probable that a dam 150 ft. high and 1,500 ft. in length will store the required volume.

From the dam a canal line 5 mi. long leads to a possible forebay site. The greater portion of this length will be in heavy cutting or tunnel. The forebay site is close to the Kumta-Sirsi road near the top of the ghat. From the forebay the pipe line about 7,000 ft. long leads down to the Kandi Nala giving a head of 1,200 ft. There is a good site for a power house on the bank of the nala situated about ¾ mi. north of mile 13 on the Kumta-Sirsi road. It is doubtful whether the tail water would be used for irrigation. It appears likely that power in the neighbourhood of 7,000 kW. could be developed, and a market for this power might be found at the towns of Kumta, 14 mi. and Hanavar 30 mi. distant. The scheme appears to be a promising one and is well worth detailed investigation.

(3) *Damanganga River Hydro-Electric Project, Nasik District.* (Map 1″ Topo. Sheet No. 46, H/12 and 16.)—The site can be reached from Nasik by Umbrale, Karanjali Adh, and Gonda. Metalled road to Adh. Motors, horse tongas and bullock carts available at Nasik. A resthouse at Umbrale, but after that tents are needed. From Adh to Gonda and Mahanjawal coolie transport only is possible.

The following are some suggestions based on a few levels taken by aneroid while making a reconnaissance of the Damanganga River. From these and the 1″ Topo. Sheet it would seem that a dam might be built across the river at a point about 20° 12′ 10″ N. by 73° 35′ 25″ E. almost due west of the " M " in Mahajawal. The catchment area above this site is 47·5 sq. mi., and is almost entirely situated in the ghats. There is no flow between February and June so that any project for this river would have to be based on monsoon flow aided by storage. The nearest rain-gauge is at Peint about 5 mi. from the centre of the catchment area. At this place the two consecutive years of lowest aggregate rainfall during the last 30 years were 1904 and 1905, when the falls were 65·1 in. and 58·95 in. giving estimated run-off of 35 in. and 30 in. respectively. On the above estimated run-off the aggregate run-off for 1904-05 would be 7,173 m. c. ft., and estimating the possible draw-off in the same proportion as that of similar cases more fully investigated, it is probable that a yearly draw-off of 4,159 m. c. ft.—that is, 132 cusecs—would be possible. As the falls occur in a length of 13 mi. the project would probably have to be developed in two stages :—

(i) The first canal might run in a N.-W. direction from the dam along the right bank of the river, entering a tunnel through the ridge to the south of Jambulmal village, debouching on the far side, and running in open cut in a S.-W. direction to a point on the hill somewhere near the island in the river at about 2·0° 12′ N. by 73° 33′ 10″ E. The first power house might be situated at a convenient place on the right bank of the river near the aforesaid island.

(ii) A pick-up weir might then be built a little way below the power house, and a second canal might be taken from the pick-up weir along the right bank of the river to a second power house, situated at the sharp bend of the river S. by W. of the village of Umrad.

Between the dam and the tail water at the first power house there would probably be about 460 ft. of fall or say, 450 ft. net head ; this would give 132×450/15=3,960 kW. continuous. Between the pick-up weir and the tail water at the second power house the fall and net head would be about 140 ft. and 130 ft. respectively ; this would give 132×130/15=1,140 kW. continuous or a total of, say, 5,100 kW.

Referring to the table on page 23 of the Preliminary Report on the Water Power Resources of India, 1919, assuming the cost of coal to be Rs. 24 per ton, a power factor of 40 per cent. and a 50 mile transmission line, it will be seen that the probable admissible cost of hydraulic development per e.h.p. installed is Rs. 511.

Therefore total admissible cost $=511\times6,840\times\frac{10}{4}$ =Rs. 87,38,000.

The proposed power house sites are about 40 mi. from the nearest point on the B. B. & C. I. Railway at Bhilad station and 30 mi. from G. I. P. Railway at Nasik station. Industrial development might begin at these places if there were a supply of cheap power.

(4) *Gira River, a tributary of the Purna River, Surat-Dangs.* (Map 46, H/13.)—The site is near Girmal, village and is within 5 mi. of the Navapur Girmal road at present under construction. Navapur is a station on the Tapti Valley Railway. No rain or river-gauge records exist for this river, the nearest rain gauges beingat Awah and Navapur. The average andminimumrainfall at these stations is :—

Awah	67·92 and 32·34 in.
Navapur	41·88 and 17·90 in.
Average	54·90 and 25·12 in.

Of the two, Awah is the most likely to represent the rainfall in this area, as Navapur is in the flat country to the N. of the hills. It appears, from the nature of the catchment area, that a run-off of 36 in. can be assumed for an average year and 12 in. in the worst year. These figures would yield 5,058 m. c. ft. and 1,686 m. c. ft. respectively. The river has little or no discharge after January, and the project must therefore be developed on the storage system. A good site for the storage work is found just above the village of Chaora where it appears that a dam about 150 ft. high and 2,000 ft. long would store 4,000 m. c. ft. The catchment area above this site is 60·5 sq. m.

The analysis (Table 40) shows that, assuming that monsoon flow was relied on for 2 months and the storage for 10 months, it would be safe to utilize 2,828 m. c. ft. of the storage annually, leaving a carry-over of 1,672 m. c. ft. to supplement the worst year's run-off. This would suffice for a constant draw-off of 100 cusecs.

A canal line would take off on the R. bank from the dam 75 ft. above river bed level and would be carried mostly in cutting or tunnel for a length of 2 mi. to a forebay site $\frac{3}{4}$ mi. N.E. of the village of Girmal, whence the pipe line would lead to a power station site 30 ft. above the river bed at the bend of the river a mile north of the village of Lahan-Girmal. The total fall obtainable is 408 ft. to the Power House plus 30 ft. draft head=438 ft. which, with the constant discharge of 100 cusecs, would yield 2,900 kW.

Six miles below the power house between the villages of Sindipara and Bardipara is a further fall of 50 ft. where, allowing 4 cusecs for losses in transit, 96 cusecs could be used to produce a further 320 kW., making the total for the project 3,040 kW. or some 9,000 kW. on a commercial load factor.

Use for power would probably be easily found either in existing mills in Surat 56 mi. off, or at new mills which (if the existence of a power scheme was recognised) might be constructed at Navapur on the Tapti Valley Railway 15 mi. off.

(5) *Hiranyakeshi River, Belgaum District.* (Maps 47 L/4 and 48 I/1, squares A3, B3, and A1 respectively.)—The site, which is 38 mi. from Belgaum, is reached by the main road leading to Vengurla and is on the headwaters of the river Hiranyakeshi, which is a tributary of the Ghataprabha river joining it about 6 mi. S.-W. of Gokak railway bridge. There are two possible methods of developing the project and the catchment areas above the respective dam sites are 13 and 15 sq. miles. The catchment runs approximately parallel to the ghat edge and is a particularly favourable one. There is practically no dry weather discharge in the river and the schemes, therefore, depend on storage and

TABLE 40.—*Gira River : statement showing size of storage required to give a constant draw-off of 100 cusecs.*

Year.	Rainfall at Awah.	Run-off.	Volume of run-off.	Contents of tank at beginning of monsoon.	Draw-off for power purposes during monsoon.	Contents of tank at end of monsoon.	Draw-off for 9 months.	Losses by evaporation and absorption.	Balance in tank at end of season.
	Inches.	Inches.	M. c. ft.	M. c. ft.	M. c. ft.	M. c. ft.	M. c. ft.	M. c. ft.	M. c. ft.
1910 . .	50·00	25	3,514	4,000	526	4,500	2,628	200	1,672
1911 . .	42·67	20	2,811	1,672	526	3,957	2,628	175	1,254
1912 . .	91·82	65	9,136	1,254	526	4,500	2,628	200	1,672
1913 . .	57·43	40	5,622	1,672	526	4,500	2,628	200	1,672
1914 . .	103·60	70	9,839	1,672	526	4,500	2,628	200	1,672
1915 . .	58·22	40	5,622	1,672	526	4,500	2,628	200	1,672
1916 . .	64·63	36	5,058	1,672	526	4,500	2,628	200	1,672
1917 . .	93·45	65	9,136	1,672	526	4,500	2,628	200	1,672
1918 . .	35·31	12	1,686	1,672	526	2,834	2,628	150	156
1919 . .	64·63	55	7,730	156	526	4,500	2,628	200	1,672

monsoon flow alone. Rain-gauges have been maintained at Amboli ghat, which is at the head of the proposed lake, by the Executive Engineer, Belgaum District, and by the Savantwadi State. These together give records from 1881 to 1889, and 1893 to 1920, or 37 years' records. The average annual rainfall over the period is 274·27 in., the minimum 179 in. in 1905, and maximum 346 in. in 1900. The heaviest daily rainfall recorded was 16·7 in. on the 4th July, 1882, while the two consecutive driest years gave 179 and 256 in. (1905 and 1906). The approximate storage capacities of the two schemes are 2,500 m. c. ft., project A, and 8,000 m. c. ft., project B. Applying the rainfall at Amboli to project A and 80 per cent. of this rainfall to project B, to allow for part of its catchment being more distant from ghat edge, the probable annual run-off in an average year is estimated at 6,200 m. c. ft., project A, and 9,600 m. c. ft., project B; while in a minimum year 3,700 m. c. ft. are estimated. These figures are based on the assumption of an 80 per cent. run-off with 350 in. rain at Amboli, and 60 per cent. with 100 in. of rainfall. With project A the run-off in the minimum year exceeds the annual draw-off, so that allowing for evaporation losses an annual draw-off at the rate of 100 cusecs could be safely depended on. In the case of project B a balance table (Table 41 on page 120) has been worked out and shows that to carry over the worst year safely the annual draw-off at the rate of 215 cusecs could be maintained continuously. The two projects would therefore give power of the order of 12,000 kW. and 20,000 kW. respectively. The two projects may be roughly described as follows :—

(i) *Project A.*—Masonry dam from the spur South of Wadi to near the junction of the Belgaum-Ajra roads, length about ½ mi., height about 80 ft. maximum. Flood waters could be discharged over the weirs on both flanks. From a point on the river about ¼mi. N.-W.of Murvandvadi an approach cut cross to the nullah N.-W. of Savantwadi would lead the water to the head-works dam and a pressure tunnel running slightly N.-W. for about 1 mi., where it joins the pipe line of about 1 mi. in length. The power house would be at a point 1 mi. and 3 furlongs bearing 44° from Yerla and the head would be about 1,800 ft.

(ii) *Project B.*—Main dam between the spurs N. of Dhangarwadi village near mile 11 on the Belgaum-Ajra road, length about ½ mi., height about 100 ft. maximum. Flood water could be discharged over a weir on the low ground on the left flank. Owing to there being low ground, North of Wadi, where the head of the Narayangad gorge indents into the Deccan, two other dams would be necessary, each about ½ mi. long and 80 and 40 ft. high respectively. From one of these dams a short canal under ½ mi. long would lead the water to the forebay in a nullah at the most easterly corner of the Narayangad gorge. The pipe line about ¾ mi. long would run to the power house site at the junction of three nullahs 1¼ mi. from and bearing 305° from Vadi; the head would be approximately 1,400 ft.

In the case of both projects the waste water after leaving the power house might be utilized for irrigation in Savantwadi State. A scheme on the lines of project B is already under investigation by Messrs. Dalchand Bahadursingh of Calcutta, who, it is understood, have applied for a concession. There are considerable deposits of bauxite near the site of the proposed works and it is intended to use the power for the manufacture of aluminium. Surplus power, if any, might be available for Belgaum, 36 mi. away, or Savantwadi 11 mi. distant from the power house.

(6) *Kaneri River, tributary of the Kalinadi River, North Kanara District.* (Map 48 I/12.) The site lies about 10 mi. to the S.-E. of Kumbharvada to the E. on the Belgaum-Karwar road, 34mi. from Londa railway station and 50 mi. from Karwar. The nearest bungalow is at Gund, 3 mi. to the E. of the city.

The dam site is 2 mi. downstream of the village of Chandegali and is situated in a narrow gorge. On the right bank the hills rise to 800 ft. above the river bed, while on the left bank they rise to 300 ft. above the bed dip, to a saddle about 250 ft. above the rivers, and then continue to rise. The site would, therefore, appear suitable for a dam 250 to 260 ft. high and about 3,000 ft. long, with a waste weir on the saddle of the left bank. The catchment area is 145 sq. mi. and is situated in an area where the minimum rainfall is probably not less than 100 in. There are no rain or river gauges in this area but it appears to be safe to take a minimum run-of 60 in., which would yield a volume of 20,210 m. c. ft. The contents of a lake formed by a dam 260 ft. high at the selected site would probably not be much more than 15,000 m. c. ft., as, judging from the map, the valley appears to have a slightly larger spread than the valley at Bhandardara where a dam 270 ft. high forms a lake with a capacity of nearly 13,000 m. c. ft. The project should, therefore, be developed on the monsoon flow aided by 9 months' storage. Assuming a constant draw-off of 600 cusecs the volume required during the monsoon would be 4,730 m. c. ft., leaving a balance of 16,480 m. c. ft. in the year of minimum run-off. Assuming that

TABLE 41.—*Amboli Project, Storage Balance Table.—Project "B."*

Year.	Total rain.	Run-on.	Run-off.	Stored.	Draw-off for 10 months.	Draw-off for 2 months.	Waste.	Balance.
	Inches.	M. c. ft.	M. c. ft.	M. c. ft.	M. c. ft.	M. c. ft.		
1881	211	12,291	9,160	7,960	6,000	1,200	0	1,960
1882	242	14,096	10,830	8,000	6,000	1,200	3,590	2,000
1883	258	15,028	11,740	8,000	6,000	1,200	4,540	2,000
1884	229	13,339	10,120	8,000	6,000	1,200	2,920	2,000
1885	205	11,941	8,830	8,000	6,000	1,200	1,630	2,000
1886	207	12,058	8,950	8,000	6,000	1,200	1,750	2,000
1887	273	15,902	12,630	8,000	6,000	1,200	5,430	2,000
1888	267	15,553	12,280	8,000	6,000	1,200	5,080	2,000
1889	230	13,397	10,180	8,000	6,000	1,200	3,980	2,000
1890		No records.				No records.		
1891	214	12,465	9,310	8,000	6,000	1,200	2,110	2,000
1892	231	13,456	10,220	8,000	6,000	1,200	3,020	2,000
1893	221	12,873	9,680	8,000	6,000	1,200	2,480	2,000
1894	222	12,931	9,730	8,000	6,000	1,200	2,530	2,000
1895	218	12,698	9,520	8,000	6,000	1,200	2,320	2,000
1896	212	12,349	9,200	8,000	6,000	1,200	2,000	2,000
1897	226	13,164	9,960	8,000	6,000	1,200	2,760	2,000
1898	227	13,223	10,010	8,000	6,000	1,200	2,810	2,000
1899	154	8,970	6,220	7,020	6,000	1,200	0	1,020
1900	277	16,135	12,860	8,000	6,000	1,200	4,680	2,000
1901	226	13,164	9,960	8,000	6,000	1,200	2,760	2,000
1902	167	5,838	8,410	8,000	6,000	1,200	1,210	2,000
1903	206	11,999	8,890	8,000	6,000	1,200	1,690	2,000
1904	208	12,116	8,980	8,000	6,000	1,200	1,780	2,000
1905	143	8,330	5,700	6,500	6,000	1,200	0	500
1906	205	11,941	8,830	8,000	6,000	1,200	130	2,000
1907	223	12,990	9,800	8,000	6,000	1,200	2,600	2,000
1908	265	15,436	12,160	8,000	6,000	1,200	4,960	2,000
1909	217	12,640	9,470	8,000	6,000	1,200	2,270	2,000
1910	207	12,058	8,950	8,000	6,000	1,200	1,750	2,000
1911	189	11,009	7,990	8,000	6,000	1,200	790	2,000
1912	244	14,213	10,940	8,000	6,000	1,200	3,740	2,000
1913	177	10,310	7,370	8,000	6,000	1,200	170	2,000
1914	270	15,727	12,440	8,000	6,000	1,200	5,240	2,000
1915	200	11,650	8,570	8,000	6,000	1,200	1,370	2,000
1916	272	15,844	12,560	8,000	6,000	1,200	5,360	2,000
1917	234	13,630	10,400	8,000	6,000	1,200	3,200	2,000
1918	183	10,660	7,680	8,000	6,000	1,200	480	2,000
1919	219	12,757	9,580	8,000	6,000	1,200	2,380	2,000
1920	177	10,310	7,370	8,000	6,000	1,200	170	2,000

From above figures the safe annual draw-off which will carry through the worst year is 7,200 m. c. ft.
Taking losses for evaporation and soakage as 400 m. c. ft. the available water is 7,200—400=6,800 m. c. ft. annually or 215 cusecs continuous.

the lake will hold 15,000 m. c. ft., 1,480 m. c. ft. would be surplussed over the waste weir, while of the storage 14,190 m. c. ft. would be used for power and 810 m. c. ft. would go in losses in the tank. From the dam a canal running in a general S.E. direction for some 9 mi. through difficult country would lead to a forebay site in a nala near the village of Komb, whence a pipe line about 1 mi. in length would lead to a power station site at the village of Holgade, on the banks of the Kalinadi river. The fall obtainable is 1,150 ft. which, with a constant discharge of 600 cusecs, would yield $600 \times 1,150/15 = 46,000$ kW. continuously. A possible use for this power would be the manufacture of pulp. Mills could be erected near the tidal waters of the Kalinadi, to which bamboos could be rafted down.

(7) *Mahadeo River, Belgaum District.* (Map 48 I/6, squares A2, A3, B2 and B3.)—The site is reached by a forest road from Khanapur or Gunji stations on the Madras and Southern Mahratta Railway, by way of Shiroli and Hemedga, the distances being 17 and 13 mi. respectively from Khanapur and Gunji. The river Mahadeo is a tributary of the R. Caudcapar, which it joins in Portuguese territory. Its catchment area above the proposed dam site is 52 sq. mi. of which a great part is in ghat area. The project appears capable of development on combined flow and storage. No records appear, however, to have been kept of the river discharge or of the rainfall in or near the catchment. A rough estimate of the discharge on April 2nd, 1921, gave 20 cusecs but it would probably fall to less than this by June. In the

absence of any contoured sheets of the catchment area it is impossible to estimate the capacity of the lake until surveys are made. The proposed dam site is at a point 2½mi. from Gawali village, bearing 35° from that village. The dam would be about 900 ft. long and from 100 to 150 ft. high, the flood water being discharged over a weir on the dam or by means of a waste-water tunnel. The land submerged will be mostly forest land and a small amount of rice land, while one small village may be partly flooded. From the dam a canal, about 4 mi. long on the L. H. bank of the river, and through difficult side-long ground, will lead to the forebay. Aqueducts and tunnels will be necessary and this is likely to be an expensive part of the work. The forebay site is not of very great capacity owing to steepness of its bed. It may be necessary to line it, as rock is not everywhere visible. From the forebay there are two possible pipe lines, one 2 mi. long giving a head of approximately 1,400 ft., and one 1 mi. long with head of about 1,100 ft. The first line would serve a power house near the junction of the Tallivadi Nala with the Mahadeo River and the site is some 15 ft. above flood level and 30 ft. above river bed level. The second line would serve a power house in the gorge below Bhimgad fort, and some difficulty is to be expected in finding sufficient room for it, as the sides of the river are very steep. There are no irrigation possibilities in British territory, as shortly below the power house site the river enters the Portuguese colony of Goa. In the absence of any rain-gauge or river discharge records it is impossible to give an accurate estimate of the power available. It would however be safe to assume an average rainfall of 100 inches and with a run-off of 70 per cent. power in the neighbourhood of 8,000 kW. could be developed. As regards a market for such power, the power house is some 26mi. from Belgaum and 16 mi. from Khanapur, where there are distilleries, tile and brick works, while near Tallivadi there are deposits of manganese. The possibilities of the scheme appear to warrant the undertaking of rainfall and river discharge investigations and should these prove favourable, detailed surveys might be carried out with advantage.

(8) *The Mahi River in Kadana State.* (Map 46 E/15.)—Some three miles from Kadana, the capital of a small State of the same name, in the Rewa Kantha Agency, the Mahi River passes through a deep gorge where the rocky cliffs on either side rise to 250 to 300 ft. above the river bed. In the gorge itself, where the distance between the cliffs is only 300 to 400 ft., the river has cut out a channel, which when sounded in 1920 was found to be 113 ft. deep. Above the gorge the valley opens out slightly, and a barrier of hard rock crosses the river bed. The proposed dam is sited on this barrier, and its length for a height of 200 ft. above the river bed, would only be 1,340 ft. The river has been gauged for some years, and the lowest recorded discharge for 12 months (1st June to 31st May) is 45,390 m. c. ft. The highest recorded flood discharge was in August 1913, when 2,000,000 cusecs are reported to have been gauged. This is probably very much over-estimated. From local information this flood rose to a height of 75 ft. above the normal low water level of the river in the gorge while immediately below the gorge, where the valley opens out considerably, the flood level was 50 ft. above the low water level. (The maximum discharge of the Indus in the last 20 years is under 1 million cusecs; probably the above figure was actually 200,000 cusecs.) During the months January to May the flow of the river is negligible, so that any project for power at this site must be on the monsoon flow aided by storage basis. Although the site is a very favourable one for a large storage work, and there is every probability that the cost per million c. ft. stored will be low, the fact that there are no natural falls precludes the possibility of making a power scheme that will pay by itself, and it will be necessary to find further use for the water.

Three good pick-up weir or barrage sites exist below the dam site, *viz.* :—

(1) 1 mi. downstream of Limbodara village. Map 46 E/12,

(2) Near the village of Harod. Map 46 E/12,

(3) Just above the junction of the Mahi and Panam Rivers. Map 46 E/12,

all of which sites are in the Lunavada State. From the most favourable of these which will probably be found to be No. 2, a canal line could be run on the right bank of the Mahi River to irrigate land in the Lunavada and Balasinor States and in the Ahmedabad district. This scheme will probably form a very good combined irrigation and power project, as given a demand for water for perennial crops, there is every possibility that an irrigation scheme would pay by itself. The Mahi, in the worst year, discharges more water than could possibly be utilized for irrigation; if a storage work was constructed to hold about 25 per cent. more than the irrigation requirements above outlet sluices, placed 100 ft. or more above the river bed at the dam site, it would be possible to utilize this artificial head for power without interfering with irrigation interests, and the extra cost of the storage work could probably be easily carried by a power scheme. The power generated could be transmitted to Ahmedabad 87 mi. away, where large industries exist, or it might be possible to form a new industrial centre at Godhra, 40 mi. from the power station site. It is desirable that this scheme should be investigated in detail.

(8) *Sonda River, tributary of the Bedti River and Gangavali, North Kanara District.* (Map 48 J/9 and 13.)—The site is reached from Kangod village, 7 mi. by foot-path. Kangod is on the Yellapur (18 mi.)-Sirsi (13 mi.) road. The catchment area at the proposed dam site is 192 sq. mi. of which probably a fifth can be classed as ghat catchment. No river gauge records are available but, in March 1920, a rough gauging gave a discharge of 25 cusecs. The only rain-gauge in the catchment area is at Sirsi. This, however, is centrally situated, and its readings may be applied with a certain amount of confidence to the whole area. The average rainfall at Sirsi is 95·89 in. and the lowest rainfall is 60·49 in. Some 60 in. may be taken as the run-off in the average year and 30 in. in the worst year, giving discharges of 26,740 and 13,370 m. c. ft. respectively. If the project is worked up on the carry-over storage system the attached analysis shows that the monsoon discharge can be relied on for 3 months and that the storage of 18,500 m. c. ft. will provide 13,750 m. c. ft. for power purposes for 9 months in the worst years on record and will leave 1,020 m. c. ft. in the tank at the end of the worst year to safeguard against a late monsoon. The dam site is situated above the village Ganeshpal, and below the junction of the Sonda and Patnad rivers. A natural fall of 352 ft. occurs $1\frac{1}{4}$ mi. below the dam site. It appears likely that a dam 250 ft. high and 5,000 ft. long will give the required storage. The waste weir would be on the right bank so as not to interfere with the canal line. The canal line would take off from the dam on the left bank and after passing through some rather difficult country would reach the spur above the junction of the Bedti and Bili rivers in a length of some 5 mi. most of which would be in a heavy cutting or tunnel. A forebay site is found at the head of a nala flowing into the Bedti river on east of this spur, whence the pipe line about 8,000 ft. long would lead to a power station site about $\frac{1}{2}$ mi. N.-E. of the village of Konki, 4 mi. by cart track from Arbail on the Karwar-Yellapur road. The fall of this length is 1,100 ft. so that, as the storage will allow of a constant draw-off of 540 cusecs, power of the order of $1{,}100 \times 540/15 = 39{,}600$ kW. could be developed. Kanara possesses no market for power of this order, and, as long as the agreement between the Indian and Portuguese Governments is in force, her coast towns are denied railway communication with the interior. With the enormous quantity of power available in the district it should not be beyond the bounds of possibility to develop industries in these towns, for the manufacture for export of cotton and other goods, from raw materials imported by sea from Sind, Kathiawar, other parts of India, and from South Africa.

TABLE 42.—*Sonda river balance table.*

Year.	Rainfall.	Run-off.	Volume of run-off.	Contents of tank at beginning of monsoon.	Draw-off for power during 3 monsoon months.	Contents of tank at end of monsoon.	Volume surplussed over waste weir during monsoon.	Draw-off for 9 months.	Losses by evaporation and absorption.	Balance in tank at end of season.
	Inches.	Inches.	M. c. ft.	M. c. ft.	M. c. ft.	M. c. ft.	M. c. ft.	M. c. ft.	M. c. ft.	M. c. ft.
1891 . . .	82·17	55	24,510	*Nil.*	4,250	18,500	1,760	12,750	600	5,150
1892 . . .	110·08	75	33,420	5,150	4,250	18,500	15,820	12,750	600	5,150
1893 . . .	93·86	60	26,740	5,150	4,250	18,500	9,140	12,750	600	5,150
1894 . . .	88·62	55	24,510	5,150	4,250	18,500	6,910	12,750	600	5,150
1895 . . .	99·35	65	28,970	5,150	4,250	18,500	11,370	12,750	600	5,150
1896 . . .	136·81	90	40,110	5,150	4,250	18,500	21,510	12,750	600	5,150
1897 . . .	96·20	60	26,740	5,150	4,250	18,500	9,140	12,750	600	5,150
1898 . . .	97·87	65	28,970	5,150	4,250	18,500	11,370	12,750	600	5,150
1899 . . .	60·49	30	13,370	5,150	4,250	14,270	. .	12,750	500	1,020
1900 . . .	117·07	80	35,650	1,020	4,250	18,500	13,920	12,750	600	5,150
1901 . . .	96·51	60	26,740	5,160	4,250	18,500	9,140	12,750	600	5,150
1902 . . .	104·05	70	31,190	5,150	4,250	18,500	13,590	12,750	600	5,150
1903 . . .	91·71	60	26,740	5,150	4,250	18,500	9,140	12,750	600	5,150
1904 . . .	82·70	55	24,510	5,150	4,250	18,500	6,010	12,750	600	5,150
1905 . . .	63·81	30	13,370	5,150	4,250	14,270	. .	12,750	500	1,020
1906 . . .	82·42	55	24,510	1,020	4,250	18,500	2,780	12,750	600	5,150
1907 . . .	115·47	80	35,650	5,150	4,250	18,500	12,920	12,750	600	5,150
1908 . . .	120·85	85	37,880	5,150	4,250	18,500	20,280	12,750	600	5,150
1909 . . .	108·39	75	33,420	5,150	4,250	18,500	15,820	12,750	600	5,150
1910 . . .	90·17	60	26,740	5,150	4,250	18,500	9,140	12,750	600	5,150
1911 . . .	74·36	40	17,820	5,150	4,250	18,500	220	12,750	600	5,150
1912 . . .	124·57	85	37,880	5,150	4,250	18,500	19,300	12,750	600	5,150
1913 . . .	101·19	70	31,190	5,150	4,250	18,500	13,590	12,750	600	5,150
1914 . . .	115·78	80	35,650	5,150	4,250	18,500	12,920	12,750	600	5,150
1915 . . .	78·37	40	17,820	5,150	4,250	18,500	220	12,750	600	5,150
1916 . . .	118·01	75	33,420	5,150	4,250	18,500	15,820	12,750	600	5,150
1917 . . .	83·40	55	24,510	5,150	4,250	18,500	6,910	12,750	600	5,150
1918 . . .	63·93	30	13,370	5,150	4,250	14,270	. .	12,750	500	1,020
1919 . . .	83·31	55	24,510	1,020	4,250	18,500	2,780	12,750	600	5,150

(10) *The Tattihalli River, tributary of the Kalinadi River North Kanara District.* (Map 48 I/12 and 16.)—The Tattihalli River joins the Kalinadi River about 3 *mi.* above the Lalguli falls, and in the last 6mi. of its course falls 156 ft. There is a site for a pick-up weir, or a possible dam site, 4 mi. up stream of the Haliyal-Yellapur road bridge, whence acanal line 13mi. long through difficult country would lead to a forebay site about 2mi. E. N.-E. of the village of Lalguli, whence a pipe line 5,000 ft. long would lead to a power station site on the banks of the Kalinadi River. The total fall obtainable is 750 ft. The river has not been gauged and only two rain-gauges exist in the catchment area of 456 sq. mi. The area is non-ghat, and appears to be in the tract of the country where the average rainfall varies between 45 and 35 in. The average rainfall at Haliyal and Kalghatgi is 39·99 in. and the minimum rainfall is 23·35 in. These figures could probably be adopted for the whole catchment area. The run-off would probably be 15 in. in an average year and 6 in. in the year of minimum rainfall, yielding 14,120 and 6,348 m. c. ft. respectively. A dam 5,000 ft. long and 150 ft. high at the site indicated above would probably store some 10,000 m. c. ft., which, if worked on the carry-over system, would allow for an annual draw-off of about 8,000 m. c. ft., yielding a constant discharge of 240 cusecs and leave 432 m. c. ft. to cover losses in the lake.

With this discharge and a fall of 750 ft. 12,000 kW. could be obtained continuously. This project is worth investigating on account of the fall obtainable, though the long canal line necessary may make it a rather expensive one.

(11) *The Tadri or Aghanashini River, North Kanara District.* (Map 48 J11 and 15.)—The Lushington Fall (380 ft.) are 3mi. by foot-path from the village of Hostot, connected with Nilkund by a muram road 5 mi. long. Nilkund is 17 mi. on a metalled road from Sirsi, a Taluka Headquarter town, and 71 mi. from Haveri station on the Madras and Southern Mahratta Railway. Another route is from Kumta by metalled road to Nilkund 24mi. The river has not been gauged but has only a small discharge in the hot weather. There is no site for a storage work close to the falls as the bed-fall of the river above the falls is rapid and the valley is narrow, but a site exists between the villages of Matimani and Hulimani about 1½ mi. upstream of the Nilkund Sidhapur road, 8 mi. from Nilkund and 11 mi. from Sidhapur. Rain-gauges are maintained at Sirsi and Sidhapur in the catchment area, from which it appears that the average rainfall in the catchment area of 240 sq. mi. is 106·79 in. while the minimum rainfall is 70·49 in. A run-off of 33 in. or 18,374 m. c. ft. can be relied on in the worst year. The dam site is situated in a gorge, where the river passes between two hills rising to about 250 ft. above the river bed, with a saddle about 200 ft. above the river on the left bank. The length of the dam would be about 2,000 ft. for a height of 200 ft. and the waste weir would be in the saddle referred to above. From the examination of the map it appears that the contents of a lake formed by a dam of this height would be less than the minimum run-off, and so the project would have to be developedon monsoon flow aided by 9 months storage. The storage capacity of the proposed lake has been assumed to be 13,750 m. c. ft. which, allowing 775 m. c. ft. for losses, would yield a constant discharge of 550 cusecs for 9 months. During the 3 monsoon months 4,335 m. c. ft. would be required for power so that during the worst year over 1,000 m. c. ft. would be surplussed over the waste weir. A better site for a dam could probably be found further upstream, but this would involve either the lengthening of the canal line or the construction of a pick-up weir. From the dam, a canal some 10 mi. long would lead to a forebay site near Durga Devi, at the edge of the ghats, on the Kumta-Nilkund road, whence a pipe line 2 mi. long would lead to a power station on the banks of the Benihol Nala near the village of Morshet, about 1 mi. above the junction of this nala with the Tadri River. The fall obtainable is about 1,400 ft. on which, with a constant discharge of 550 cusecs, some 51,300 kW. could be obtained continuously. This project is well worth detailed investigation, should a call for power arise in this part of the country.

(12) *Vaiturna River, Nasik District.*(Map 47E/9.)—This river rises on the southern slopes of the Trimbak range in the Nasik District, and after flowing south for some miles finds its way over the edge of the ghats. The above ghat catchment area is 62·23 sq. mi. and is very favourably situated as regards rainfall. Three rain-gauges are maintained in or near the catchment area, *viz.*, Trimbak, Waghera and Kusegaon. The average rainfall at these stations is remarkably regular :—Trimbak 93·33, Waghera 90·71, and Kusegaon 89·32 in. The combined average rainfall of 91·12 in. may be adopted for the catchment. The minimum rainfall is 42·88 in. A run-off of 60 in. in an average year and 15 in. in the worst year may be assumed. These run-offs would yield 8,674 m. c. ft. and 2,168 m. c. ft. respectively from a catchment area of 62·23 sq. mi. The discharge of the river has not been gauged but from local information there is little or no flow after December. The project must therefore be developed on the monsoon flow aided by storage. A good site for a dam exists 2 mi. to the S. of the Ghoti-Sirghat road crossing between the villages of Wai and Dhargaon. The dam section and cross-sections upstream have been surveyed and from

these it appears that a dam 150 ft. high and 3,142 ft. long, with a waste weir on the right bank, would store 5,358 m. c. ft. A higher dam might possibly be constructed, but difficulties would probably be encountered with the waste weir site, and the height given above appears to be the economical height.

With a storage of this capacity and a worst year's run-off of 2,168 m. c. ft., it will be possible to utilise 3,600 m. c. ft. from the storage annually, leaving a balance of 1,758 m. c. ft., as a carry-over to meet a bad year. This 3,600 m. c. ft. represents a constant discharge of 111 cusecs. A canal line would take off on the left bank from the dam site and, after passing through some moderately difficult country, would be carried in tunnel through a ridge to a forebay site found in a nala about 1½ mi. south of the village of Wagia. From the forebay site, a pipe line 5,300 ft. long would lead to the river bed 832 ft. lower down, and allowing for placing the power station well above high flood level, the available head may be taken as 800 ft. The storage will yield 111 cusecs continuously so that the power that can be developed on the above fall is 6,660 kW. continuously. The generating station will be 67 mi. from Bombay, 37 mi. from Kalyan, 23 mi. from Igatpuri and 8 mi. from Nasik, all places where the need for power exists or is likely to do so in the future. The project is well worth detailed investigation.

(13) *Venna River Hydro-Electric Project, Mahabaleshvar.* (Map 1" Topo, Sheet No. 47 G/9 and 13.)—The site of the existing lake, at present used for the water-supply of Mahabaleshvar, and the level of which it is proposed to raise 30 ft. for power purposes, is about 1 mi. N.-E. of Mahabaleshvar, from which place it can be reached by car. The catchment area of the lake is only 1 sq. mi. of ghat area. From February to June there is no flow from the streams into the lake. The lowest recorded rainfall is over 139 in. which at 70 per cent. run-off would give a volume of 921 m. c. ft. At the suggested full supply level of R. L. 4,263 the lake would cover about 86½ acres instead of 42 acres as at present, and would contain about 102·43 m. c. ft. instead of about 20·18 m. c. ft. as at present. Raising further than this is not practicable, as the submerged land would be too valuable. The canal would be taken along a falling contour on the left bank of the Venna Nala to a forebay, situated at a point about 17° 55′ 25″ N. by 73° 44′ 50″ E. ½ m. S.-W. of Awkali, whence a pipe line about ¾ mi. long would lead to the power house. This would be situated in the Venna Nala at a point about 17° 54′ 45″ N. by 73° 44′ 50″ E. about 1 mi. from the foot of the falls. The tail water would flow into the nala. The outlet level of the present lake is R. L. 4,216 and the nala bed at the power station about R. L. 3,105 giving a total fall of 1,111 ft. Deducting 11 ft. for fall in canal, etc., the available head would be 1,100 ft. As the lake would be filled every year, the whole of the extra 82 m. c. ft., impounded by raising the dam, would be available. It is not proposed to run the plant during the monsoon unless Panchgani is to be supplied as well as Mahabaleshvar; thus 82 m. c. ft. would be used in 9 months giving 3·5 cusecs. This would give some 250 kW. continuously for the 9 months.

The power would be used for pumping the water supply of Mahabaleshvar and for lighting, and a plant of some 600 kW. or more could be installed. Referring to the table on page 23 of the Preliminary Report on the Water Power Resources of India, 1919, assuming the cost of coal to be Rs. 24 per ton, a power factor of 40 per cent. and practically no transmission line, it will be seen that the admissible cost of the hydraulic development per e.h.p. installed is about Rs. 636, or the total admissible cost 5½ lakhs.

100. Burma; known sites.—The following summary relates to known power sites of which reconnaissances have been made, and so much information as is available follows. It will be observed that most of the sites in Burma can be developed on flow alone.

TABLE 43.—*Burma; summary of known sites.*

Serial.	River or site.	Nature of supply.	Site number.	Constant flow assumed, cusecs.	Head, ft.	Probable continuous power, kWs.	REMARKS.
(1)	Balu Chaung	Flow	(i)	100	500	3,300	
			(ii)	160	1,000	10,000	
(2)	Bernard Myo River	Do.	...	10	3,000 or more.	2,000	
(3)	Chaunggyi Chaung	Do.	...	14	1,500	1,400	
(4)	Chindwin River	Do	...	3,000	30	6,000	

Serial.	River or site.	Nature of Supply.	Site number.	Constant flow assumed, cusecs.	Head, ft.	Probable continous power kWs.	REMARKS.
(5)	Helaung Chaung . .	Flow	...	50	2,000	6,000	
(6)	Irrawaddy River . .	Do.	At Sinbu.	10,000	80	50,000	
(7)	Kainggyi Ye-ta-goon . .	Do.	...	5	1,500	500	
(8)	Konwet or Kinwe River .	Do.	...	20	2,000 ?	2,000	
(9)	Nam Kwe	Do.	...	25	1,100	1,800	
(10)	Namma River	Do.	...	300	120	2,400	
(11)	Nam Tamphak River . .	Do.	...	200	900	12,000	
(12)	Salween River . . .	Do.	At Hatgyi	20,000 ?	90 or more.	120,000	
(13)	Shweli River	Do.	At Selan	4,000	1,000	250,000	
(14)	Sittang River . . .	Flow and storage . .	...	50	1,200	4,000	
(15)	Taping River . . .	Flow	...	500	500	17,000	
(16)	Thaukyegat River . .	Flow and storage .	...	300	200?	4,000	
					TOTAL .	492,400	

(1) *Balu Chaung, S. Shan States.*—(i) This stream enters Imle Lake valley near Indemze and has a discharge which is believed not to fall much below 100 cusecs. It was partly examined in 1904 and again in 1920. There are no clear falls, but rapids are numerous and extend for several miles up to a height of about 1,000 ft. above the lake. (Map 93 D/11, 15.) By lifting dams, if not otherwise, development may be possible *if* the ground will hold water. This, however, is doubtful. By open channel (somewhat costly) it seems probable that half the fall or $100 \times 500/15 =$ 3,300 kW. continuous could be obtained.

(ii) The river draining Imle Lake to the S. is also called Balu Chaung. The minimum discharge is unknown but is probably considerably greater than 160 cusecs as other streams flow into the lake. There are natural falls of 600 ft. and a number of small falls within a few miles of where the river reaches the Nam Pawn. The lake has a large water-spread and swamp area, and by raising it a few ft. regulation could be obtained. The total fall is some 1,000 ft. all of which can probably be used. The continuous power is not less than 10,000 kW. and may be three times as much.

(2) *Bernard Myo River, Mogok.*—This river, 9 m. N. of Mogok, is a tributary of the Kin Chaung and Shweli. The minimum discharge, due to springs, is about 10 cusecs or more and there is a drop of 3,000 to 4,000 ft. in a short distance. The catchment is about 120 sq. m. and Mr. Raikes reports that "springs and reservoir sites appear to be numerous in this area." The continuous power is probably not less than 2,000 kW. (Map 93 A/8.)

(3) *Chaunggyi Chaung.*—A tributary of the Nammeik and Shweli (map 93 A/12). The discharge is believed to be never below 14 cusecs and there is an available head of 1,500 ft. or 1,400 kW. continuous.

(4) *Chindwin River, tributary of Irrawaddy.*—This large river has a catchment of the order of 5,000 sq. m. mostly unsurveyed, on map 83/0. The Kanti falls, 20 m. above Kanti, are about 30 ft. normally but it is possible that they may disappear in the rains (cf. Narbada R.). The minimum discharge is believed to be about 3,000 cusecs, and if flood regulation is possible development is also possible. The continuous power will be of the order of 6,000 kW. if development proves possible.

(5) *Helaung Chaung, tributary of Hpawngow.*—This rises near Wetwun and falls about 2,000 ft. in 14 m. between the railway line there and Hkelawng. The minimum discharge is of the order of 50 cusecs, and some 6,000 kW. may be expected. (Map 93 B/12, 16.)

(6) *Irrawaddy River.*—It is very doubtful if economic development of this immense river is possible. A rough project was drawn up by Mr. Hare for damming the river at the defile below Sinbu and diverting it by a channel to the E., *viâ* the Nainsang and Mole

rivers, a matter of 45 mi. It is doubtful if this is practicable unless flood regulation on an enormous scale is possible. Nevertheless the power obtainable is almost beyond conception, though there appear but small prospects of it ever being required in so remote a district. Some 28 m. above Myitkina the Irrawaddy proper is formed by the confluence of the Mali Hka (W.) and the N'Mai Hka (E.). The former has a fall of 510 ft. in 155 mi. and the latter 739 ft. in 121 mi. approximately. Both rivers have many gorges and rapids, but there appears no prospect of using these in the present century.

Mr. Hare's proposal is to utilize the whole dry weather flow of the main river on a fall of 80 to 100 ft. near Sinbu, which is at the mouth of the first defile, some 79 mi. below Myitkina. Here the river runs in a narrow gorge in high hills for about 33 mi. before emerging some 6 mi. above Bhamo. The passage through this defile appears to be somewhat of a geological freak, as an easier passage could have been effected. At the gorge entry the river backs up some 80 ft. in flood times, at Sinbu gauge, and has reached 102 ft. If the waters were headed up to 140 ft. here they would be diverted over the divide between the Namsang Chaung and the Mole Chaung and, avoiding the defile, would have reached the main bed again just above Bhamo by the Mole and Taping rivers. Mr. Hare suggested that the river should be led off at low water at the Tahena bend, in an escape channel, taking off from the mouth of the Namsang Chaung at level 400 ft. while the gorge itself is dammed; alternatively a diversion tunnel could be constructed; as the whole supply would probably never be utilized this could afford a duplicate permanent flood outlet. The lake formed behind the proposed dam would be of enormous extent, so that flood regulation is definitely a possibility; if carried up to the 450 ft. contour the waterspread would be about 325 sq. mi. and another 10 ft. would about double this, 1 foot giving some 9,000 m. c. ft. extra. If the whole of the excess water were diverted as proposed there would be a head at the dam of from 80 to 100 ft. It appears as though a constant draft of at least 10,000 cusecs could be obtained and probably far more. On an 80 ft. head this would mean about 50,000 kW.

7) *Kainggyi-Ye-ta-Goon.*—This discharges into the Madaya River, near the Mandalay Canal headworks. Only about 500 kW. could be obtained, as no storage is possible. The discharge drops to 5 or 10 cusecs but the fall is 1,500 to 1,700 ft. (Map 93 B-7.)

(8) ***Konwet** (or **Kinwe**) **River, Mogok.***—This is not marked on the maps (93 A/4, 8). It has been stated to have a minimum flow of about 20 cusecs and a fall of 2,000 ft. in a few mi. and may probably be good for 2,000 kW. or more. A tributary of the Kin Chaung is marked under this river as also having a cold weather discharge of 20 cusecs (?) and a fair fall.

(9) *Nam Kwe, Yamethin.*—A combined irrigation and power project can be carried out on this river. The irrigation scheme consists in storing and diverting the head waters of the Nannge Chaung towards the plains near Yamethin by means of a dam near Nam Kwe and a tunnel through the northernmost branch of the stream flowing past Konywa; map 93 D/2, 3, 6, 7. With a head of 1,100 ft. 50 cusecs would be available for 12 hours a day throughout the year for power. Assuming that by a pick-up weir or otherwise this flow could be spread over the 24 hours (25 cusecs) the continuous power would be 1,800 kW.

(10) *Namma River.*—This joins the Nam Yao at Se-en railway station and flows into the Namtu E. of Hsipaw and below Mansan Falls. In a deep gorge 12 mi. up from its junction with the Nam Yao it runs through a large "natural bridge" in the limestone, over a series of rapids. There is a fall of 120 ft. in the 600 ft. above and 200 ft. below the bridge. The discharge in November was estimated to be 600 cusecs so the minimum is probably not above 300. Owing to the fissured rock it is doubtful if a storage reservoir could be constructed, though a site for one exists above here. The site would, it is said, be very costly to develop; though on the face of it a low dam, with a short tunnel and pipe appear possible. The power available is 2,400 kW. (Map 93 F/10, 14 and 93 J/2.)

(11) *Nam Tamhpak River.*—This joins the Nam Pawn near Wan Man and is said to have a good discharge and fall near there. Probably 200 cusecs with a fall of 900 ft. is near the mark, or 12,000 kW. It is in the vicinity of the Balu Chaung and Nawng Htao Lake which are both said to have good falls and discharges. (Map 94 E/5.)

(12) *Salween River.*—The Hatgyi rapids 100 mi. S.-E. of Taungyi and the same distance N. of Moulmein are well known by repute though few people appear to have seen them. They are some 40 mi. above the entry of the Yunzalin River and below the entry of the Taungin River. Reports are conflicting, and there are said to be falls of from 70 to 300 ft. Probably the lower figure is more correct for these rapids, but others may exist further up. The minimum discharge is very great, of the order of 20,000 cusecs, and flood discharges of a million cusecs (as large as those of the Indus) are believed to

occur; the floods rise 90 ft. when no doubt the fall mostly disappears. If flood regulation is at any place possible (para. 33) there is no doubt enormous power capable of development by lifting dams and it is safe to estimate at least 120,000 kW. as possible.

(13) *Shweli River, tributary of Irrawaddy.*—This great river is said to have a discharge of 4,000 cusecs normally in April. It is reported to have falls (the largest 34 ft.) aggregating 1,000 ft. in 5 mi. This is below the large swamp or lake at Selan, which could doubtless be slightly raised for flood regulation and storage. The elevation at Selan is about 2,400 ft. and the land is cultivated, so that no great submergence would perhaps be possible. There is granite available. The site is probably worth about 250,000 kW. continuous and may be even better if storage can ensure proper regulation of floods. The upper reaches below Namkhan and the Kyau Ktabo rapids are also mentioned, as well as the Nam Chit tributary falls of some 300 ft. (Map 93 E/6, 9, 13.)

(14) *Sittang River.*—There is said to be a good power site on this river N. of Pyinmana, near Yezin village and Taungnyo. Further N. 20 miles due E. of Yamethin, there is a fall of about 1,200 ft. reported. The discharge falls to about 50 cusecs but could be supplemented by storage. The possibility of tunnelling through the watershed was mooted, which would bring the tail waters to where they could be used for irrigation. Although the rock is limestone, which is generally badly fissured in Burma, it is stated that earthen bunds have been used here in the past with success. It seems probable that upwards of 4000 kW. could be obtained continuously. (Map 94 A/1, 5; 93 D/3, 4.)

(15) *Taping River, tributary of Irrawaddy.*—The confluence is near Bhamo. About 31 mi. up the river from the confluence, on the Bhamo-Tunhong road, there is believed to be a cold weather discharge of 500 cusecs and a drop of 500 ft. in 5 mi. The site is worth examination and may give 17,000 kW. or more continuously. The Tunhong gorge beyond Kalechet has also been mentioned. (Map 92 H/11, 14.)

(16) *Thaukyegat River, tributary of Sittang.*—A site 6 mi. S. of Toungoo has been partly examined, on maps 94 A/11, 12, 16; B/9, 13. The catchment is considerable and on the N. or main branch a reservoir site (about 1,000 m. c. ft.) appears possible. The discharge in March 1919 was 300 cusecs, and most of the small feeder nalas have a little water in them. The S. branch can possibly be led round by a channel to the reservoir site from whence an open channel would apparently lead to a good forebay and pipe line route. No scheme has yet been drawn up, but it seems probable that about 4,000 kW. can be obtained continuously.

101. Central India ; known sites. *Bhopal ; Gadaria Nala.*—This stream runs parallel to the railway from Bhopal to the Narbada at Budni (map 55 F/9), where a new industrial city is in process of making. Local engineers drew up a rough project, on lines suggested by the Survey, and Messrs. Bull and Meares visited the site in January 1920. Various alternative methods of development are possible, but the confirmed data are so far altogether insufficient to form a judgment on. The new city will probably require some 3½ million units (kWh.) per annum. The catchment area is about 34 sq. mi. with annual rainfall generally between 36 and 40 in. The run-off is likely very high, from the nature of the ground. The average run-off is likely to be of the *order* of 1,800 m. c. ft. A dam site at about R. L. 350 ft. was examined and found favourable, but the capacity has not at present been determined. A further possible reservoir site exists at about R. L. 316 ft. and a third site at about 240 ft. probably the best of the three for initial development. From this lowest site there is a fall of 52 ft. in 4,000 ft. Clearly on so low a fall large storage is necessary. Possibly by going further a total fall of 72 ft. may be obtainable. Several possible methods of development were suggested to the Darbar for survey. The estimated consumption of 3½ mi. units is equivalent to 400 kW. continuous, and this can probably be obtained. As the project depends on storage any load factor or peak load can be met.

102. Central Provinces ; summary of known sites.—The following pages give abstracts of the reconnaissance reports on a number of sites in the Central Provinces which appear to be well worth further detailed examination and survey. Some of them will almost certainly prove worth developing if there is a market for the power; but it is essential not to lose sight of the fact that a water power site is often ruined for good if a partial development only is planned. To enable the site to be fully developed, nearly the whole cost of the hydraulic lay-out must be incurred; and, unless the power can also be fully utilized the units that are generated have to bear the whole of the capital charges.

The investigations were made during 1920 under the direction of Mr. Powys Davies, Executive Engineer, Officer-in-charge, who was later succeeded by Mr. N. C. Bhattacharji, temporary engineer. The five circle officers (supervisors) employed were Charan Singh, B. S. Nagoji, K. Fariduddin, Heera Singh and D. K. Kieju, all of whom did excellent work for the Survey.

By following the directions contained in the "Reconnaissance, Survey and Report Form," printed on pp. 19—28 of the Second Report (para. 37 *supra*), admirably logical reconnaissances have been recorded. These are on record in the office of the Chief Engineer, Hydro-Electric Survey, and contain a mass of useful data regarding rainfall and run-off with maps and plans, discharge curves and so forth. Owing to the closing down of the work in the Central Provinces the data have mostly not been correlated; this would in volve months of work and will, it may be hoped, be undertaken hereafter. At present, as is well known, the calculation of the flow from a catchment is little more than intelligent guess work. Regular gauging of the rivers, and the provision of automatic water stage recorders in the more important ones, is very necessary. The exceptional drought of 1920-21 offered a chance that may not recur for many years; in the interests of India it is to be hoped that this will be so; but the closing down of all investigation in this area at such a time is a disaster from the point of view of the Survey of water power resources.

It will be seen that practically all the projects would depend on storage for many months, while the heads are mostly low or medium with very long pipe lines. These conditions make for expensive development, but only actual survey can determine whether such projects can compete with fuel developed power.

The following is a summary of the sites detailed below and the continuous power which they appear, on present information, likely to afford:

TABLE 44.—*Central Provinces; summary of known sites.*

Serial.	River or site.	Nature of supply.	Site number.	Constant flow assumed, cusecs.	Head, ft.	Continuous power, kWs.	REMARKS.
(1)	Bewas R.	Storage for some months.	...	120	200	1,600	
(2)	Chika'da Plateau	Ditto	(i)	12	1,200	800	(i) and (ii) are alternatives.
			(ii)	27	450		
	Chitarewa—See Sitarewa						
(3)	Denwa R.	Ditto	...	176	300	3,500	
(4)	Indravati R.	Flow and Storage	(i)	Probably too expensive.			
			(ii)	Ditto			
			(iii)	1,200	100	8,000	(iv) and (v) are additional to (iii), (vi) is alternative.
			(iv)	1,200	200	16,000	
			(v)	1,200	250	20,000	No. (iii) is likely to be a cheap development.
			(vi)	Not examined.			
	Kasaha—See Silgi.						
(5)	Machna R.	Flow and Storage	(i)	33	465	1,000	(ii) is additional to (i).
			(ii)	30	350	700	No. (i) would be a cheap development.
(6)	Mahanadi R.	Storage	...	85	400	2,250	
	Moga—See Purna.						
(7)	Nagdooari R.	Flow and Storage	...	56	730	2,700	
(8)	Nahara R.	Storage	...	90	660	4,000	
(9)	Narbada R.	Flow and Storage	...	1,000	170	11,000	
(10)	Patna R.	Storage	...	44	300	880	
	Pench—See Silewani Ghat, paragraph 85.						
(11)	Penganga R.	Flow and Storage	(iv)	657	250	11,000	For (i) (ii) (iii) see entry below.
(12)	Purna and Moga R.	Storage	(i)	55	430	1,500	
			(ii)	Doubtful utility.			
			(iii)	102	100	680	(iii) is additional to (i).
(13)	Silgi, Kasaha and Sankul N.	Storage	...	193	550	7,000	
(14)	Sitarewa	Do	...	78	715	3,700	A cheap scheme to develop.
(15)	Son-bhadra N.	Do	...	213	180	2,550	
(16)	Tapti R.	Flow and Storage	(i)	450	100	3,000	
			(ii)	450	400	12,000	(ii) is additional to (i).
(17)	Canal falls		Many		...	...	
					TOTAL	113,860	kWs.

NOTE.—Those projects marked as "Storage" depend mainly on monsoon storage for a period of 1 to 6 months.
Those rivers marked as "Flow and Storage" have some perennial flow, but it must be supplemented during the hot weather.

(1) *Bewas River, tributary of Ken, Saugor District.*—This was examined in the neighbourhood of Lidhora Khurd Railway station, map 55 I/13. The catchment is 280 sq. mi. and the rainfall in the two driest consecutive years was 31·8 and 20·8 in. respectively, giving an estimated yield of 5,990 and 2,400 m. c. ft. The site of the dam appears to be near Richhawar on square 6 at R. L. 1,600, where it is proposed to store a gross 6,000 and net 4,200 m. c. ft. but apparently the site would hold larger storage to allow for a carry-over from good to bad years. A channel on the R. bank some 8 mi. in length, with 1 mi. of pipe, would give a fall from 1,600 ft. (*plus* height of water) to 1,400 ft. E. of Padaria village on square 8 of the map. A constant discharge of 120 cusecs (probably more) with a fall of 200 to 250 ft. would give power of the order of 1,600 to 2,000 kW. continuously. The scheme appears *prima facie* to be a favourable one, likely to prove reasonable in cost on commercial load factors, and it is worth detailed investigation. Saugor town is close by.

(2) *Chikalda Plateau, Melghat Taluk, Amraoti District.*—In the Preliminary Report, page 84 (Chikalda) and page 85 (Melghat) mention was made of this area (including McKenzie Falls) as one of those proposed by Mr. Batchelor. The original proposal put forward was for a main reservoir on the Baram Sati Nadi above McKenzie Falls, about 1 mi. N.-E. of Gawilgarh Fort, whence a fall of 1,300 ft. is obtainable. It was proposed to divert the nalas on both sides into this main storage, *viz.*, on the W. the drainages from Chikalda Hospital to Chandni Burj or Machi Tal and on the E. from Motha village. The catchment would be only 6 sq. mi. and the average yield in two bad seasons is reckoned at 156 m. c. ft. only, giving under 400 kW. continuous. This proposal is therefore valueless. The site comes into map 55 G/7 but for details the 4 in. Forest map, sheet XIV (Chikalda Forest Reserve) must be referred to. Examination of the above-mentioned site suggested two other possible methods of development to the investigating officer.

1st site.—It is suggested to place a bund across the Silona nala, 1 mi. S. of Silona village (squares 4 and 7 of 1 in. map) where the catchment is 4·9 sq. mi. and to carry the water along R. L. 2,750 to a main reservoir on the Sepan Nadi $\frac{1}{4}$ mi. N. of Kamapur village (squares 4, 5). The catchment of the Sapan Nadi here is 7·8 sq. mi. at R. L. 2,700. The waters of the Jamunala (Jamuda ?) nala on the east, with a catchment of 0·8 sq. mi. would also be diverted to the reservoir. A channel would then run along R. L. 2,700 to a reservoir on the Motha Marki nala, some 3 mi. S.-E. of Kamapur, cutting through the spur between the Sapan and its tributary. The Motha Marki nala would provide a catchment of 2·4 sq. mi. at its reservoir site near the Motha-Ellichpur road. Thence a channel could be constructed near R. L. 2,700 to where it cuts the nala flowing towards Manbhung (square 8). From a forebay here the pipe line would run down to a power station N. of Dhamangaon at R. L. 1,500. There would be 5 nalas to be dammed, 9 mi. of channel and $1\frac{3}{4}$ mi. of pipe line, mostly on difficult ground. The total catchment is 16 sq. mi. giving a minimum yield estimated at 416 m. c. ft. but a far greater normal yield. As the fall is 1,200 ft. the continuous power would be of the order of $\frac{416}{35} \times \frac{1200}{15}$ or say 950 kW. but with additional carry-over it may prove more on examination.

2nd site.—The second alternative proposal for this area is to dam the Sapan Nadi between R. L. 1,950 and 2,000, $\frac{1}{2}$ mi. N.-W. of Arnadi village (square 8), where the catchment is 23 sq. mi. To supplement this the Morapatha Nala and its tributary from Majri village on the E. could be dammed at R. L. 2,000, the combined catchments being 12·9 sq. mi. Channels of 3 and 5 mi. would do this. The channel from the main reservoir would run between R. L. 1,950 and 2,000 for 3 mi. and then with a pipe line $\frac{1}{2}$ mi. long will drop to R. L. 1,500 at a power house North of Dhamangaon village. The total catchment is 36 sq. mi. with a bad year yield estimated at 936 m. c. ft. giving an assured flow of 27 cusecs and probably more with carry-over from good years. The continuous power is of the order of 27× 450/15 or 800 kW.

None of these projects would be cheap to construct considering the small power available, but they merit further examination.

(3) *Denwa River, Hoshangabad and Chhindwara Districts.*—This is a tributary of the Tawa and Narbada, rising in the S. of the Pachmarhi Hills and flowing round to the N. of them. The site examined is opposite mile 34 of the Piparia-Chhindwara Road, 4 mi. W. of Sitadongri village (map 55 J/11, square 1). The river is perennial, though the flow falls very low ; it was 10 cusecs on 21st May 1920. The catchment area is 177 sq. mi. largely forest, and is mostly within the 70 in. rainfall contours around Pachmarhi. Pachmarhi records show an average of 73 in. and a minimum of 37·8 in. with as much as 18 in. of rain on one day. The two driest consecutive years gave 69 and 37·8 in. The yield is reckoned to average 9,360 m. c. ft. with an exceptional minimum of 2,500 m. c. ft. The dam, a mile downstream of

Bandhan, at the place referred to above, would be 1,600 ft. long and 110 ft. high giving a gross capacity of 8,780 and effective 6,185 m. c. ft. The submerged land is forest, partly belonging to Pagara State, the river forming the boundary between Hoshangabad and Chhindwara. From the dam an open channel would be carried along the R. bank over 8 mi. of difficult country, at about R. L. 1,700, to a forebay a little N. of Totar Pahar (55 J/10, square 3). There would be two large nala crossings and 15 smaller ones; a tunnel of 1,600 ft. will reduce the length by a mile, and much of the route is precipitous and may involve further tunnelling. The forebay site is 5 mi. S.-W. of milestone 24 on the road named. The report proposes damming a nala for this purpose, but it would appear far cheaper to excavate a forebay, for which the ground appears suitable on the 1 in. map. The pipe line, including a tunnel of 1,060 ft. would be 1½ mi. long and would give a fall of 300 ft. to the Dudher tributary, 2 mi. W. of the name on the 1 in. map and 2½ m. W. of the 24th milestone. The dependable discharge is about 176 cusecs from the storage alone, which would be increased during most of the year by the natural flow; and with some extra carry-over it is probable that 200 cusecs could be obtained in the worst years. Taking the lower figure the power would be 176×300/15 or say 3,500 kW. continuously. Pachmarhi is near by and there are possibilities in the way of a tramway there, but the load could not be absorbed at present. The project would be moderate in cost, namely about Rs. 900 per kW. continuous or say Rs. 300 per kW. installed, for the hydraulic development only.

(4) *Indravati River, Chitrakot fall, Bastar State.*—This is 23 mi. W. of Jagdalpur and is shown on sheet 41 of the old 1 in. Central Provinces and Vizagapatam Agency Topo. Survey and is on map 65E/12. The catchment above the fall is 6,400 sq. mi. of which about half is under cultivation. The total monsoon yield is estimated on Binnie's method to be 362,000 m. c. ft. based on a mean monsoon fall of 52·8 in. There are not enough rainfall stations to enable Barlow's method to be applied, but the average total rainfall is over 60 in. The river has not been regularly gauged over a long period, so the information available is somewhat scanty. Gaugings during 1920, however, are tentatively assumed to show that, with storage, a constant discharge of 3,000 cusecs during the whole of the 7 dry months can be depended upon, while the discharge in the wet months is far greater.

The figures given are as follows:—

TABLE 45.—*Discharge and make-up for Indravati River.*

Month.	Assumed discharge of stream. (Cusecs.)	Make-up from storage. (Cusecs.)	Quantity of make-up (m. c. ft.)
October	3,000	*Nil.*	*Nil.*
November	2,500	500	1,296
December	2,000	1,000	2,678
January	1,600	1,400	3,750
February	1,300	1,700	4,112
March	1,200	1,800	4,821
April	800	2,200	5,702
May	500	2,500	7,196
	equal to 25,890 m. c. ft.	TOTAL	29,555 m. c. ft.

1st proposal.—The project would, therefore, preferably be developed on combined flow and storage. The dam site is 700 ft. upstream of the Chitrakot fall; the length would be 5,400 ft. with a maximum height of 63 ft. But the submerged area of over 60,000 acres covers very valuable agricultural land and many villages, and it is therefore probable that some less expensive site would have to be found; the compensation at this site would be over 13 lakhs. As reconnoitred the above reservoir would contain 41,400 m. c. ft. effective, the bed level being at R. L. 1,707, cill level 1,720 and highest level 1,770.

The natural waterfall is about 100 ft. in height but by means of a contour channel on the L. bank for 15 mi. a fall of 300 ft. is obtainable from a suitable forebay site opposite Karli. The length of channel is some 15 mi. mostly on cliff. A pipe line 2¼ mi. long, of which 1 mi. would be in tunnel, leads to the power house site at the western Beja village. (It would be preferable to use the tunnel for the channel and to have the forebay on the W. of the spur, thus greatly shortening the pipe line.) The power house site is stated to be 50 ft. above bed level and 20 ft. above flood level, but no R. L. is given. If the fall of 300 ft. is to the power house site it seems probable that that site could be lowered so that the whole (variable) draft head below could be utilized, giving about 10 per cent. more fall and power.

The power available with the above lay-out would be of the order of 3,000×300/15 or 60,000 kW. continuously. The cost of the hydraulic development is roughly estimated to be Rs. 500 per kW. continuous, or say one-third of this per kW. installed, so the project is distinctly a cheap one. For reasons indicated however this project may be considered impracticable, considering that it is in a Native State. If the large storage were ever justified it could be carried out as a supplement to the less ambitious projects that follow.

2nd proposal.—If Chitrakot fall alone were developed, with storage as indicated above, there would be no open channel and a pipe line of only 1,100 ft.; and a good power house site exists on the left bank, well above H. F. L. The effective fall is stated to be 75 ft. but this evidently assumes that the draft head from power house to bed level would be lost; the full head of 100 ft. would naturally be utilized, giving 3,000×100/15 or 20,000 kW. This site is also much more accessible.

Bastar State is very isolated and far from any present demand. At a distance of about 65 mi. there are promising schemes near Jeypore, which is nearer by that amount to Vizagapatam, so there is not much prospect in the coast direction. For the present, however, the object is to ascertain the most practicable schemes in case power should be required.

3rd proposal.—It seems clear that the great storage contemplated by the local investigating officer would not be permissible. But from data given above it is probable that a minimum perennial discharge of about 1,200 cusecs can be depended upon to about the end of March. The April discharge is taken as 800 cusecs and the minimum measured in May was about 400 cusecs. To obtain a constant minimum discharge of 1,200 cusecs some 3,100 m. c. ft. only would be required instead of 41,000 m. c. ft. The contour plan of the site shows that this storage would be practicable and probably reasonable in cost; at contour R. L. 1,740 some 3,500 m. c. ft. could be obtained with a comparatively small waterspread. Using the natural fall only, the power capable of development would be 1,200×100/15 or 8,000 kW. With no channel, a short pipe line, and a low dam this would certainly prove a cheap development.

4th proposal.—If this scheme were carried out the fall below could still be utilized. The old maps show no levels, but the river below the fall runs in a gorge. At some point to be determined a pick-up weir would be placed across the river, such that the tail waters would discharge into this small reservoir without serious loss of head. From behind this weir a tunnel would be taken straight through the spur to a point near Bintha, whence the remaining fall of 200 ft. (probably 250) could be developed by a short pipe line to near Karikot. With the regulated flow of 1,200 cusecs the power here would be an additional 16,000 kW. continuous. The length of tunnel might be not more than about 3 mi. but this is a matter depending on the slope of the river bed and the height of the pick-up weir.

5th proposal.—The report states that in 26 mi. below Chitrakot there is a fall of 550 ft., or 250 ft. over and above the two projects last outlined, the balance occurring in 11 mi. If the upper schemes materialized the lower reaches—and possibly the reach from below the fall to Karikot—could be developed by means of a series of lifting dams of 50 ft. or so, *vide* paragraph 31 of this Report above. The extra power available is 20,000 kW. at any rate, however obtained. Tunnelling seems impracticable on these reaches.

6th proposal.—The Report further states that the Indravati enters Bastar State at R. L. 1,800 while, through the range to the S., the Kolab River at its junction with the Ganesh-bahar from Bastar is R. L. 1,500. (Map 65 J/1.) A 16-mile tunnel however is a serious obstacle to developing in this direction. It is however worth examination, as the lie of the land may be more favourable than it appears from the maps.

(5) *Machna River, tributary of Tawa and Narbada, West of Betul* (Map 55 G/13.)—Upper site (see further entry below). (i) This site is reached from Deogaon village at mi. 9½ on the Betul-Chicholi road. The catchment area is 136 sq. mi. and the two consecutive driest years gave 18¼ and 31½ in. of rain respectively. The mean yield of dry years is taken as 1,135 m. c. ft. dropping to 429 m. c. ft. in the worst year. There is a small flow even in the dry months, averaging about 13 cusecs, but dropping to under 2 cusecs in June. By means of an earthen dam 2,000 m. c. ft. could be impounded, giving an available storage stated to be 1,840 m. c. ft. A mean flow of 32½ cusecs could be obtained, in the worst year, with the carry-over included in these figures. In 1920 a day's rainfall of 6·4 in. resulted in a flood discharge of 25,000 cusecs; the heaviest fall recorded in a day is 14·61 in. The earthen bund would be about 5,800 ft. long and 74½ ft. maximum height with an average of 27 ft. it would be situate between Deogaon and Padal Khurd villages, 8 mi. S.-W. from Betul (or Badnur). Flood waters would be surplussed by means of a waste weir into a small nala N. of Padal Khurd, for which the site is good. Part of the submerged land would be agricultural and the rest waste, but two villages with 60 houses would be included. The Betul-Ellichpur road would also have to be raised slightly for about ½ mi. From the dam

an open channel in earth of 2·3 mi. on the left bank would lead to a forebay at R. L. 2,000; some deep cutting up to 45 ft. would be required through the watershed, with two syphons and two road bridges. The forebay site chosen would have a large regulating capacity, carrying some 14½ m. c. ft. (if so much proves necessary, which is doubtful). From the forebay a pipe line of 2½ mi. would lead to a power house on the banks of the River Tapti, near mi. 11 from Betul on the Ellichpur Road, at an elevation of R. L. 1,545. This gives a fall of 455 ft. The selected site is 10 ft. above H. F. L. and 40 ft. above bed level. It seems probable therefore that, as reaction turbines would be used on this head, a further fall of 10 to 25 ft. could actually be obtained by placing the wheels lower down and using the draft head. The site is generally favourable, and the cost of storage is estimated at only Rs. 211 per m. c. ft. The total cost of the hydraulic development up to, but excluding, the forebay is estimated to be only 4¼ lakhs or say Rs. 500 per kW. continuous; it would therefore be about one-third of this amount per kW. installed, which is cheap. The power obtainable continuously will be of the order of 32·5×455/15 or nearly 1,000 kW. so that on commercial load factors a plant of 2,500 kW. or more could be installed at an exceptionally low cost of about Rs. 175 per kW. up to the forebay or perhaps not above Rs. 350 including the plant, which could generate 8½ million units per annum. Plans and estimates are on record, and the site is certainly worth detailed survey.

(ii) A second site is 8 mi. from Chicholi, in Betul District, see preceding entry. The site examined is on map 55 F/16 and reached by cart track 10 mi. N.-W. from the 44th mi. of the Betul-Itarsi Road. A dam site was selected 1 mi. downstream of village Bondri, on the left bank, from which by means of a long channel a fall of 350 ft. is obtainable. The river is almost perennial, and generally carries some water till about the middle or end of May; on 30th April 1920 the flow was 3·8 cusecs. The catchment area above the site is 263 sq. mi. mostly undulating land under cultivation. The rainfall in the two driest consecutive years was 18¼ and 31½ in. and the effective yield (mean of the two years) is given as 8·35 m. c. ft. per sq. mi. Over the whole catchment this gives 2,200 m. c. ft. If the upper and more favourable site on the Machna R. (q. v.) is developed its waters would be diverted to the Tapti and 136 sq. mi. of catchment would be lost except for such floods as might be escaped into the river. This must not be overlooked and in the present project as drawn up the net 127 sq. mi. only are considered. The yield in the above conditions would therefore be 2,200×127 or 1,060 m. c. ft. while in a year of exceptional drought not more than 400 m. c. ft. would be obtainable. The necessary carry-over has been allowed for in the scheme as drawn up. A dam 2,000 ft. long and 130 ft. high at the highest point would impound some 2,000 m. c. ft. at the point named, submerging a village and some good land. The channel proposed on the right bank is 6 miles long, including two tunnels aggregating 4,850 ft. It would appear possible to shorten the route greatly by means of syphons or suspension bridges at the intervening streams. A smaller dam near the end of the channel would store 33 m. c. ft. additional, for regulation, at a moderate cost of 3½ lakhs. The project as drawn up includes a further short channel to a forebay and a pipe line ¾ mi. long to a good power house site. There appears, however, to be a possibility of carrying a pipe line through a short spur from the regulating storage and thence down a shorter route to a point some way lower downstream. The tail waters would not be required for irrigation. It would appear probable that about 1,000 m. c. ft. could be depended upon in the worst year, namely 400 yield and 600 carried over, giving a flow of some 30 cusecs throughout the year. This is equivalent to 700 kW. 24 hours continuous power. Rough estimates of the cost of the hydraulic development come to about Rs. 10 lakhs so that the cost per kW. continuous would be about Rs. 1,400 for this development. This on commercial load factors would be some Rs. 500 per kW. installed, which is not unreasonable, implying some Rs. 650 to Rs. 700 with the plant. It is for consideration whether the site should not preferably be developed for the full catchment, to the exclusion of site (i) preceding.

(6) *Mahanadi River, tributary of Son, Jubbulpore District.* (Map 64 A/7, 8).—The site examined is a few mi. E. of Kundam village. Here the catchment area is 96 sq. mi. and the mean yield of the two driest years is estimated to be 2,976 m. c. ft. giving 85 cusecs. The maximum storage to be provided for is estimated at 4,700 m. c. ft. for the maximum yield, and the dam site proposed at R. L. 1,850 (apparently on the 7th sq. of map 64 A/2) would carry 3,900 m. c. ft. with a length of dam of 3,000 ft. and height of 50 ft. A length of open channel of 12 mi. would, it is stated, give a fall of 1850—1450 or 400 ft. No details are given, but apparently the tail waters would be discharged into the Labhera Nala on the 6th sq. of map 64 A/7. The power available is of the order of 85×400/15 or

2,250 kW. continuous 24-hour power. A somewhat obscure note to the report indicated irrigation possibilities near the power house on Labhera Nala, where an additional catchment of 19 sq. mi. will yield over 500 m. c. ft. with a fall of 200 ft. The connection is not clear, and the scheme merits completion.

(7) *Nagdoari River, Hoshangabad District.*—The best site discovered on reconnaissance was 2 mi. S.-W. of Nimghan village, square 3 of map 55 J/6. The stream is a tributary of the Denwa, Tawa and Narbada, rising on the N. slopes of the Pachmarhi Hills, and reached from Sohagpur. The catchment at the site is 25½ sq. mi. of forest land. The average yield, determined by Mr. Barlow's method, is estimated at 1,690 m. c. ft. while in the two worst years it would be 1,367 and 667 m. c. ft. A dam 660 ft. long and 250 ft. high in a gorge is suggested, but the cost of this would appear to be prohibitive. The capacity would be 1,367 m. c. ft. of which it is reckoned that 1,017 m. c. ft. would be available in each of the two driest consecutive years. This gives a continuous discharge of some 29 cusecs. The river is perennial, and carried 26½ cusecs before the monsoon, on the 3rd June 1920; further gauging is however necessary before this figure can be accepted as a minimum. The total continuous discharge is for the time being taken as 56 cusecs, but it is doubtful if it would be so much. A tunnel of 7,200 ft. followed by an open channel of 2,700 ft. (or, more probably, a pipe) would lead to a forebay on the R. bank, N. of the site, where a pipe line 7,500 ft. long would give a fall of 730 ft. into the nala 1 mi. N. of Kokra village at R. L. 1,270. The dam site is at R. L. 1,850 with a full supply level of R. L. 2,102 as proposed. The power capable of development would be of the order of 56×730/15 or say 2,700 kW. continuous and the hydraulic development is estimated roughly to cost 42 lakhs. For the present therefore the project would be very expensive even if fully developed. It is probable, if gaugings show that there is always a fair minimum flow, that the scheme would work out cheaper per kW. with a far less costly dam, carrying enough water to supplement the flow during the dry months to 30 or 35 cusecs.

(8) *Nahara River, Baiher Tahsil, Balaghat District.*—This is mentioned in the Preliminary Report, page 86, as worth reconnaissance; and the reconnaissance shows it to be worth survey. The site is on map 64 B/4 and 8, and in detail on the 4 in. Forest map 112 S.-E., 1. The river is not perennial and would be developed on storage. The catchment is 111 sq. mi. steep and hilly, with monsoon rainfall of 34¼ in. and 40½ in. in the two driest consecutive years, at Baiher, which is outside but near the catchment. The probable mean annual run-off is 6,300 m. c. ft. while in the driest year it is taken, by Barlow's method, to be 1,796 m. c. ft. It is proposed to build a masonry dam near Sale village, 800 ft. long and 126 ft. high at maximum. This would store some 4,000 m. c. ft. Thence an open channel of 5½ mi. on the L. bank would lead to a forebay above the junction of the Uskal and Nahara rivers. A pipe line of 6,000 ft. would then give a fall of 660 ft. to a power house below Tikaria village. Taking the dependable continuous discharge as 90 cusecs (with the carry-over provided) the available power is 90×660/15 or say 4,000 kW. continuously. The hydraulic development is estimated roughly to cost 30½ lakhs, or say Rs. 800 per kW. continuous, which gives a very reasonable outlay on commercial load factors. It is conceivable that the Uskal R. might be combined with this.

(9) *Narbada River, Mandla District.*—This project proposes to bridge across the loop in the river of which Mandla town is near the centre; from 30 to 45 mi. of bend could be short-circuited by a channel some 12 mi. long (more or less) with some tunnelling or deep cutting. The river is perennial, but the discharge dropped to 28 cusecs at the site in May 1920. Storage would therefore be necessary to supplement the hot weather flow. The catchment is 3,380 sq. mi. at the proposed headworks, situated near Mohania, 14 mi. N.-E. of Mandla (map 64 B/6, 10). This is below the junction with the combined Burhner and Halon Rivers, which are accountable for some two-thirds of the total discharge. If these rivers were regulated as proposed, and possibly the main river also, there would be no difficulty at the pick-up weir in the combined river at Mohania.

The proposals sent in deal with three reservoir sites on these tributary rivers and one on the river itself, with a total capacity of 35,500 m. c. ft. but the sites have not been fully investigated. They are :—

1st on the Burhner River (Barmer on old maps) map 64 B/14, near Parsa and Dintri villages, where the catchment is 616 sq. mi. with a probable yield of some 17,000 m. c. ft.

2nd on the Halon River, map 64 B/15, between Phonk and Bija near Chapartola village, where the catchment is 330 sq. mi. and the probable yield 7,700 m. c. ft.

3rd on the Narbada itself near Dindori, map 64 F/1, where the catchment is 862 sq. mi. and the probable yield 11,000 m. c. ft

An open channel some 12 to 15 mi. long is proposed from a pick-up weir near Mohania to a forebay site near Kondra, where there is a road bridge (map 64 B/6); but see alternative proposed later. The available head, with a pipe line 1,500 ft. long, is given as 150 ft. to a power house site 80 ft. above bed level and 20 ft. above high flood level. It appears therefore that at least 170 ft. head can actually be depended upon, using the draft head, and considerably more except at very occasional flood times. On the forest map 110 N.-E. 1 the fall is given as 1,575—1,425= 150 ft. net, whereas spot levels on the map itself show a bed level of 1,284 ft. instead of 1,425 ft. but an arbitrary datum was probably taken. There is a site for regulating storage about 2 mi. back from the forebay, and with so long a channel this may be advisable to the extent of about 1 day's supply (say 80 m. c. ft) unless the forebay site offers similar facilities. The maximum flood discharge of the main river at Mohania in 1920 was 278,000 cusecs on 8th August; the actual maximum is unknown but may be far greater. Further investigation is required, especially as regards the effect of the dams on the reaches above them. It is estimated that with storage to tide over the dry months 1,000 cusecs can be obtained. This, on 170 ft. head, is equivalent to 11,000 kW. continuously.

The project is worth detailed examination, to supplement the reconnaissance report. *If practicable* it would appear preferable to place the headworks near Dupta, 12 mi. further N. than Mohania, where a considerably greater head would be obtainable with a channel of about the same length. Only survey can determine if this can be done. It would involve a further pick-up weir on the combined Burhner and Halon rivers and a channel from it to the headworks through the intervening spur on map 64 B/9. The additional capital cost of this alternative can be balanced against the additional value of the power from the extra head obtained.

(*10*) *Patna River, Damoh District.*—A site was examined near Salaia Railway station, Bina line, on map 55 M/13, where the catchment is 90 sq. mi. The rainfall of the two driest consecutive years was 24·9 and 31·9 in., the lowest record being 21 in. (1868). Yields of 1,140 and 1,940 m. c. ft. are estimated for the two years and more than this quantity of effective storage could apparently be obtained a mile upstream of the railway bridge; a dam of 4,000 ft. at about R. L. 1,450 would give a waterspread of 23 sq. mi. A channel of 6 mi. with a tunnel of 3,500 ft. in addition, along and through the ridge to the west, would give a fall of 300 ft. with 4,000 ft. of pipe line, discharging into the tributary of the Padri N. above Majholi (square 5) which joins the Patna lower down. With a minimum discharge of 44 cusecs the power would be of the order of 44×300/15 or 880 kW. continuous power. Further examination is required.

(*11*) *Penganga River, Yeotmal District.*—This is mentioned in the Preliminary Report, page 86 and again in the Appendix to "List of Sites," two possible developments being referred to.

1st site.—The site at Sahasru Kund near Bittargaon, Kinwat Forest Reserve (map 56 I/3) has not been examined; the natural fall is shown as 120 ft. on the map but beyond the fact that the river is perennial there is no information.

2nd site.—The second of these sites is in Kelapur Forest Reserve (map 56 I/5) and was examined locally by Mr. Nagoji, who found no fall or prospects.

3rd proposal.—In the Second Report, page 62, the suggestion was made of a possible development of the great double loop which embraces both the above sites and covers a large part of map sq. 56 E and I. This certainly merits further examination, in conjunction with what follows.

4th proposal.—The smaller of these bends, between Brahmangaon village and Phulsangwi village (56 E/14), —both shown on the Atlas sheets—has however been examined and offer good promise of power. There is a possible site for a reservoir near Sindgi village on square 6 of this map, 4½ mi. S. of Dhanki. A dam or earthen bund of considerable length—some 3 mi.—would be required for the stored water to command the 1,300 ft. contour, the bed of the stream being at about R. L. 1,250, and the ground very level. The catchment is 3,100 sq. mi. and the average rainfall of the two worst years is taken as 21·2 in. and the catchment is classed as C in Mr. Barlow's method—see para. 23. The run-off has been taken as 15 per cent. giving 7·4 m. c. ft. per sq. mi. or 23,000 m. c. ft. per annum, equivalent to 657 cusecs. From the reservoir a channel would run along R. L. 1,300, with various nala crossings and some heavy cutting (50 ft.) near the summit at Kharus Khurd. It is stated that the channel, some 13 mi. in length, would for the most part not be expensive to construct. The forebay would be made by a dam across the nala 2 mi. N. of Kharus Khurd, between cliffs, and could be of fairly large capacity. Thence a fall of some 250 ft. is obtainable with 1½ mi. of pipe, to a power house 2 mi. S. of Ningnur village (squares 5, 6) at an elevation of R. L. 1,050 or less. The power available is therefore some 657×250/15 or 11,000 kW. continuous, so that on commercial load factors some 30,000 kW. could be installed if there were need of it. The distance is about 120 mi. only to Nagpur.

This is one of the most promising sites yet reported on, and it certainly merits detailed and early investigation. The investigation however should extend over a larger area, so as to embrace the second great loop; it may be possible to find such an alignment for a channel, with a tunnel through the ridge, that the waters released from the single storage could be used a second time. Or, again, the fall proposed above ends far above, and many miles from the main river, in a subsidiary nala; possibly a reasonably short fall can be found to utilize the whole head with a longer open channel. If so the power would be greatly increased. An extra 100 ft. would mean a further 4,000 kW. continuous, and would justify a large additional expenditure. Furthermore, if regulation at one site were effected, it might be possible to use the regulated flow at a series of lifting dams further downstream, in the manner indicated above for the Indravati R.—*vide* para. 31 also.

(12) *Purna River, Amraoti and Betul Districts, in conjunction with Moga River, Ellichpur.*—Separately these streams have been relegated to the list of " useless sites," but the investigating officer suggests the possibility of combining them usefully. Three sites are suggested, of which the third would use the tail waters of the first. (Map 55 G/11.)

(i) A dam on the Purna a mile S. of Junapani and ½ mi. upstream of the Ellichpur-Betul road bridge, with an open channel on the 2,000 ft. contour up to near station R. L. 2546, where a short tunnel would be required and a drop to R. L. 1,550 or say 430 ft. net would be available to near Pipalna. The length of channel would be over 8 mi. of difficult ground. In conjunction with this, the N. tributary of the Moga N. could be dammed at Kothal Kund so as to flow into the channel ½ mi. S.-E. of the village, at mile 18 on the road. The catchment areas are 100 and 20 or 120 sq. mi. together and the yield is estimated at 1,340 and 430 or 1,770 m. c. ft. in all, which could apparently be stored at the sites chosen. Taking this as 55 cusecs the power available would be about 1,500 kW. continuously.

(ii) To dam the Moga main nala at Kundi and run a channel along at R. L. 1,750, dropping at the junction with the N. tributary where there would be a fall of about 150 ft. The yield from the 40 sq. mi. of catchment is estimated at 1,100 m. c. ft. but this appears to be excessive as it is based on 29·7 in. of actual run-off. By itself this scheme is useless, but the idea is to utilize the regulated flow again in the third scheme. It would be better to collect the water there and omit consideration of this site, if it can be done.

(iii) To dam the Moga at Sipala, where the tail waters of both Purna and Moga as well as the yield from the extra catchment would be impounded. A constant discharge of 102 cusecs is estimated as possible. From the reservoir a channel on R. L. 1,500 would enable a drop to R. L. 1,395 to be obtained or say 100 ft. giving another 680 kW. continuous.

None of the three projects appears particularly promising as the power is small and the cost of the works would be large. In the case of No. (i), which alone has a fair fall, it would probably be worth while to continue the channel along the 2,000 ft. contour on the S. side of the tunnel, or, alternatively, to avoid the tunnel and continue on the N. side of the ridge, up to a point which would then be either 1 mi. or 2 mi. due W. of Pipalna Khurd, where a fall of nearly 550 ft. would be obtainable to the stream at Khumai R. L. 1,450. The extra 3 or 4 mi. of conduit would probably be balanced by a shorter pipe line, with greater head and power. Even the 1,500 kW. continuous assumed implies, on commercial load factors, a plant of 3,500 to 4,000 kW. A further possibility would be to dam the two streams as in (i) and to divert the waters of the Purna into the reservoir on the tributary of the Moga near Kothalkhund on the 2,000 ft. contour. It is not certain from the 1 in. map that this is practicable, but it should be examined. If the levels work out, a much shorter channel could then be carried along on the R. bank of the tributary to a point below the station R. L. 2,270 whence a fall of some 400 ft. (more or less) would be obtainable to the neighbourhood of Dhaba Dhana. The project merits further examination of the yield of the catchments, the storage capacity obtainable by the dams, the best channel route, and the falls with length of pipe line.

(13) *Silgi, Kasaha and Sankul Nadi, Jubbulpore District.* (Map 64 A-11, 12).—This is a combined scheme embracing 3 small tributaries of the Mahanadi which flows into the Son; they rise in the hills near Shahpura. The catchment areas are 138+56+24=218 sq. mi. and the maximum and mean aggregate yields are calculated to be 10,680 and 6,760 m. c. ft. giving a dependable discharge of 193 cusecs. Storage sites are available on all three streams and are capable of holding 8,640, 8,070 and 3,060 m. c. ft. respectively which is much in excess of the yields. A connecting cut 2 mi. long would run from the Silgi to the Kasaha and one of 2,000 ft. from the Kasaha to the Sankul. From the Sankul a 5½-mi. channel would lead to the

forebay, where a pipe line $2\frac{1}{2}$ mi. long would give a fall from 2,000 to 1,450 ft. or 550 ft. A pipe line of this length is a serious drawback unless the main drop can be concentrated in a comparatively small length, with a surge tower at the top of that length. Probably survey will show better results by a shorter pipe line with a small loss of head. It is unfortunate that the Sankul storage is the smallest of the three, *viz.*, 3,060 m. c. ft. The continuous 24-hour power available may prove of the order of $193 \times 550/15$ or over 7,000 kW. and the scheme merits detailed examination.

(14) Sitarewa (or Chitarewa) River, Narsinghpur District.—This is a tributary of the Narbada, on map 55 J/14, and the reservoir site lies some 9 mi. S. of Mohpani on squares 5 and 6. The stream dries up in March, so would have to be developed on storage. The catchment is 99 sq. mi. mostly forest. The annual monsoon rainfall at Tamia and Mohpani respectively is: mean 60 and 48; minimum 32 and $27\frac{1}{2}$ with single falls of 13 in. recorded at both stations. Calculated by Mr. Barlow's method (para. 23 *supra*) the probable run-off in an average year is 2,120 m. c. ft. and the minimum about 800 to 1,000 m. c. ft. An effective storage of 2,720 m. c. ft. would require a dam 650 ft. long and 167 ft. high at about R. L. 2,083 in the bed. It is proposed to have the take-off of the channel 2 mi. S. of the dam site, but the plan does not show the matter clearly. Two miles of open channel, on fairly easy ground, lead to the forebay. A pipe line of 3,200 ft. gives a fall of 715 ft. into a small nala to the west, on square 2 of the map, which does not rejoin the river. With a discharge of 78 cusecs the power will be of the order of 3,700 kW. continuous. The cost of the hydraulic development is roughly given as 16 lakhs, which would give a reasonably cheap scheme. It is noted that as the tail waters do not return to the stream future irrigation might be affected. The loss of this stream however would be the gain of its neighbour, the Dudhi, commanding a similar area S. of the Narbada and E. of the Dudhi. By means of a 15 mi. channel (in place of 2 mi.) a fall of 950 ft. could be obtained into the Sitarewa, and the extra power would probably be worth the extra cost, if the ground is not too difficult to negotiate. The cost of the hydraulic development is estimated to be some Rs. 430 per kW. continuous, which would be an exceptionally low cost per kW. installed on commercial load factors.

(15) Son-bhadra Nadi, tributary of the Denwa and Tawa, Hoshangabad District.—This site is 2 mi. S. E. of Dhain village on the 7th sq. of 1 in. map 55 J/3 and 25 mi. E. of Taku railway station. The stream rises partly in the W. slopes of the Pachmarhi Hills. The stream is not perennial and power would depend on storage. The catchment area at the site is 187 sq. mi. mostly forest. The nearest raingauge station is Pachmarhi, which is outside the catchment and in a small zone of high intensity; while the average rainfall is 70 in. here it is only 60 in. a few miles west and in the catchment, according to the contoured rainfall map of India. It is uncertain if this factor has been taken into account in calculating the run-off by Mr. Barlow's method (para. 23 *supra*). The results given are 12,400 m. c. ft. in an average year and 4,890 m. c. ft. in a minimum year; possibly these figures should be reduced in the ratio of 7 to 6, but, on the other hand, Mr. Barlow's method appears to have been found to give results too low in the Central Provinces. The total monsoon rainfall in the two driest years, according to the report, was 69 and 37 in. of which 23 and $11\frac{1}{4}$ is calculated to be available. The main dam site is $1\frac{1}{4}$ mi. S. E. of Dhain and the dam would be 850 ft. long and 114 ft. high. There would also be subsidiary flank dams, and flood waters could be safely discharged. The reservoir capacity would be 10,000 m. c. ft. with effective storage of 7,459 m. c. ft. but could apparently be made larger if the average yield justifies this. The submerged land is mostly forest, with two small villages. The take-off would be from one of the subsidiary dams, in still water, as the stream is heavily charged with silt in the rains. An open channel of $3\frac{1}{2}$ mi. over easy ground leads to a forebay 6 m. W. of Dhain where a pipe line 3,900 ft. long would give a fall of 180 ft. into the Nonpani Nadi, which eventually reaches the Tawa. There are no irrigation rights existing or prospective. A further reservoir site exists 10 mi. upstream, which could not by itself be usefully employed for power; but as the rainfall in good years is high it is possible that this storage might be worth developing for additional carry-over to equalize bad years. It would stop most of the silt and enable perfect regulation to be effected, by letting the waters down the bed of the stream as required. The power would be of the order of $213 \times 180/15$ or 2,550 kW. continous 24-hour power, and the hydraulic development is roughly estimated to cost about 17 lakhs. This is some Rs. 670 per kW. continuous, so that on commercial load factors the project would be very reasonable in cost.

(16) Tapti River, above Burhanpur.—In the list of "useless sites" in the Central Provinces the Tapti is written off on the lines of investigation pursued locally (see para. 130). Nevertheless it is possible

that the river can provide larger power on other lines, namely by means of a single large upper storage and lifting dams—*vide* para. 31 above. At site 5 of those mentioned in the "useless" category the constant discharge under the worst conditions is given as about 450 cusecs. The elevation of the bed is about R.L. 1,030, but all further data are wanting. Let it be assumed that in this neighbourhood a main storage, large enough to impound the average yield of the catchment, could be constructed without detriment, and that the draw-off level is 50 ft. above the regulated flood level of the bed. Let the mean height between full supply level and minimum draw-off be another 50 ft. Then the discharge of 450 cusecs under a mean head of 100 ft. will give 3,000 kW. continuously. Even allowing for the fact that this, on commercial load factors, would enable a plant of 6,000 to 10,000 kW. to be put up it might not be commercially practicable.

The case would however be materially altered if this regulated flow were used at a series of lifting dams below, say in 50-foot steps (see para. 31 *supra*). In the next 100 mi. or so to the junction with the River Purna there is a fall to about R. L. 630, or a further 400 ft. Eight lifting dams of 50 ft. each would cover this and give a further 12,000 kW. continuous power without taking into account the larger additional catchment area, which a second main storage might impound. It is desirable that the Tapti should be further investigated along these lines, as it appears probable that 15,000 to 20,000 kW. continuous could be developed from it.

(*17*) *Canal falls.*—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.

103. Coorg ; **known sites.**—Several sites have been mentioned in Coorg, *viz.*, (i) the Abbi catchment basin scheme, map 48 P/11, (ii) the Saratabbi waterfall, map 48 P/16, also on the Barepole River, and (iii) the Jenparai fall (or Janepari) map 48 P/16, on the same river. The Executive Engineer, Coorg, drew up a scheme for using the Abbi fall, but the prospects were not sufficient to warrant further action. The catchment areas of the Abbi and Saratabbi falls are too small to be of service, as the possibilities of storage are also small. The Janepari fall however is worth investigation. The contours are so close on the 1 in. map that a photographic enlargement was prepared. From this it would appear that by means of an open channel in the rock a fall of 1,000 to 1,250 ft. can be obtained instead of the 150 ft. of the fall itself. The channel would be 5 or 6 mi. long (according to the tunnelling effected through spurs) ; if a 9-mi. channel were built the total fall would be 1,500 to 1,700 ft. An impounding dam could be built at about R. L. 2,450 or 2,500 near Kadike Motti, but the capacity has not been determined. There seems very little doubt that some 15 cusecs could be assured, giving some 1,500 kW. of continuous power ; but examination by an engineer versed in the work is necessary.

1C4. Jammu and Kashmir State ; **known sites.**—(*1*) *Chenab River, Riazi.*—Although not in British India this project would probably find its outlet for the sale of power in the Punjab, and it is therefore dealt with. A good deal of investigation has, it is believed, already been done. Reference to the 1-in. map 43 K/16 shows a great bend in the Chena a few miles N. of Riazi. Although far smaller thanb the Sutlej loop it is 10½ mi. round and only 1½ mi. across the short-circuit. It has been proposed to dam the river at the headworks, but it is doubtful if more than a diversion dam would be justified; if, however, an extra 50 or 100 ft. of head could be obtained in this way it would be so much gained, and it might even be possible to get enough storage in this way to increase the minimum flow. The R. L. at the headworks site is about 1,474 ft. and at the tunnel exit about 1,316, giving a gross drop of 158 ft. without any lifting dam. The tunnel would be about 8,600 ft. long or of course less if the height of it were raised by a dam. The cost of the dam might be balanced by the reduction in the cost of the tunne lplus the additional power. The normal flow does not fall below 6,000 cusecs, but 4,341 cusecs is the minimum recorded at Marala headworks. If it is assumed that the head at the diversion would about compensate for losses the minimum power available, without any definite lifting dam, will be about 2,900×150/15 or 29,000 kW. continuously. There is a smaller loop, within the great loop, with a fall of 35 ft. which could be used for construction purposes ; the river has already nearly cut through the very narrow intervening neck here. The highest flood in the last 20 years at Marala was 542,000 cusecs ; but a flood of 713,000 cusecs occurred in 1893.

(*2*) *Jhelum River, near Muzaffarabad.*—Like the preceding entry (Chenab) this project, although actually in Kashmir territory, is unlikely to be developed for Kashmir needs; the existing site at Mohora, further upstream, with a hydraulic development laid out by Col. Lotbiniere for 20,000 h. p. has so far only been utilized to about one-tenth of its capacity. Mr. H. W. Nicholson, B.Sc., A.M.I.C.E., Executive Engineer, after completing the preparation of the Bhakra dam project, was placed on special duty with the Hydro-Electric Survey; but before he had taken up his duties he was recalled to work on the Sutlej Valley irrigation project. Later on, before proceeding on leave, he handed over to the Survey a note on the possibilities of the Jhelum river at the hair-pin bend at the bridge near Muzaffarabad, on 1-in. maps 43 F/7, 8, 11, 12. This description is based on Mr. Nicholson's note, the comments being added.

The slope of the river is about 30 ft. a mile, and the project is based on tunnelling through the ridge so as to short-circuit a considerable length of the bend. There is no one outstanding alignment for the tunnel, as in the case of the Sutlej, Chenab and Jumna loops, and Mr. Nicholson examined no less than seven alternatives on the contoured maps. The following table shows the sites and data of these tunnels; lengths are taken from the maps, the fall is taken at 30 ft. a mile and the drop in the tunnel is taken at a slope of 1 in 2,000. The slope requires to be checked by levelling.

TABLE 46.—*Alternative tunnel sites on Jhelum.*

Tunnel	Length, ft.	Distance from bridge miles.			Fall, ft.	Nett fall exclusive of pipe losses, ft.
		Upstream.	Down-stream.	Total.		
A-A	5,000	1·2	3·6	4·8	144	141
B-B	11,300	3·5	0·0	9·5	285	279
C-C	19,900	6·0	8·6	15·5	465	455
D-D	32,900	12·0	13·8	25·8	774	757
E-E	51,000	15·8	19·5	35·3	1,059	1,033
F-F	57,700	16·7	21·3	38·0	1,140	1,111
F-E-F	58,500	10·7	21·3	38·0	1,140	1,110

The letters refer to a deposited map, but the reduced distances enable the points to be measured off. Clearly the shorter tunnels A-A and B-B would permanently put a very fine site out of action, by limiting the fall to a fraction of that available. The tunnels C-C and D-D would give practically the same power per foot of tunnel—and the cost of the tunnel would evidently be the predominant factor. The tunnel E-E s distinctly less favourable in this respect, besides being of unwieldy length for two working faces only, and the same remark applies to tunnel F-F. The last alternative, F-E-F involves two tunnels in series, of 6·2 and 5·5 m. in length respectively, and consequently gives four working faces; furthermore the tunnels can be brought out in the Agar Nala on the level, enabling a balancing reservoir to be constructed.

On the whole the tunnel D-D, with a working head of about 750 ft. is clearly the most favourable one to consider, until survey settles the matter. The formation of the hills indicates that there should be little trouble in driving the tunnel, which would be a gravity and not a pressure tunnel. The pipe line will be of reasonable length. The headworks would be near Garhi, on the Murree-Kashmir road, the intake dam being entirely in Kashmir territory. The tunnel through the spur would also be in Kashmir territory, entirely under a lofty ridge. The power station would be over the river a little above Kohala, on the Murree-Kashmir road, where the river itself is the boundary between British and Kashmir territory. A very small exchange of land would remove any difficulties on this score, if it were desired by both parties to construct the works. The existing roads serve all the sites, while transmission lines would be entirely in British India.

The minimum discharge of the Jhelum at Mangla, for the last 20 years is about 2,944 cusecs; the maximum during that period is 364,000 cusecs, but a flood discharge of 500,000 cusecs occurred in 1893. A project for a barrage in the Woolar Lake beyond Baramula was prepared by Mr. Purves, late Chief Engineer, Punjab Irrigation, to impound 167,000 cusec-days; this is still under investigation. If carried out it would give an extra 1,000 to 2,000 cusecs according to the period when the water would be used for irrigation; the natural flow from the time of the melting of the snows is of course very great. There are other storage possibilities also in the lakes of the main river and in its tributaries, so that the short period of minimum could undoubtedly be made to increase its yield. The minimum power available is practically $3,000 \times 750/15 = 150,000$ kW. continuous. This project, interlinked with that of the Sutlej River, and, in turn, with the Jumna, would provide power for the whole of the area bordering on the Himalayas for some time to come. Construction power is available from Mohora, near by. It is also recorded by Mr. Nicholson that the site is situated in the Sirmur series and Nummulitic geological beds, which are particularly suitable for various electro-chemical industries as well as for portland cement. The site is without question one of the finest in the whole of (geographical) India.

105. Madras; known sites.—The following pages give abstracts of the reconnaissance reports on a number of sites in Madras which appear well worth further detailed examination and survey. Some of them will certainly prove worth developing if there is a market for the power.

The investigations were begun by Mr. R. T. Sneyd, M.C., and continued after that officer's retirement by Mr. James Tate, Executive Engineer, Officer in charge of the Survey in Madras.

A good many of the sites require storage for their full development but rainfall conditions are more favourable in Madras Presidency than in most parts of India and most rivers are perennial. Most of the projects have moderately high heads; one has 5,000 ft.

Sites already investigated to an extent which makes an estimate of the minimum power reliable are in a separate list above; sites not examined at all are also separate.

The table below is a summary of the sites detailed below and the continuous power which they appear, on present information, likely to afford:

(1) *Chagattakall Sanabba and Chagattakall Doddabba Rivers.*—These two rivers near the Madras-Mysore boundary unite as the Sankada Gundi River at the foot of the Western Ghats. The former has a catchment area of 3 sq. mi. and a natural fall of 500 ft.; the latter a catchment of 6½ sq. mi. and a natural fall of 800 ft. The locality is close to Bhatkal harbour, and 20 mi. distant from the Haladi River, Kunchikal Abi scheme (q. v.). A project has been worked out by Mr. H. D. Rice, who considers that 1,000 and 1,400 ft. head could be developed, and that 4,700 m. c. ft. could be annually obtained and stored. If so a constant discharge of 140 cusecs on 1,400 ft. head gives 13,000 kW. of continuous power. It is not clear whether the fall is in British or Mysorean territory; in most cases hereabout the boundary divides the catchment and the fall.

(2) *Coonoor and Karteri River.*—These are referred to in the Preliminary Report, p. 89, a project having been drawn up by the present writer in 1905 for utilizing these streams for the electrification of the Nilgiri Rail-

TABLE 47.—*Madras; summary of known sites.*

Serial	River or site.	Nature of supply.	Site number.	Constant flow assumed (cusecs).	Head (ft).	Continuous power (kWs).	REMARKS.
1	Chagattakall Sanabba . ,, Doddabba	Flow and Storage	...	140	1,400	13,000	Mr. Rice's project.
2	Coonoor and Kateri R.	Do.	...	20	1,500	2,300	
3	Kolab R., Tetliguma	(See Bagra Falls)	(ii)	200	210	4,000	Dependant on development at Bagra, q. v.
4	Machkand R., Duduma falls	Flow and Storage	(i)	290	580	11,000	
	Ditto ditto.	Regulated flow from (i)	(ii) etc.	290	...	10,000	Dependant on regulation at (i); series of lifting dams.
5	Nagavalli R.	Flow	...	190	80	1,000	
6	Palni Hills; Pinjikavo project.	Storage	...	...	...	5,400	
7	Palni Hills; Porandalar River	Do.	...	15	1,500	1,500	
8	Palni Hills; Kumbar River or Manjapatiar.	Do.	...	15	1,500	1,500	
9	Vaniar River	Do.	...	14	500	450	
10	Varani River Kunchikal Fall.	Do.	...	40	1,400	3,750	Probably more.
		TOTAL	...	...	...	53,900	continuous.

way. The scheme was abandoned at the time, but has lately been re-examined in view of the further power requirements of the Government Cordite Factory at Aruvankadu. This factory at present obtains its power from the upper reaches of the Karteri River—see para. 64. Various alternative developments of the same site have been considered in some detail, so as to make comparison possible ; two of these schemes were not originally the work of the Survey, but they were revised by Mr. Tate, who also added the third. In all cases the intake and water supply are the same, so that if development proceeds it is a matter of which of the three methods gives the best results. All three projects involve tapping the combined streams near Runnymede station, Nilgiri Railway (map 58A/15), and thence constructing an open channel to a point where there is a considerable drop. The following are the broad outlines :—

TABLE 48.—*Alternatives on Coonoor and Karteri Rivers.*

Main storage.	45 m. c. ft. in existing reservoir enlarged. I	15 m. c. ft. from existing reservoir. II	15 m. c. ft. from existing reservoir. III
Minimum discharge assumed.	12·2 cusecs	12·2 cusecs	12·2 cusecs.
Minimum constant flow with storage.	16·2 cusecs	15 cusecs	15 cusecs.
Channel	8,000 ft. for 21 cusecs (insufficient).	15,800 ft.	About 12,000 ft.
Forebay capacity	50,000 c. ft.	Not stated	Not stated.
Pipe line, length	2,600 ft.	6,700 ft.	About 5,000 ft.
Working head	1,000 ft.	2,100 ft.	1,500 ft.
Plant assumed, total	1,850 kW. (1,200 kW. working).	3,000 kW. (2,000 kW. working).	2,250 kW. (1,500 kW. working)
Transmission line to Cordite Factory.	5¼ m.	8 m.	6¾ m.
Total estimated cost	14½ lakhs	23 lakhs	15·9 lakhs.
Cost per kW. of working plant.	Rs. 1,160.	Rs. 1,150.	Rs. 1,060.
Estimated cost per unit under working condition.	0·63 anna	0·55 anna	0·53 anna.

It appears clear that the third project will be the cheapest. The minimum gauging of 12·17 cusecs was found in connection with the railway project referred to, in 1905, after the driest year known ; the rainfall in this year was 41·05 in. against an average of some 60 in. over a catchment of about 65 sq. mi. The average flow for such a year may be taken as 23 cusecs, and the storage required to carry over the dry season of one year and to get 23 cusecs from the run-off of the worst year, with 5 dry months, is reckoned at 130 m. c. ft. In the course of the railway investigation sites suitable for the storage then required were found on both rivers ; but their full capacity was not determined. There is however little doubt that at least 20 cusecs constant discharge could be obtained. On the 1,500 ft. head this would give 2,300 kW. continuous 24 hr. power.

The headworks site at Runnymede is at about 4,800 ft. and No. II project above carries the flume to not far off Lamb's rock. It would be practicable, with some tunnelling and a forebay in the rock, to reach a point beyond this cliff, above the station where R. L. 4.471 is recorded on the 1 in. map. From here there is a clear fall down to R. L. 1,500 or (allowing for the channel) not less than 3,000 ft., in a horizontal distance of about 1½ mi. and directly beneath Kallar station. It might be necessary to lay the pipes in a tunnel, as has often been done elsewhere ; but the additional 900 ft. of head over project II gives 40 per cent. more power and *may* prove the cheapest project in the end.

(3) *Kolab River at Tetliguma, Vizagapatam District.*—This site is where the river falls from the 2,000 ft. Jeypore plateau to the Malkangiri level, on map 65 J/9, 13 in Lat. 18° 44, Long. 82° 12. It has a usable fall of only 210 ft. according to Mr. Sneyd's notes, and storage is probably out of the question ; if however the Bagra site were developed above the minimum flow at Tetliguma would be materially increased. It is, therefore, a reserve site for the future and with the regulated flow from Bagra would give some 4,000 kW. continuously. (See also the Bagra Falls on this river para. 88.)

(4) *Machkand River, Koraput Agency, Vizagapatam District.*—Some information regarding the 540 ft. Duduma falls on this river, about 80 mi. from Vizagapatam, was given in the Preliminary Report, p. 90 and Addendum to " List of Sites," and in the Second Report, p. 74. The Koraput plateau is at a general elevation of some 3,000 ft. and it is drained by the Machkand and the Kolab Rivers which later unite at Motu as the Sileru River, tributary of the Godavery. Below the plateau, at about 2,000 ft., is the Jeypore plateau, drained by the Kolab and Indravati Rivers (q. v.). Some 30,000 continuous H. P. at least is available between 3 sites on these rivers, and far more eventually. Attention has been mainly concentrated on the Bagra Falls on the Kolab (q. v para. 88), so not much additional information is available as to the Duduma falls. The site is on map 65 J/6 and is reached by many stages from Salur, B. N. R. The catchment area above the falls is 904 sq. mi. and the average annual rainfall at 4 stations in the locality is as follows :—

Jeypore 75 in. of which 64 in. falls from June to September.
Koraput 59 ,, ,, ,, 49 ,, ,, ,, ,, ,, ,,
Padwa 54 ,, ,, ,, 37 ,, ,, ,, ,, ,, ,,
Pottangi 63 ,, ,, ,, 45 ,, ,, ,, ,, ,, ,,

The fluctuations in 22 years are, for Jeypore, 46 to 105 in. and Koraput 40 to 84 in. The lowest conceivable run-off is many times the highest possible storage, so the point is a minor one except as regards surplussing, which is well provided for. There are two alternative dam sites; one examined by Mr. Sneyd is 1½ mi. above the falls, and another further upstream 2½ mi. above the falls, giving 40 ft. of extra head as well as cheaper storage was found by Mr. Tate. Both have solid granite foundations. The latter site has not been surveyed, but the former will serve present purposes; the surface area of its lake would be 83 m. sq. ft. and taking 30 ft. effective on a 100 ft. dam the capacity would be 3,300 m. c. ft. This would give 190 cusecs for the 6 dry months. The lowest recorded gauging was about 100 cusecs in May of an exceptionally dry season following a poor monsoon. Normally there is likely to be 300 cusecs to the end of the year. The minimum supply with storage is conservatively estimated as 290 cusecs. The land submerged by the dam is of little value. The original reconnaissance suggested a pick-up weir some 300 yds. below the main dam, for feeding the open channel, which is ¾ mi. long. It is probable however that with so short a length a pipe directly off the reservoir, leading to a surge tower above the main fall, would be preferable. If however the upper dam site is found the best an open channel would be necessary. Two forebay sites exist, the better one entailing a loss of some 15 ft. of head. There is no natural site for the power house; Mr. Sneyd suggested excavating one underground in the rock, out of the way of the spray of the waterfall. Probably this is the best solution of the problem. The waterfall is 540 ft. high and at least 580 ft. head could be obtained from the lower dam or 620 ft. from the upper dam. The power available with storage, under the worst conditions, will be $290 \times 580/15 = 11,000$ kW. continuous 24 hr. power, at a very reasonable cost.

The above however is only a small fraction of the power in this river. If the Duduma falls were harnessed, and the flood waters regulated at the main dam, there would be a constant flow of some 300 cusecs minimum down the river bed, subject only to the 24 hour variations. The main falls appear to be at an elevation of some 2,400 ft. and thereafter there are rapids for a great distance. At least a further 1,000 ft. of fall is available which, given the initial flood regulation, could be developed by means of a series of lifting dams. The larger tributaries would greatly increase the minimum flow and probably a further flood regulating storage would be necessary, or more than one. With so much power possible this could be faced. At least a further 10,000 kW. could be obtained in this way. If it proved possible to impound the whole run-off of the upper catchment, as seems likely from the nature of the ground, the river would be good for nearer 50,000 than 21,000 kW.

(5) *Nagavalli River at Royagedda, Vizagapatam District.*—Mr. Sneyd reported " a simple and cheap development within two miles of the Royagedda station on the projected Parvatipur-Raipur line of the B. N. R. Estimated yield about 750 kW." A latter note gives the power as 1,000 kW. continuous with a head of 80 ft., but no details are at present available. This is on Mr. Tate's list for further examination. The site is in Lat. 19° 10, Long. 83° 30 on map 65 M/8. See however the Kolab and Machkand Rivers in this district.

(6) *Palni Hills*; *Pinjikave power and irrigation project, Koniar River, Madura District.*—This is the revival of an old irrigation scheme considered and dropped—for apparently insufficient reasons—in the 'sixties of the last century. Mr. Sneyd in the course of his reconnaissances found the site, and the old report on it, and at once saw its great value for power. The story begins in 1861 when Col. D. Hamilton was in the Kodaikanal area and came accidently across an old breached earthen dam, stated by him to be some 600 ft. long and 90 ft. high, in the upper reaches of the Kumbar river, not far from the watershed, and 12 mi. West of Kodaikanal. Examining the ground behind the dam he found clear indications of the high water level in the once existing lake; but no local tradition even existed to show when the work had been constructed and destroyed. The assumption, however, was that the stored water was used for irrigation in the plains on the far side of the watershed, thousands of feet below, thus anticipating a common present day practice in hydro-electric work. The lake only filled to a height of some 50 ft. at the dam, but even so was stated by him to have had a capacity of some 4,000 m. c. ft., with a catchment of 30 sq. mi. Mr. Tate finds that catchment only 6·2 sq. mi. and the dam only ?80 ft. long. After some years discussion the Madras Government finally decided in 1872 not to proceed with the rebuilding of the dam, and the project was forgotten. In later years a reservoir has been constructed in the neighbouring catchment beyond the watershed, for a similar purpose of irrigation. Mr. Sneyd in 1919 marked the site off for investigation, judging it to be probably capable of giving 8,700 kW. on a head of about 5,000 ft.

In 1920 Mr. Tate examined the site and drew up a plan and a complete project in the rough. The situation is on map 58 F/8, at an elevation of over 7,000 ft., while the plains below, over the watershed, are at about

1,500 ft.; there is therefore a clear fall of over 5,000 ft. in a few miles.

Mr. Tate's project does not altogether agree with Mr. Sneyd's proposals, but the discrepancy cannot be traced exactly. In rough outline a dam would be built on the Koniar River about 7 mi. below the old dam site at Pinjikave and the waters diverted thence to the existing Berijam reservoir, where the maximum water level is 7,040 ft. Thence the water would flow for 4 furlongs in the natural channel to a regulating tank (miscalled a forebay). From here it is proposed to construct an open channel for 1½ mi. involving a fall of 120 ft. to a point where the pressure pipe would begin. At this point the forebay proper would have to be built on this plan ; but the more effective method would be to utilize this 120 ft. of extra fall in a pipe, with a surge tower at the end of it, in which case the forebay would be as presumed by Mr. Tate ; the pressure pipes starting at the surge tower. The main fall is then over 5,200 ft. Mr. Tate proposes that it should be taken in two stages ; the first gives a fall of 2,500 ft. (or 2,620 ft.) in 10,000 ft. From the tail race of this upper scheme the above comment holds good ; the water should be collected in a second forebay with a light pipe line of 1 mi. for the small drop of 100 ft. at the end of which a surge pipe would be required ; then there is a second fall of 2,500 ft. (2,600 ft.) in 8,750 ft. into the Varahanadi River above the Thalaiyathur irrigation anicut.

The development in two stages would probably be preferable to taking the whole fall in one. Using pipes and surge towers as suggested the gross falls would be 2,620 and 2,600 ft. respectively, or about 2,550 ft. net each.

By building a new bund at Berijam, lower down, and removing the present one, an additional 1½ sq. mi. of catchment (giving 13 sq. mi. in all) as well as extra capacity would be obtained, *viz.*, 150 m. c. ft. in all. The details regarding the Koniar catchment and capacity are not clear. In the 1868 report the Pinjikave catchment is definitely given as 30 sq. mi. and the old tank capacity (up to the well-marked high water line) 4,000 m. c. ft. Mr. Tate gives the same catchment as 6 sq. mi. only and the reservoir capacity as 300 m. c. ft. only.

When the existing Berijam irrigation project was sanctioned in 1905 the run-off was taken as 34 per cent. of the monsoon rainfall, though 60 per cent. was actually ascertained in the case of the Kodaikanal water supply close by. The average is very unlikely to be below 40 per cent. Mr. Tate takes the minimum run-off to be 35 per cent. of the minimum rainfall for the South-West and North-East monsoon periods, apart from the minimum perennial flow. This is equivalent to 14 in. of run-off on a catchment of 13 sq. mi. giving 423 m. c. ft. The constant flow from storage is therefore 13 cusecs in the driest year, of which 3 cusecs are allowed for local irrigation, leaving 10 cusecs for power. The minimum perennial flow is taken as 6 cusecs, giving 16 cusecs in all for power in the worst year.

The continuous 24-hr. power available at each of the two stages is some 2,700 kW. or 5,400 kW. in all. Mr. Sneyd's estimate of 7,500 kW. continuous (using the old dam site) seems to be based on the catchment area given in the old official reports, which appear to be incorrect. Mr. Tate's rough estimate for the whole project complete, *including 13,200* kW. of *working plant*, is 77 lakhs only, which would mean about Rs. 580 per kW. installed. The hydraulic development up to the upper forebay would be extraordinary cheap, *viz.*, about 5 lakhs only for the storages, etc., the pipe line, as always on very high heads, would be by far the most expensive part of the power plant. If the upper site and fall were developed on their full storage the project would almost certainly be a very cheap one.

Over and above power, some thousands of acres (probably 8,000) could be irrigated in the plains. Mr. Sneyd points out that objections were raised, in the 1869 report, to cutting off 30 sq. mi. of catchment from the Amaravathi river, into which the Kumbar flows ; but he considers that this would not in fact have any serious effect as it is not even part of the main catchment. Even the local Kumbar irrigation would not, in his opinion, be seriously interfered with ; it could be continued from the new lake. The advantages of this combined power and irrigation scheme are very great and it is hard to understand why it has lain dormant since 1872. It appears worth careful detailed survey.

The Pinjikave project appears by far the best in these hills, but Mr. Sneyd has examined 3 other possibilities in the Porandalar River, the Kumbar River and the Gundar River ; the last-named is useless for power. All are on map 58 F/7, 8.

(8) *Palni Hills ; Porandalar River* is formed by the junction of the Gundar and Vannantoraiar (or Pumbarai) streams. There are some 200 to 300 acres of irrigated land in the latter valley, which would absorb all its water in a bad year. Storage on a comparatively small scale is possible, with a high and expensive dam, and the probable minimum flow with storage is taken as 15 cusecs. The fall available is about 1,500 ft. so some 1,500 kW. continuous could be obtained. (Map 58 F/7.) Mr. Sneyd considered this project the most

favourable one in these hills after the Pinjikave site (q. v.).

(9) *Palni Hills ; Kumbar* (*or Manjapatiar*) *River.*—The upper reaches of this river, above 6,000 ft. elevation, are entirely exhausted by terrace irrigation in dry years ; small reservoirs could be made at several points, which would be valuable for irrigation but not of sufficient capacity to be worth their cost for power. Similarly, down to the junction of the three chief branches, all the water is required in the dry weather. Here there is a fall of 1,500 to 2,000 ft. to the plains. The minimum flow at the junction point, where the headworks would be, is estimated at 5 cusecs. With the small storages mentioned, if they proved reasonable in cost, 15 cusecs altogether might be obtained giving some 1,500 kW. continuously. The headworks storage would not be more than that of a large regulating forebay.

(10) *Vaniar River ; Shevaroy Hills, Salem District.*—In response to a request from the Director of Industries, Madras, Mr. Tate visited Yercaud to collect information as to the possibility of finding factory power for Salem in these hills ; the Vaniar River, 10 mi. N. E. of Yercaud and 21 mi. N. E. of Salem appears to offer the only practicable scheme (map 58 I). The catchment is 24 sq. mi. and a 40 ft. dam is proposed at a point opposite Vellakadal, 7 mi. N. E. of Yercaud. The run-off in the worst year, 1892, which followed two seasons of defective rainfall, is reckoned to be 8½ in. Taking the longest period without rain as 6 months the required storage is estimated at half the minimum run-off, or 237 m. c. ft., which could be obtained with the proposed dam ; this, however, allows no carry-over. With a minimum flow of some 2 cusecs and some 12 cusecs from storage the constant flow is assumed to be 14 cusecs ; the estimate appears to be conservative. There is a head of 500 ft. available, with a channel of unspecified length and a pipe line 2,550 ft. long. A good forebay site apparently exists with ample regulating capacity. Six miles below the reservoir site there is an irrigation anicut on the Vaniar, with a supply channel irrigating a direct ayacut of 99 acres and feeding the Venkatasamudram tank with an ayacut of 250 acres. There is a further anicut 10 mi. lower down feeding 656 acres directly and indirectly from Alarpuram tank. The upper indirectly irrigated area might be affected, but it is probable that with the continuous flow from the tail race the ultimate effect would be beneficial to irrigation.

The continuous power available is $14 \times 500/15$ or say 450 kW. only and the cost would be very high (about 18 lakhs) ; but further investigation may put a better complexion on the case.

(11) *Varahi River, tributary of Haladi, S. Kanara District.*—The Kunchikal Falls on this river were examined by Mr. Sneyd in 1920, and pronounced favourable for development. While the falls are in British territory however the catchment area and storage sites are in Mysore. The site is on map 48 O/2 square A1 of 1″ map. The catchment area is about 18 sq. mi. lying within 10 mi. of the edge of the Western Ghats. As there are no intercepting hills the average rainfall is probably 150 in. ; there is a small area with this intensity on the rainfall map of India, including this catchment. On the lowest computation there will be a run-off of 2,500 m. c. ft. average, and as this is greatly in excess of the amount that can be stored the figure is not of importance. A good storage site exists 400 yds. above the falls and with a 75 ft. dam some 300 ft. wide at the base it is estimated that 250 m. c. ft. could be stored. There are also further storage sites higher up. Difficulties will occur as to surplussing, both during construction and when working, unless the dam will allow of surplussing over its crest. The bed is solid rock and the sides are precipitous. From the information available it seems probable that the best method of development would be by running a pipe directly from the draw-off point of the reservoir, leaving sufficient "dead water" to enable silt to be cleared by under-sluicing. The cliffs on both sides of the ravine are very steep, and whether an open channel or pipe is used it would probably have to be inside the cliff in tunnel. Mr. Sneyd suggested a pick-up weir 200 yds. below the dam, but there is no apparent necessity to sacrifice the (variable) extra head at the dam. The available head is given as 1,350 ft. from a forebay at the end of a short open channel, and will therefore be 1,400 ft. or more if a closed pipe is used from the dam. The length of open channel is given as about 1,000 ft. in addition to 600 ft. of the river bed. This 1,600 ft. should preferably consist of a pipe, laid on a comparatively small slope, ending in a surge tower ; the extra power obtained would clearly give a very good return on the extra expenditure. The pressure pipes would then originate at the surge tower, and the cost of the forebay would be eliminated. The power house site is favourable and ample, and the whole project would be very reasonable in cost.

There are further possibilities of diverting the Malatte (Malati) Hole Nala into the Varahi at the 2,000 ft. contour near Settigalakoppa. There is believed to be a flow of at least 20 cusecs minimum in this stream for 5 months, and ample water for the rest of the year. The proposed storage of 250 m. c. ft. will give a further 20 cusecs in the dry period, or 40 cusecs in all. This on 1,400 ft. is equivalent to 3,750 kW. continuously.

The final possibilities are much greater. If the minimum run-off assumed can be stored it would give a further 60 cusecs all the year round of 100 in all. The diversion involves a tunnel of only about ¾ mi. in length, immediately S. of the place mentioned, on square 5 of map 48 O/2. The Malati Hole would then be dammed 2 mi. S. E. of that point, where the 2,000 ft. contour crosses. The project is a promising one.

106. Punjab ; known sites.—At present no hydro-electric survey has been initiated in this province because, as stated above, attention has been concentrated on one large project and its branches. The first step in the Survey, which it is hoped will be begun this year, is to make thorough reconnaissances of the whole Himalayan area of the five rivers and their tributaries ; it will then be possible to say what sites are worth detailed investigation. It may, however, be noted that two projects usually associated with the Punjab, namely. those on the Chenab at Riazi and on the Jhelum at Muzaffarabad, are actually in Jammu and Kashmir States, respectively ; they are noted on under this head. Such information as is available regarding Punjab rivers will be found in the following chapter.

107. Rajputana ; Alwar ; known site.—*Ruparel River at Bara.*—A proposal to make a storage weir at Bara (map 54 A) has long been under consideration. Mr. Bull visited the site in March 1920, and Sir Thomas Ward, Inspector General of Irrigation, also visited the site. The dam site is in a narrow rocky gorge and very suitable. The annual rainfall varies from 9·8 to 58 in. at Thanagazi and the river runs dry in February. During 28 years there has been less than 10 in. in 3 years and less than 19½ in 11 years. From 1899 to 1903 there was a run of bad years, and Mr. Bull considered that *at least* a year's carry-over would be necessary. There is no fall in the river, and the fall must therefore be obtained from so much of the dam as is below draw-off level. With a dam of 100 ft. in height some 2,640 m. c. ft. could be stored up to R. L. 320 ft. Above R. L. 288 ft. this gives 1,650 m. c. ft. of useful storage with a head varying from 92 ft. to 60 ft. It is reckoned that 1,100 m. c. ft. are required for the load obtainable, thus leaving 550 m. c. ft. or 6 mo. supply in reserve with a full reservoir. On an average head of 76 ft. the continuous power would be 160 kW. giving 1·45 million units per annum, which can be taken at any rate required subject to the total limit. Examination of the probable run-off shows that even this could not always be depended upon, in a bad series of years, but further investigation is required. The estimated constant discharge of 19 cusecs in the cold weather and 44 cusecs from April to July would be valuable for irrigation. Mr. Bull strongly recommended further investigation of the river, both normally and in floods, as the percentages of run-off in the various years are based on experience and not on actuals. In doubtful cases like this actual gaugings are the only safe criterion. A water stage recorder has now been installed.

108. Travancore ; known sites.—Eleven projects have been examined under the direction of the Travancore Darbar, all on rivers flowing West. As they are consecutively numbered on the map prepared it will be best to give them here in the same order, with such particulars as are known. The power available is not stated.

(1) *Tambraparnir River, at Valiathumugam falls.*—This site is on map 58 H, lat. 8° 30′, long. 77° 20′. There are falls of 1,200 ft. in 1¼ mi. with a very small catchment (about 3½ sq.mi.) in the hills near Ambasamudram. The river appears from the map to flow into the Indian Ocean ; there is another river of the same name rising near the same spot, flowing E., from which mills are worked—see para. 69. The falls drop into Kodayar Lake. The yield is not known.

(2) *Nevvar River, at Kombe-Kani falls.*—This site is 6 mi. W. of No. I of this list, on the same map. The catchment area is 5 sq. mi. only and there is a fall of 500 ft. in 1 mi.

(3) *Ittikaru River, at Meenmutty falls.*—This is situated near the road at lat. 8° 55′, long. 77° 8′ on map 58H/1. The catchment is 115 sq. mi. and there is a fall of 350 ft. in 7 mi.

(4) *Kallada River, at Kadurutty falls.*—This site is on a branch of the Kallada River, 1½ mi. N. E. of No. 3, and also on the road on the same map. The catchment is 50 sq. mi. and the fall 250 ft. in 2 mi.

(5) *Kallada River at Ootakal falls.*—This is 2 or 3 mi. N. W. of Nos. 3 and 4 on the same map. The catchment is 230 sq. mi., but the fall is not shown.

(6) *Giri Aur Nala, tributary of Kakki Aur.*—This is on map 58 G, lat. 9° 10′, long. 77° 15′. The catchment area is under 5 sq. mi. and there is a fall of 40 ft. only. The Kakki Aur has a catchment of 83 sq. mi. at the 500 ft. fall lower down. This is to the S. W. of Periyar Lake. This stream falls into No. 7.

(7) *Peruntenaruvi River, above junction* with Kakki Aur (see 6). This site is within 6 mi. S. W. of a bay of Periyar Lake. The catchment of the Lake is 230 sq. mi. so that the known inflow should be a good guide to all these neighbouring sites. The catchment of No. 7 is 53 sq. mi. but it is divided between3 tributary streams, two having falls of 250 ft. and the third of 350 ft.

(8) *Perinjancutty River, tributary of Periyar R., Cardamom Hills.*—This appears to embrace the

" Cardamom Hills reservoir " site, at one time proposed to supplement Periyar Lake. It is at Kallar, map 58 G, lat. 9° 50′, long. 77° 15′. The catchment is 73 sq. mi. and there is a fall (Thural falls) of 300 ft. some 5 mi. W. of Kallar. The suggestion may be ventured that with so many other sites near by this catchment would benefit the people of India more if utilized as originally proposed.

(9) *Mudrapuzhar River at Pallivassal falls.*—A fall of 400 ft. is already utilized here, at Munnar, map 58 F/4, *vide* para. 69. The total fall is shown on the map as 800 to 1,000 ft.

(10) *Periyar River at Karimbankurha falls.*—This site is on map 58 G/1, west of 8 and S. of 9 and 12 mi. or so from each of these. The catchment is 300 sq. mi. and there is a fall of 30 ft. The excess from Periyar Lake flows down its original course here, with this additional catchment.

(11) *Periyar tributary.*—This site is some 14 mi. N.W. of 9 and 10 and has a fall of 80 ft. map 58 B/16.

Chapter 14.—Areas and Rivers not yet examined.

109. Summary of reconnaissances not yet undertaken.—The following paragraphs show, by Provinces and States, in alphabetical order, what remains to be done before the first stage of the Survey can be said to be completed. The list itself may quite probably omit many entries which should be present. Such estimates of power as are given are far more speculative than those in earlier chapters, but in some cases (*e.g.*, the Punjab) there is some definite information available. The following table is a summary of this chapter.

Table 49.—*Summary of areas and rivers not examined.*

Reference.	Province or State.	Number of entries.	Possible continuous power, K.W.
Para. 110	Assam	17	300,000 ?
„ 111	Bengal	3	650,000 ?
„ 112	Bihar and Orissa	25	30,000 ?
„ 113	Bombay	18	20,000 ?
„ 114	Burma	70	300,000 ?
„ 115	Central Provinces	31	10,000 ?
„ 116	Kashmir	3	20,000 ?
„ 117	Madras	7	5,000 ?
„ 118	North-West Frontier Province	5	[1,000,000]?
„ 119	Punjab	30	[662,000] ?
„ 120	Rajputana	1	small ?
„ 121	United Provinces	18	20,000 ?
„ 122	Native States of India	..	No information.
	Total	228	3,017,000

110. Assam ; areas not investigated.—Attention in Assam has so far been concentrated mainly on (i) the Cherrapunji plateau and (ii) possible sources of power for the projected Hukong Valley Railway link to connect Assam and Burma. As noted in the Preliminary Report, the whole area of the Khasia, Jaintia and Garo Hills offer large possibilities which must remain entirely problematical until examined. The hills are mostly virgin forest, passable only to elephants. From Tura in the Garo Hills to Calcutta the distance is 250 miles, so that much of the industrial area of Bengal is within practicable transmission distance of these hills. The Mymensingh and Dacca districts are much closer, while the tea districts of Cachar and Sylhet lie at the very foot of the Khasia hills. As the general elevation of the hill plateaux is 3,000 to 4,000 feet above the surrounding plains, and the mean rainfall varies from 100 inches on the outskirts up to 300 and 400 inches around Cherrapunji the unknown possibilities are great ; their utilization however depends entirely on large water storage sites being found, and these must not depend on very high dams owing to the area being subject to earthquakes. In the absence of any information let it be assumed that it may be possible to utilize the minimum rainfall of 100 in. over 500 sq. mi. (which is less than a quarter of the elevated area), with an average head of 1,500 ft. Using the approximations again reprinted in the present Report, 100 in. over 500 sq. mi. would give about 3,000 cusecs throughout the year, or *300,000 kWs.* on 1,500 ft. head. It is clearly worth while to endeavour to locate a fraction of this power, as it is beyond cavil that eight or ten times that power is annually dissipated in the torrents.

Of the large hill area of Assam to the east of the ranges mentioned it is better to say nothing, since the country is wild and uncivilized and quite out of reach of any industrial life at present ; the rainfall however varies between 75 and 100 in. over many thousands of square miles of elevated land.

The Himalayan slopes on the north of Assam are in Bhutan, and the great rivers which make a steep descent into the Brahmaputra are snow fed from ranges of 18,000 ft. and upwards, with a rainfall probably exceeding 100 in. ; this area however is outside the purview of the Survey.

Mr. Blenkinsop reports that " the Kopili River and the Sobansiri River should well repay investigation." The former has not been found in the Atlas, and no indication is given of its whereabouts ; the Sobansiri is a tributary of the Brahmaputra on map 83 I, flowing in from the Miri Hills, north Lakhimpur. It has a very large hill catchment and there is no doubt as to its value for power; but it is very remote. Neither of these rivers appears in the Preliminary Report.

The following is an alphabetical list of the sites suggested as possible in the Preliminary Report pp. 66 *et seq.* and elsewhere, none of which have been examined as yet, with such information as was given before.

(1) *Abong River, North Cachar.*—Near the Subong Tea Estate there is said to be a good reservoir site, as noted in the addendum to the Preliminary Report.

(2) *Bhugai River, Garo Hills,* map 78 K/7. This is unsurveyed so far as modern maps go. The average rainfall from April to October is about 90 in. over a catchment of some 85 sq. mi. at Silhat, where the Naranga R. joins.

(3) *Dibrugarh.*—A site, said to be good for 26,000 H. P., has not yet been found or investigated. It may be the Subansiri R. mentioned above. (Or Hukong V.)

(4) *Dudhnai River, Garo Hills,* map 78 K/13. At the junction of the Manda and Chinchura tributaries the catchment is about 110 sq. mi. with an average rainfall of some 100 in. between April and October. The slope of the stream is steep, but the area has not been surveyed in detail.

(5) *Jadukata or Kynshiang R., Khasia Hills,* map 78 O. There are many falls on this river, and the catchment above those of 70 ft. shown on the ¼ in. map, in the Nongstoin area, is about 24 sq. mi. with an average rainfall of some 90 in. between April and October.

(6) *Jatinga River at Damchara, A. B. Ry.*—This site is on map 83 G/4. A reconnaissance has shown that it is possible to store some 3,000 m. c. ft. at the hairpin bend near mile 277 of the line, just below the junction with the Ka Yeng tributary, using a 90 ft. dam. The catchment is about 96 sq.mi. with an average rainfall between 144 and 250 in. It is reported that there would be great difficulty over the long flume required, of about 10 mi. The project has therefore been left over until Maibang has been further examined. Flow would be more than sufficient for 6 months annually, and the storage and flow would give 190 cusecs for the rest of the year. Some 250 ft. of fall is obtainable, giving about 2,500 kW. continuously.

(7) *Jinari or Didram River, Garo Hills,* map 78 K/5. This has a catchment of about 100 sq. mi. at Rocksaun, with rainfall of the order of 100 in. and a steep slope.

(8) *Kiang River.*—Location unknown, but referred to in the addendum of the Preliminary Report as deserving of reconnaissance.

(9) *Kopili River.*—See beginning of this paragraph.

(10) *Kulsi River, Khasia Hills,* map 78 O/5. The catchment area at the Kulsi swamp exit is over 100 sq. mi. with average rainfall of 100 in. The stream is perennial, and has a rapid slope and falls higher up. The swamp or lake is almost at plains level, but is of very large area. There are possible dam sites apparent on the 4 in. to the mile forest sheet 28 N. E.4, where the gorge is only ¼ mi. wide. The bed level here is only 184 ft. If, however, a high dam were built the water-spread would be very large, when once filled; and the top 50 ft. or so might afford considerable power with the head due to the balance of the dam above draw-off level.

(11) *Krishnai or Damring River,* map 78 K/9. The catchment at Chelteret is about 200 sq. mi. and the slope is steep.

(12) *Monas River.*—This flows into the Brahmaputra from Assam, and has a large perennial flow. The fall in British territory may be considerable. (Map 78 J/13.)

(13) *Mongseang Lake.*—This is an alternative site in the Hukong Valley region, see para. 78. Mr. Blenkinsop reported a storage site with a fall of 2,000 ft.

(14) *Sobansiri River.*—See beginning of this paragraph.

(15) *Sympana Nala.*—See Mongseang lake above. This nala also offers storage and a fall of 1,600 ft.

(16) *Umian River, Khasia Hills.*—This crosses the main road to Shillong at Barapani, where a reservoir site may exist, with a catchment of 20 sq. mi. There is no information as to falls. (Map 78 O/14 and 83 C/1, 2.)

(17) *Um Rai River, Khasia Hills.*—This is a tributary of the Um Tru (q. v.) and crosses the Shillong road. The discharge here has fallen as low as 1 cusec. The Laroh rapids have not been identified. (Map 78 O/13.)

111. Bengal; areas not investigated.—So far the Government of Bengal has been unable to look into its water-power resources. For the most part the province consists of the alluvial delta of the Ganges, and is practically at sea level. It was explained in the Preliminary Report that rivers with a fall of a few inches to the mile in a flat plain cannot be utilized for power; they are already liable to overflow their banks with disastrous consequences, and any obstruction such as a lifting dam (para. 31 *supra*) to give the lowest practicable working "head," would result in certain and far worse inundations. Furthermore the head so obtained would be certainly lost through the afflux of the tail waters, in flood times.

(1) The smaller tributaries of the Great Rangit in the neighbourhood of Darjeeling have already been examined to some extent, but the Great Rangit and the main stream of the Tista, into which it flows, require detailed investigation (Preliminary Report, p. 70, and Appendix to List of Sites). These rivers may prove

suitable for the ordinary type of low head lifting dam development. The difficulties of construction would be considerable, but there are well known parallel cases of large rivers being harnessed in steps at a series of lifting dams; *vide* para. 31 *supra*. Up to the junction of the two rivers near Kalimpong there is a fall of over 300 ft. with a minimum discharge said to amount to 10,000 cusecs. If it were possible to develop this power in stages it would amount to 200,000 kW. minimum.

(2) Above the junction the slope increases greatly, and the minimum discharge of the Tista alone is said to be 1,250 cusecs up in Northern Sikkim. If development proved feasible the two rivers above their junction could (apart from tributaries) possibly give another 800,000 kW. and as a rough conjecture 400,000 kW. may be entered. Even allowing for the fact that suitable sites cannot always be found it is probable that the Tista and its tributaries together could be harnessed to give 500,000 kW. in the aggregate. The question therefore resolves itself into (i) investigation for possible sites, (ii) the economics of developing these in competition with Bengal coal.

(3) The Hill Tippera ranges and their continuation in the Chittagong Hill Tracts are even less known, and it is impossible to say what power they may contain. The annual rainfall is probably over 100 in. upon a hill area of 1,500 sq. mi. or more, equivalent to some 9,000 cusecs for the year; but the main rivers appear to be mostly at altitudes below 500 ft. Whether the great storages, which the Atlas sheets appear to encourage, are in fact present; and, if present, whether they represent agricultural land which could not be flooded; it is for the future to decide. In any case the falls obtainable would depend on lifting dams and would be low and therefore expensive in terms of horse-power from stored water. It is however by no means impossible that the district has considerable power, as there are no detailed maps available of this practically unsurveyed area. It is little more than guess work to say that from 30,000 to 50,000 kW. are probably obtainable. Discharges of certain streams in Chittagong district follow.

Minimum discharges observed in March-April 1919.—In the absence of more detailed information the following discharge observations may be recorded. Of the streams mentioned, the Jaldaka is dealt with elsewhere in this Report, as also are the Darjeeling streams.

	Cusecs.
Jalpaiguri District.	
Mahananda River at Titulia	172
Karatoa	40
Rangpur District.	
Jabunasari River near Badurganga	100
Ghagat River near Railway bridge	24
Dharla River at Kurigram	3,081
Bangali River	276
Malda District.	
Tangan River near Muchia	78
Kalindy River near Nema Sarai	127
Purnabhaba River near Rahanpur	82
Bogra District.	
Karatoya River near ½ mile E. of Titulia	3½
Nagore River	17½
Tulshiganga River	7½
Jabuna River	½
Duars District.	
Jaldaka River near Railway bridge	231
Kusi Diana River, near bridge	3
Murti River, near bridge	6
Rydak River at Vhutanghat	609
Janti River near Jainti	15
Darjeeling District.	
Little Rangit at R. L. 3,000 near Pul Bazar	23
Kahil (or Baluabash) at R. L. 3,000 ft. near Pul Bazar	9½
Balasun River (1915)—not minimum	66
Ranjoo and Ryang (1915)—near Tista—not minimum	50
Chittagong District.	
Khootakhali Chara near bridge	5
Eadgaa Chara at Mahantarghat	18
Sona Chara at Jaoria Nala	1½
Bagkhali at Cowerkhoop	24
Matomoohary at Kokra Mouza	81
Hizalia (Rejoo) at bridge	½
Bara Kumira Khal at Kumira	¼
Sital Jharna at Pachlish	¼
Santa at Santa	*nil.*
Halda at Wazirhat	27
Dolu at Somadurpara	11
Ichamati at Rangoomia	*nil.*
Silak at Silak	5

112. Bihar and Orissa; areas not investigated. It will be seen elsewhere in this Report that not much of this Province has been examined so far. The northern boundary is below the foothills of the Nepal Himalayas, and if any development is possible here it can only take the form of lifting dams with low heads on the rivers debouching into the plains. Of these the Atlas sheets show (from East to West) the Kankai, the Kosi, the Balan, the Kamla, the Baghmati together with some smaller rivers. Of those mentioned the Kosi is by far the largest. In the absence of information as to cold weather discharges it would be rash to speculate on what power (if any) could be depended upon from these rivers. The rainfall rises from 50 in. to 75 in. over the border and in the higher altitudes is probably greater; furthermore the winter rains in the higher altitudes will lie as snow till late in the season, while the Kosi and its great tributaries are fed from the great snowy range itself, including Mount Everest and Gauri Sankar. If therefore lifting dams are practicable within the borders of the province, *i.e.*, if they can be built without flooding large stretches of agricultural land—the possibilities are considerable; but no estimate is possible.

Regarding the Hazaribagh-Ranchi plateau, drained by the Damodar, the Subarnarika and the Brahmani, with their many important tributaries, the general elevation is over 2,000 ft. running up to 3,000 and

4,000 ft. on the west. Modern maps are not available for most of the areas likely to be of use, so that reconnaissance alone can determine what sites there may be. The mean rainfall is between 50 and 60 in. but is very variable. A few sites have been examined, as recorded elsewhere, but general examination is necessary. No estimate of the power available is possible in most instances.

To the south of the province the Mahanadi passes through the Eastern Ghats in Daspala State, and it appears certain that development by means of lifting dams is possible. Enquiries have been made regarding this site, which is some 250 miles from Calcutta.

Of possible sites suggested in the Preliminary Report, pp. 71 *et seq.*, and later, the following have only been casually examined or not examined at all.

(1) *Balan River and Bagmati River.*—See remarks above.

(2) *Bansloe River.*—Discharges of this river, with the Brahmini and More rivers, were taken in Bengal, near the boundary between provinces, in September and October. They are available, but they give no indication of the hot weather flow. The higher contours of the river are in Bihar and Orissa.

(3) *Brahmani River.*—See Bansloe R.; the same remarks are applicable to this similar river. There are rock barriers and rapids of about 14 mi. through Gangpur State.

(4) *Bhera Nadi, near Ormanjee, Ranchi.*—There is a fall of 500 ft. but storage possibilities are small and unexamined as yet.

(5) *Dardhari River, Pakripat plateau.*—There is a fall of over 600 ft. where the river drains off the S.-E. site of the plateau. A dam site examined below Pirapatal would be very expensive to develop, as would also be the open channel to above the power station site at Tendar. It is believed that only 1,100 kW. continuous would be available; but the site merits further investigation. Enquiries have been made regarding it for use in connection with aluminium refining.

(6) *Garha Nadi, Singbhum.*—The site at Dutaura, 4 mi. N. of Dhirol P. W. D. rest-house, on the Chaibasa-Moholia road, has not been inspected in detail. There is no natural fall, so development by lifting dam (with storage above it) would be essential. The cost of storage would be heavy, but if a *succession* of lifting dams can be employed (see para. 31) the site may prove useful. (Map 73 J/6.)

(7) *Ib River, tributary of Mahanadi, Sambalpur.*—Mr. Clayton reports that Mr. Walker, who investigated reservoir sites a generation ago, found a very fine one on the Ib with 2,365 sq. mi. of catchment and a capacity of 14,500 m. c. ft. Unfortunately the railway bridge now passes through the site, which is therefore lost. There may however be other storage sites. When the Ib gets within 8 or 9 mi. of Sambalpur (map 64 O/15, 16), it takes a sudden turn to the W. and falls into the Mahanadi 12 mi. upstream of the town. There is a fall of 102 ft. in this stretch, while the ridge to be cut through to utilize it is only about 20 ft. above the Ib flood level. Something may hereafter be made of this river.

(8) *Indravati River.*—(*See also* under Central Provinces). The Gazetteer says "In these hills of the Dangala area of Kalahandi (Feudatory States of Orissa) the splendid stream of Indrawati takes rise near Thuamul; it quickly gathers volume, and even in February roars and rushes down its hilly course in seething cataracts, in its short wild rush to the plains and the State of Bastar to join the Godavari." Lifting dams are clearly indicated, but there is no further information as to the river in Orissa.

(9) *Jonk River.*—Mr. Clayton reported that a reservoir site was partly surveyed on this river in 1865; a map exists locally, showing the site. With a catchment area of 1,750 sq. mi. a storage of no less than 37,000 m. c. ft. was calculated to be stored by a 165 ft. dam. Mr. Clayton pointed out that if only the upper half of this storage were used for power, with a head varying from (say) 100 to 165 ft., it would make a promising scheme. The dam is quite short. If 25,000 m. c. ft. are assumed as stored above the 100 ft. level this would give some 700 cusecs which on an average head of 130 ft. is equivalent to 6,000 kWs. continuously. This seems well worth further examination, as the tail waters could still be used for irrigation and the cost could be shared between the two purposes.

(10) *Kamla River.*—See introductory remarks to this paragraph.

(11) *Kanchi River.*—The Dasan Ghag fall 6 mi. S. of Taimara, at the 19th mile of the Ranchi-Bandu road, is about 150 ft. and can be increased to about 200 ft. with rapids. The dam sites have not been examined; but the catchment area above would be under 200 sq. mi. and the main reservoir would probably impound the whole yield. The scheme is reported as worth further investigation. (Map 73 E/8, 12.)

(12) *Kankai River.*—See introductory remarks to this paragraph.

(13) *Karo River, Ranchi.*—The Perua Ghag falls, 6 mi. S. of Topkara, which is on the Khunti-Kamdera road, are 100 ft. high. The catchment area is about 500 sq. mi. A reconnaissance was made upstream from 10 mi. above the fall, and showed no good storage site. The 10 mi. stretch has not been examined. Further investigation is desirable.

(14) *Koel River, North.*—Two places have been reported from the Son Canals reservoir survey as possibly useful. Each has a fall and rapids amounting to 150 ft. The Gazetteer mentions the rocky bed and rapids north of Hutar coal fields (map 73 A/1, 2) and near Parro.

(15) *Konhar River, Sarguja and Palamau.*—There are 5 or more falls on this river, falling from the Sonabira plateau, close to the border between Bihar and the Central Provinces, including the Chota and Burra Pooai Ghag and Post Ghag, all apparently in Sarguja State.

(16) *Kosi River.*—See introductory remarks to this paragraph.

(17) *Kurhadi River, Bonai.*—The Gazetteer says that "the stream runs fast and clear, falling in cascades along its boulder strewn course and forming deep pools and eddies; on both banks it is closely shut in by towering forest clad hills." Lifting dams are a possibility.

(18) *Mohana River, tributary of Phalgu, Hazaribagh.*—In the Preliminary Report, p. 72, the Tamasin and Harikhal falls, of 50 and 60 ft., were mentioned; they are 10 mi. S. of the Grand Trunk Road. Extra head can be obtained at Itkhori and storage from 200 sq. mi. of catchment may be possible. The site has not yet been examined. (Map 72 H/3, 4, 8.)

(19) *More River.*—See Bansloe R.; the same data are available for this similar river.

(20) *Nettarhat.*—A fall of 900 ft. is possibly obtainable here, but the catchment is small. The site has not been examined fully.

(21) *Rozo River.*—Mr.Clayton reported that there were "obvious possibilities" in the way of small falls (probably lifting dams) combined with storages in this river.

(22) *Sankh River, Rajdera.*—There is a natural fall of 175 ft. 3 mi. from Rajdera,Pakripat-Netarhat plateau, and by means of a dam ½ mi. above the falls 350 ft. could be obtained. The power station site however would not be convenient, and the open channel would be expensive. The catchment is only 32 sq. mi. A cheaper alternative would be to dam the river at Rajdera and tunnel 600 yards through the hill, when a fall of 500 ft. would be obtained. The project depends on storage however, and it is doubtful if as much as 750 kW. could be obtained. Examination is however desirable. (Map 73 A/3.)

(ii) The site at Perua Ghag, lower down, 12 mi. N. of Kochdega and 4 mi. E. of Kundra, on the Gumla road, has also not been examined; see Preliminary Report, p. 72. The natural fall is only about 23 ft., but it could be raised by a lifting dam no doubt. The catchment is 900 sq. mi. (Map 73 B/5.)

Enquiries have been made regarding the Sankh in connection with aluminium refining.

(23) *Son River.*—This has not been examined; storage would be valuable for irrigation in the Son Canals.

(24) *Subarnazeka River.*—For the Hundru Ghagh falls, see "Sites investigated" in Chapter 12. The Chandil site, 4 mi. from that village, has not been examined yet. By storage and a lifting dam (or dams) for head, there may be useful developments. The storages above Hundru Ghagh falls would materially benefit this lower scheme. (Map 73 J/5.)

(25) *Usri River, Hazaribagh.*—The Irrigation Department in Bengal reports this river and its proposed storage as useless in that province; but it may be possible to develop it in Bihar and Orissa. There is a fall of 180 ft. at Usri, 7 mi. from Giridih, near the Gobindpur road. It has not been examined. The Bengal Government contemplate flood regulating reservoirs on the Upper Damodar and Barakar rivers, below the Usri junction.

113. Bombay; areas not investigated.—As noted in para. 82 *supra* the Survey has been closed down by the Government of Bombay. The work so far done has been facilitated by Mr. Beale's earlier survey of the irrigation possibilities of the Deccan from reservoirs. While the Northern and Central areas are the most likely to develop industrially, there are equal possibilities further South though in regions which at present do not require power. In this connection there is always a chance that possible industries may not be pushed forward for lack of power facilities while power sites are not examined because there is no market. One of the objects of the Survey was to break this vicious circle. Generally it may be said that the whole Presidency has been divided up into districts, in each of which reconnaissances have been made of likely sites; but another two years' work at least would have been required before it could be said that the water power resources of Bombay would be known. In Sind there seems no likelihood of finding water power on any useful scale; the projected Sukkur barrage on the Indus appears at first site to be attractive, but during floods the small head given by this barrage will completely vanish. Even the power required for operating the gates will, it has been decided, be supplied from a fuel driven power station. Hereafter, it is said that the Rohri canal, fed from the barrage, will have falls aggregating some 40 ft. which can be concentrated and produce some 15,000 h. p. (according to Dr. Sumner). At present however the canal is not built.

The following is a list of rivers and sites not examined, with such information as is available.

(1) *Bhatsa River, Thana District.*—There are said to be falls in this river at a site indicated near Shahpur,

but no details are known except that the rainfall in the catchment of nearly 400 sq. mi. is very high; probably 200 in. 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. A power scheme *might* interfere with the Bombay water supply, which is of vital importance. (Map 47 E/7.)

(2) *Bhima River, Poona District.*—This was investigated during Mr. Beale's survey, for irrigation, and it is probable that a combined project is possible.

(3) *Ghatpraba Valley, Belgaum District*; as in (2).

(4) *Ghod River, Poona District*; as in (2).

(5) *Girna River, Nasik District*; as in (2).

(6) *Godavery River, Nasik District*; as in (2).

(7) *Indus River at Sukkur.*—See remarks above in this para.

(8) *Kadoa River and tributaries, Nasik District*; see (2).

(9) *Kolaba District.*—Only small power schemes are possible here.

(10) *Krishna Valley, Satara District.*—See remarks on serial number (2) above.

(11) *Malapraba River, Belgaum District.*—There are falls in this river but no details are known at present. The catchment area is about 250 sq. mi. and extends through the zones of 30 to 100 in. rainfall, which mostly falls between May or June and September. It has been investigated for irrigation, and a combined scheme is probably practicable. (Map 48 M/1.)

(12) *Mula River, Ahmednagar District.*—There are two Bombay rivers of this name; one is dealt with under the "Nila Mula Project." The other rises in the Trimbak hills, which have a rapid drop from about 5,000 ft. elevation down to 2,000 ft. The catchment area at the site indicated appears to be about 180 sq. mi. with a monsoon rainfall averaging 30 to 40 in. but probably far higher in the upper reaches; it is confined however to the monsoon period. The river has been examined for irrigation, and a combined scheme may be possible. (Map 47 E/11, 15.)

(13) *Nira River, Bhor State and Poona.*—This has been investigated for further irrigation work and a combined scheme may be possible. It was noted in the Preliminary Report that "after the new Bhatghar 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." For the Bhatghar dam, see "Power Developed," Chapter 10.

(14) *Prajhra River, West Khandesh*; see remark on serial (2).

(15) *Pur River, Nasik and Dhurampur State.*—Mr. Bowers notes that a project on the lines of that on the Damanganga River (para. 99) may be possible.

(16) *Ratnagiri District.*—Only small schemes are possible.

(17) *Tungabadra River, Belgaum District.*—This has been investigated for irrigation and appears promising for a combined scheme.

(18) *Wakal River, Udaipur State.*—A high fall project may be possible here; see also para. 122.

In addition, Mr. D. A. Vichare, L.C.E., M.L.A., late Executive Engineer, Bombay P. W. D., has called attention to the latent possibilities of the rivers in Kolhapur State. These are all tributaries of the Kistna, rising in the W. Ghats, and include the following:—

Dudhganga R., map 47 L/3.

Panchaganga R. with its tributaries the Kasari and Bhogavati, and the Tulshi which joins the latter, all on map 47 L/1, 2.

Varna River, map 47 L/1.

Vedganga R., map 47 L/3 and its tributary the Chakotri River.

114. Burma; areas not investigated.—It will take some years to make reconnaissances of all the possible sites in Burma, of which there are certainly hundreds, apart from further possibilities in the great rivers. No doubt many of the rivers in the list below may eventually find their place among the "useless sites," but time alone can show.

(1) *Bean River.*—There is said to be a fall of 1,100 ft. on map 95 J/12 and K/9.

(2) *Bilin River, near Papun.*—This is said to be worth examination for storage sites, but it runs dry for 3 months. No information as to falls (map 94 G). There appears a possibility of diverting part of the head waters of the Thelaw Klo and Yunzalin rivers into this stream.

(3) *Che Chaung, Yaw district.*—This stream rises on the Mt. Victoria range and is reported to have "plenty of water" even in the dry season. It is also stated that any one of the mountain valleys here could be used for storage. There is a promising gorge about 4 mi. above Yeshin village, 45 mi. from Pauk.

(4) *Chipwi Chaung.*—This tributary of the N'Maika comes from the Panwa pass, map 92 K/1, and is reported to have a rapid fall.

(5) *Chirikha stream.*—There is a fall in this of about 150 ft. in ¼ mi. near the 8th mile on the Sinlum-Loilaw road; also a further fall of 50 ft. where it falls into the Taping River, between Kalichel and Khalon Kha on the Chinese road (map 92 H/11).

(6) *Dabalat waterfall.*—This is on an unnamed tributary of the Lesser Tenasserim River. About 30 mi. from that town there is " a large fall."

(7) *Enkan gorge.*—This perennial stream in the Katha district is said to be worth examination, but it has not been identified.

(8) *Hpawngaw Chaung*, tributary of Namtu.—This is said to fall 2,000 ft. above Hkelawng. The flow on 19 March 1920 was 120 cusecs and the minimum is believed to be about 100.

(9) *Indawgyi Lake.*—This has an area of some 40 sq. m. 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 simple. There is no information regarding falls. Map 92 C/7, 8.

(10) *Kadingasin Chaung, Prome.*—There is a fall of about 50 ft. some 12 mi. N. of Paukkaung, with hills on both sides which would facilitate dam construction. There is a large flat valley above, mostly of waste land. The stream is dry for 3 months, but with the large storage available there are possibilities (map 85 M/12, N/1, 9). There are further falls higher up.

(11) *Kaw Kareik Chaung.*—This rises on the Dawnas at about 3,000 ft. and has a rapid fall through a narrow gorge. The stream is believed to be perennial.

(12) *Khin or Kin Chaung.*—This is a tributary of the Nammeik and Shweli on maps 93 A/4, 8 and B/1, 5. A discharge of 76 cusecs was measured near the junction with the Kinwe or Konwet, in 1919, but the date is not given. There appear to be many falls, including one of about 600 ft. near the road crossing, but little is known for certain. The Bernard Myo (q. v.) joins this stream.

(13) *Kun Chaung, Toungoo.*—This is said to have possibilities. The tributary Sinmakadin has falls but storage would be necessary as the flow is very small at the end of the dry season. Map 94 A & B.

(14) *Kyaukgyi Chaung, Shwegyin.*—Said to have possibilities. Map 94 ?/6, 13.

(15) *Kyauksit Chaung, Yaw.*—This rises on Mt. Victoria and has a very steep descent with a perennial discharge. Map 84 H/3.

(16) *Lam Pai Chaung.*—A tributary of the Haungtharaw, 25 mi. S. of Kaw Kareik. It rises on the Dawnas at about 3,000 ft. and has a rapid fall. Map 94 L/3.

(17) *Lampar River.*—Said to be perennial with a large fall.

(18) *Lemru River, Akyab.*—This flows into Hunter's Bay and is said to have possibilities in the " Unadministered Area." Map 84 H/8, 7, 6, 2. Downstream from Pengwa the river has been examined without success. North of that place there is a hair-pin bend which would give a fall of 200 ft. with a 3-mile tunnel. The discharge in April 1921 was 400 cusecs, but heavy floods come down.

(19) *Lenya River, Mergui.*—Said to have power sites and has a catchment of some 700 sq. mi. Map 96 I/15, 16.

(20) *Lilu Chaung, tributary of Mon.*—Near Paungseik, Shwegyin District, there is a fall of 100 ft. with perennial flow. Map 94 B/14.

(21) *Madaya River or Nampai, tributary of Irrawaddy.*—This has a minimum discharge of about 350 cusecs near Mandalay and 200 cusecs S. of Kyauktalone. As high up as Mogok it also has a good discharge and a fairly rapid fall of about 60 ft. a mile. As the bed slope is mostly very even any development by canal would be expensive; but for lifting dam development it would probably be ideal as the stages would have great storage capacity. The catchment at Gwe Kyaung is about 1,200 sq. mi. Map 93 B. There are some rapids and falls as well as storage sites.

(22) *Maisa Khaing Chaung.*—The site has not been identified but two falls of 50 and 75 ft. are reported near Kyaukpon. Also two falls of 40 and 100 ft. higher up, known to the Karens as the Donwe and Kyaukop falls. Map 94 ?.

(23) *Mali Hka.*—This is one of the main sources of the Irrawaddy. At Lat. 26° 51′ it contracts to a width of 40 or 50 yards at Taping gorge. The perennial discharge is very great and small falls are known, but floods (unless regulated) would render development difficult. Map 92F/12 to 16.

(24) *Man River, tributary of Irrawaddy.*—Said to have possibilities below Ngape. A discharge of 40 cusecs was found near Payagyi on 7th April 1919, but the river may dry up. There is a possibility of piercing the watershed. The district is very unhealthy. Map 84 L/8, 12.

(25) *Manipur River, tributary of Myittha.*—This is stated to be good for about 3,000 kW. but little is known about it. The stream has a quick descent and is subject to heavy floods from a catchment of 4,000 sq. mi. The great Loktak lake near Imphal in Manipur is included, and could clearly be used for flood regulation. (Map 83 H.)

(26) *Mawhal or Ledan Chaung, Katha.*—There is a big fall reported on this stream 3 m. above Mawhan railway station, mile 620. Above the fall there is a flat open valley with no permanent cultivation, suitable for storage. This would be required, as the stream runs low in the dry weather. Map 92 D/2.

(27) *Mindon or Maton Chaung, tributary of Irrawaddy.*—The upper reaches in Thayetmyo district are said

to be worth examination. Map 85 I. The catchment is about 600 sq. mi.

(28) *Mole River, tributary of Irrawaddy.*—North of the Taping this falls rapidly along the Chinese frontier and down a narrow gorge as it leaves the frontier. Power of about 4,000 kW. could be cheaply obtained.

(29) *Minpaw.*—A 30,000 h. p. scheme has been mentioned, with a fall of 280 ft., but it is not identified. May be the Nampaw on map 93 E/13 ?

(30) *Mon River, tributary of Irrawaddy.*—This rises in the high lands W. of Mt. Victoria. The upper reaches are said to be worth examination, but nothing definite is known as to power sites. Below Hmindingyin and above the canal headworks at Mezali it is probable that good storage sites may be found, useful both for power and irrigation. The discharge at the canal headworks in May 1919 was 450 cusecs and above the junction with the Dwe Chaung 279 cusecs. There is a good slope in the higher reaches, but they are very unhealthy. Catchment about 800 sq. mi. Some of the tributary streams, especially that joining near Dwe, look favourable on the map (84 L/2). This tributary carried 48 cusecs near Paiksok in April 1919.

(31) *Mu River.*—The lowest recorded discharge is 95 cusecs ; locality not known. There may be possibilities in the upper reaches. Map 84 M.

(32) *Myaungcho River, Thaledan Forest.*—Said to have possibilities 28 mi. from Padaung, opposite Prome. The discharge is not great but a fall of 1,000 ft. is believed to exist.

(33) *Myittha River, tributary of Chindwin.*—Near its junction with the Chindwin this river, which includes the Manipur River (q. v.), is said to have a series of rapids and a large discharge, but it is of doubtful value except in the upper reaches above Kalewa. The lower reaches are at times navigable. The catchment area is about 10,000 sq. mi. A value of 2,000 kW. has been taken, but this is very speculative and probably far below the mark. Map 84 I.

(34) *Myitnge River, tributary of Irrawaddy.*—Part of the lower reaches of this river was examined in 1920. The hair-pin bend 20 mi. E. of Maymyo proved disappointing, as the drop round it is only 20 ft. The river is used for logging and carries a normal discharge of the order of 5,000 cusecs. The floods rise 30 ft. or so and it is very doubtful if the river can be used unless it be higher up.

(35) *Nam Chit, tributary of Shweli.*—Said to be perennial and to have falls of some 300 ft. (Map 93 E/2.)

(36) *Nam Et River, tributary of Myitnge.*—This is known also as the Namlang in the lower reaches. The river is reported to have falls varying in height up to 12 ft. between Keng Kam and Na Makkaw. An examination of the map (93 C/10, 14 and G/1 to 3) shows considerable fall but it is not known whether a useful head can be obtained in a reasonable distance. The dry season discharge is said to be about 300 cusecs from a catchment of about 1,000 sq. mi.

(37) *Nam Haw.*—This falls into the Salween below Mahaung and is said to have power sites. Map 93 J/11.

(38) *Nami Chaung.*—This tributary of the Chaungyi, Nammeik and Shweli is believed to have a minimum discharge of 8 cusecs with a fall of 1,500 ft. or more. Map 93 A/12. A branch of the same might also be used.

(39) *Nam Hka, tributary of Nam Lang.*—Falls on this stream near Mong Tung, N. Shan States, have been mentioned. (Map 93 F/4, 8, 12, 16.)

(40) *Namhpak Hka, tributary of Taping and Shweli.*—This has a "good volume of water even in the dry season." At a place about 3½ mi. from the Sinlun-Monglai road there is said to be a fall of 800 ft. in ½ mi. (Map 92 H/7, 11.)

(41) *Nam Hsawn or Nam Mong.*—Said to have a good fall and discharge above its junction with the Namma. Map 93 J/5.

(42) *Nam Hsin.*—Has been mentioned. Map 93 F/?.

(43) *Nam Lam, tributary of the Shweli.*—This stream joins the river on the L. bank just above Kyusa and 16 mi. above Molo. It is reported to fall 2,000 ft. in about 4 mi. in cascades of 20 to 100 ft. The stream is perennial, with a fair flow in April, and neighbouring streams could probably be combined with it. Map 93 E/3.

(44) *Namli Hka, tributary of N'Mai Hka, Bhamo.*—Rises at an elevation of over 8,000 ft. S. of Badon and is said to have power sites. Map 92 G/14, 15.

(45) *Nam Pan, tributary of Nam Teng.*—Reported to have a dry weather discharge of 400 cusecs and a considerable fall near its junction with the Nam Teng. Map 93 H/12, 16 ; L/3, 4, 7, 8.

(46) *Namparga River, tributary of Chindwin.*—Said to have a large discharge and rapid slope.

(47) *Nam Pawn, tributary of Salween.*—This river is navigable up to Lat. 19° and has a large perennial discharge. There are falls between Hsatung and Karenni, but of no great height, and there are probably rapids in the upper reaches. The catchment above Lat. 20° is some 1,600 sq. mi. with rainfall of 40 to 50 in. Map 93 G, H.

(48) *Nam Susa.*—Has possibilities. Map 93 A/12.

(49) *Nam Tabet or Tabak Kha.*—This tributary of the Irrawaddy is said to be worth examination near

Sima, map 92 G/12. Where the Lwema Kha joins up, 2 mi. E. of Namlang, there is a gorge with a drop of about 150 ft. with a good perennial discharge and possible storage.

(50) *Nam Tawn Chaung.*—This is said to have a good discharge and several falls. Map 93 H/10, 11, 14, 15.

(51) *Nam Teng.*—In addition to the site mentioned earlier there is a further one reported nearer the source, with a fall of 150 ft.

(52) *Namyok Chaung, tributary of the Uyu and Chindwin.*—A perennial stream with a fair discharge and said to fall between 2,000 and 3,000 ft. in 10 mi. Map 83 O, P.

(53) *Nam Yom.*—Has been mentioned as possible near its junction with the Nam Teng. Map 93 H/12, 16.

(54) *Nawng Htao Lake.*—At Wan Man 3 mi. N. of the junction of the Nam Tamppak with the Nam Pawn. The lake is fed principally from springs at its northern end and is reported to be deep. The discharge into the larger river is by a swift stream now working several country oil-mills. Probably 1,000 to 1,300 ft. or more head could be obtained. Map 93 E/5 and 92 H/4, 8.

(55) *N'Maikha River.*—One of the main sources of the Irrawaddy. It has many rapids and the discharge is large (2,000—4,000 cusecs ?) all the year round. Map 92 G/10, 14 ; J/4 ; K/1.

(56) *Pathe Chaung, Toungoo.*—This may have enough power for immediate local needs, but is a small stream without reservoir sites ; it has been brought to notice because it rises near Thandaung, where the rainfall is over 200 in. Map 94 A/12.

(57) *Pin River.*—This tributary of the Irrawaddy flows from the old volcano Popa, near Pakokko and Yenangyaung. The catchment at Magyigon is about 40 sq. mi. only, but the stream is spring fed. Map 84 O/4, 8 ; P/2, 6.

(58) *Pyu River, Toungoo.*—This stream leaves the hills by a gorge with a fall in it, some 6½ mi. from Pyu railway station. The dry weather discharge is very small, but the stream is said to be worth examination. Map 94 B/2, 6.

(59) *Salin River, tributary of Irrawaddy.*—Reservoir sites are said to exist on this river and would be necessary, as the rainfall is not great and the discharge of the tributary streams falls very low. There may be possibilities in the remote Mt. Victoria area. The tributary which runs from Kodakham towards Laungshe is said to be worth reconnaissance. There is no definite information, but it is believed to be good for 750 kW. with storage.

(60) *Saw Chaung, Yaw.*—The gorge above Saw and 75 mi. from Seikpyu can, it is said, be dammed to a height of 80 or 100 ft. There is a good dry weather flow and considerable fall in the upper reaches. (Map 84 K/4 and G/16).

(61) *Shwegyin Chaung* ; see Yunzalin River among sites investigated. This river itself may also have sites. Map 94 G/13.

(62) *Sinma Kadin Chaung, Toungoo.*—A fall of 80 ft. is reported on this tributary of the Kun Chaung (q. v.) 24 mi. from Pyu. It is perennial.

(63) *Sinbo Sin Ma falls, Tavoy.*—A series of small falls. Map 95 J/7, etc.

Tabak Hla River.—See Nam Tabet.

(64) *Tandin falls, N. Arakan.*—This river is used for timber flotation and has a 60 ft. fall which may be worth reconnaissance. Map 84 D ?.

(65) *Tenasserim River.*—Rapids and waterfalls are reported in the upper reaches of this river. Map 94 J, O, P, L. Examination is in progress. Below Mitta there seem to be no falls, but there are reservoir sites which could be utilized for lifting dams. The discharge is not known.

(66) *Yaw River.*—This rises on Mt. Victoria range and is said to have a perennial flow and a rapid bed fall. A dam site has been suggested where the stream breaks through the Pondaung range of hills, 20 mi. from Pauk. Map 84 K/3, 7.

(67) *Ye Pyan waterfall.*—This is on an unnamed tributary of the Hpawngaw Chaung, about 20 mi. E. of Maymyo and 4 mi. N. E. of Hkelawng. The stream falls from a plateau at 4,000 ft. elevation and has a sheer drop of about 1,000 ft. The discharge on 19 March 1920 was 6½ cusecs, so that storage would be required to make anything of the site. Map 93 B/12, 16.

(68) *Yu River, tributary of Chindwin.*—There are falls about 20 mi. up from the confluence which are said to be worth examination. Map 83 L/3, 8, 12.

(69) *Zamayi River.*—There is a waterfall in forest compartment 91 and the river is believed to be worth prospecting. Map 94 G.

(70) *Zingyaik Chaung, Thaton.*—Although this runs dry for some months reservoir sites may, it is anticipated, be found. There is a good fall. Map 94 J/8.

115. Central Provinces ; areas not investigated.—Of the sites on pages 84-88 and in the supplement of the Preliminary Report, the following do not appear to have been examined so far. The only information available is that in the place quoted, the relevant parts of which are reprinted here :

(1) *Ban River*, tributary of Purna, near Wari. This flows from the Gawilgarh Hills, Satpura Range, near the border of Jalgaon and Akot taluks, map 55 C/12, 16. There is said to be a natural fall of 60 or 70 ft. which can be increased by rapids or a dam or both. The

catchment is 130 sq. mi. and the stream does not entirely dry up. Reservoir sites are said to exist. The annual rainfall is small (about 30 in.) and precarious.

(2) *Bearma River*, tributary of Ken, at Khumergar. Here there is said to be a favourable reservoir site with a catchment of over 400 sq. mi. below the junction of the Sonar, where a flood discharge of 235,000 cusecs has been recorded. The site is on map 55 M. near Damoh, and the rainfall during the monsoon is about 43 in. but is liable to practical failure.

(3) *Bewas River*.—Said to be worth examination.

(4) *Chornai River*, at Uprora. This is near Bilaspur, map 64 J/10, and there is believed to be a reservoir site with a catchment of 150 sq. mi. and some perennial flow. A fall of 100 ft. is mentioned. The monsoon rainfall averages about 50 in., and Mr. Batchelor believed that 8,000 h.p. could be obtained. This is very doubtful.

(5) *Darekasa Waterfall*, Gondia. This is situated in hilly country near the railway station of Gondia, Bengal Nagpur Railway, map 64 C/11, 12. The stream dries up and no information is available as to storage.

(6) *Denwa River*.—No information.

(7) *Deo River*, Balaghat.—This rises on the Baihar plateau and flows into the Waingunga. Near Bhanpur the catchment is 120 sq. mi. (Map 64 C/5, 6, 9.)

(8) *Erai River*, tributary of Wardha, near Chanda. Reservoir sites are mentioned 12 mi. N. of Chanda. The catchment is about 300 sq. mi. and small falls are known. (Map 35 P/4, 8.)

(9) *Ghisari River*, near Dhansura. There is said to be a natural fall here of "several hundred feet," but the stream practically dries up. It has not been identified.

(10) *Gogra River*, near Sohagpur. There are said to be rapids here, but nothing is known as to the site.

(11) *Hasdo River*, near Chhuri and Korba—See note below (30.) Reservoir sites are suggested where this river leaves the hills, with a catchment of 2,800 sq. mi. at Garaghat, elevation 1,000 ft. 10 miles N. of the railway there are rapids with a perennial flow (unspecified).

(12) *Kanhan River*, at several points. 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 mi. S. 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 ft. contour is 178 sq. mi. increased, before the junction with the Pench to about 1,200 sq. mi. Four other points on this river between Khapa and the above were also referred to. (Map 55 K/15 ; O/3, 8.)

(13) *Kapadhana Falls*, below Amarkantak. These are said to be about 100 ft., but nothing further is known.

(14) *Machna River*.—Said to be worth examination.

(15) *Madu River*, tributary of Wardha, at Destaura. It is said that storage can be obtained here from 200 sq. mi. of catchment. Map 55 G/15 ?

(16) *Mhas River*, between Waigaon and Hingna. A small storage is indicated here, in Nelgaon district (map 55 D). Possibly the Mun and Paingunga rivers could be developed into this, which would increase the catchment from 90 to 450 sq. mi.

(17) *Munyari* (?) *River*, near Bilaspur. An old irrigation project here may be worth revising for power. Map 64 J.

(18) *Murna or Morna River*, at Shaikla. There is said to be a reservoir site here, 16 mi. S. of Akola, map 55 D/15 and H/3. The river nearly dries up.

(19) *Nagdooari River*.—Said to be worth examination.

(20) *Nimgahan*.—At an elevation of 2,700 ft. there is said to be a perennial stream with a rapid drop of 1,000 ft.

(21) *Patna River*.—Said to be worth examination.

(22) *Pench River*.—(See also Silewani Ghat scheme.) There is said to be a storage site at Bhiwagarh, 22 mi. N. of Nagpur, with a catchment of 1,700 sq. mi. The catchment is 527 sq. mi. at the 2,000 ft. contour. (Map 55 O.)

(23) *Rakshadah Fall*, near Berar Pani. This is on the border of the Lurmi range and Mandla district, and there is said to be a fall of 1,300 ft. in a mile.

(24) *Son River*, near Langi and Bijagarh. No information is available, but this is said to be worth reconnaissance N.-E. of the place named. (Map 64 C.)

(25) *Son-bhadra River*.—Said to be worth examination.

(26) *Tan River*, at Pendra. This is near Bilaspur (map 64 F). A reservoir site is indicated at an elevation of 2,000 ft., with a rapid fall of 700 ft., near Marai. (Map 64 F.)

(27) *Tawa River*, at Bagra. This is near Itarsi, Great Indian Peninsula Railway on map 55 F/14. There may be favourable sites near the junction with the Denwa River.

(28) *Uskal River*, Balaghat near Udwa. There is said to be a fall of 1,000 ft. in a reasonable distance on

the river, which is perennial, and a considerable reservoir site is indicated. The catchment above the junction with the Nahara is 130 sq. mi. and considerable power is indicated.

(29) *Waingunga River.*—This is worth reconnaissance. The catchment above 2,000 ft. is 275 sq. mi. and above 1,000 ft. 1,800 sq. mi.

As will be seen elsewhere in this Report, nearly all hydro-electric projects in the Central Provinces have to depend on storage for a good many months in the year; perennial rivers are few and far between and the annual rainfall is precarious and very variable. Storage sites are however found on many rivers, and not a few of them would be reasonably cheap to develop. Carry-over storage for bad seasons would generally be required (see paras. 27 to 30 *supra*) and this will add to the capital cost of such projects. On the other hand, water storage for irrigation is the chief need of the province, in view of its famine record. There is therefore a reasonable prospect of combining forces for both purposes, even though their needs are somewhat dissimilar. For irrigation the demand is intermittent and seasonal; for power the draft is fairly continuous all the year round. If both purposes are to be served it is necessary to impound the tail waters after passing through the turbines, until they are wanted in the irrigation channels. This means additional cost, but does not necessarily kill the schemes.

(30) In this connection Mr. Clayton, late Chief Engineer, Bihar and Orissa, pointed out that a site had been investigated on the Hasdo (either in the Central Provinces or in Bihar and Orissa) with a catchment of 1,700 sq. mi. and a storage capacity of 5,900 m. c. ft. with a 90 ft. dam, and further possibilities with a higher dam. This may be the place on map 64 J/9, 10 above Chhuri and Korba, mentioned in the Preliminary Report. The officer who actually investigated the Hasdo reported that "nine miles N. of Champa, and 28 mi. above its junction with the Mahanadi, the channel of the Hasdo is almost choked up by a high irregular bar of rocks which extend from Deori on the R. bank to Chikbenla on the L. bank." There may be good falls here.

(31) Mr. Clayton also pointed out some time ago that when the Jonk storage (q. v. in para. 112) was investigated several other reservoir sites were examined on the tributaries of the Mahanadi, all of which are on record in the Province. Of these the Mand site (64 N and O) had a catchment of 1,940 sq. mi. and a capacity of 10,000 m. c. ft. and the Tel site (map 64 P) a catchment of 3,500 sq. mi. and a capacity of 33,000 m. c. ft., both dams being 90 ft. high only. These are in the Central Provinces apparently.

116. Kashmir; areas not investigated.—As Kashmir already has more existing and developed power than can be utilized (para. 63), together with two known sites of great capacity (para. 101), it has so far not been necessary to look further afield.

(1) *Chenab River.*—The known Riazi site is referred to under "Sites examined," but the great tributaries of this river undoubtedly contain much further power. They are unnamed on the Atlas sheets; but the largest one, joining up on map 43 O/11, 15, is snow-fed from a very large catchment and falls rapidly from the high peaks down to about 3,600 ft. at the junction.

(2) *Kishenganga River, tributary of Jhelum.*—This snow-fed river has a catchment of over 2,000 sq. mi., all at high altitudes, out of the 13,000 sq. mi. of Himalayan catchment of the main river. Its valley is "throughout very precipitous, and for the greater part little better than a chasm in the mountains. Its basin is peculiarly narrow and elongated, being in places only 17 mi. wide from water parting to water-parting."* There is undoubtedly large power to be obtained from this river, even in its lower reaches. It joins the Jhelum at Muzaffarabad, in the middle of the loop referred to under that river.

(3) *Punch River, tributary of Jhelum.*—This river joins the main river in the plains. Above Kotli, where the catchment is some 1,400 sq. mi., there is likely to be large power available. The river rises in the Pir Panjal range, at altitudes between 11,000 and 16,000 ft., so that it will be snow-fed to a considerable extent during the hot weather. The minimum discharge recorded since 1916 is 300 cusecs at Tangrot and the maximum 270,000 cusecs.

117. Madras; areas not investigated.—The following sites are mentioned, on information of more or less definiteness, as having possibilities, but they have not been examined as yet.

(1) *Anamalai Hills, Aliyar River, Coimbatore District; and Sholiyar (or Suruli) River.*—In the Preliminary Report, page 89, mention was made of two possible sites, neither of which has been examined. Mr. Tate hopes to visit the Aliyar River this year; the site is at Lat. 10° 25 Long. 77° 00 near the boundary of squares B/15 and F/3 of map 58. It has been stated that of the total fall of 2,000 ft. 500 ft. could be utilized; but the actual head may be anywhere between these limits. The minimum discharge is believed to be about 6 cusecs. The catchment area is not known, but the rainfall from April to November is between 40 and 75 in. and discharges up to 800 cusecs are mentioned. Probably from 1,000 kWs. or more, continuous, can be developed with storage.

* Burrard and Hayden, *op. cit.*, page 170

The Kalianapandal Falls in the Sholiyar River may or may not be another name for the same site. A minimum discharge of 6 cusecs with a fall of 300 ft. is on record, but the fall may be capable of extension.

(2) *Bhavani River, Coimbatore District.*—The falls near Thondai, 22 mi. from Coimbatore and 13 mi. from Metapollaiyam, are mentioned on page 89 of the Preliminary Report. The site is at Lat. 11° 15 Long. 76° 30′ on map 58 A. The site is near the "Silent Valley" site (q. v.) and may be the same. Mr. Tate hopes to visit it this year. The falls are said to be about 50 ft. The catchment area is given as 400 sq. mi. and the rainfall is not known between the 20 and 75 in. limits. Discharges are believed to vary from 3,000 to 40 cusecs.

In the Malabar District (*loc. cit.*) a fall of 2,500 ft. in 3 mi. is shown on the maps in the upper reaches of this river, 45 mi. from Coimbatore and 21 mi. from Ootacamund. No other details are known.

(3) *Kavindinyanadki River, Chittoor and N. Arcot.*—The Mardana falls are 17 mi. from Gudiatham Railway Station and 3 mi. from Mardana. The fall is about 700 ft.

(4) *Kolakambe waterfall, Nilgiri Hills.*—This is near the Karteri River (q. v.), on map 58 A/11, 12. By means of a tunnel 1,000 ft. head could, it is believed, be obtained. The minimum flow is said to be 10 cusecs and storage is possible. It is believed to be good for some 2,000 kW.

(5) *Nurpurya River, Nilgiris.*—This is mentioned in the Preliminary Report, page 91, but has not yet been visited. The site is near Cherambadi village, near Glenrock Tea Estate, Wynaad.

(6) *Silent Valley Forest Reserve, South Malabar District.* (Map 58 A/8.)—As stated on page 91 of the Preliminary Report, there are unexamined possibilities here ; a reservoir site is known to exist, with rainfall of about 150 in. in the catchment and a "considerable drop" into the plains S. of Mannaghat. The officer in charge of the survey hopes to visit the site this year. (See also Bhavani R.)

(7) *Singamputti scheme, Madura District.*—Nothing is known of this at present.

118. North-West Frontier ; areas not investigated.—There has been no survey in the North West Frontier Province so far, and it is doubtful whether the cost of any such general survey would be warranted. The area is largely wild and uncivilized, subject to frequent raids, and lacking in present or prospective industries. It is possible that minor projects may hereafter be developed for special purposes, but the difficulty of guarding transmission lines would remain. In the Preliminary Report, page 94, certain rivers were mentioned ; and for the sake of completeness these may be summarized again here, with some additional remarks.

(1) *Indus River.*—This becomes a North-West Frontier Province River above Attock, where it first enters the Punjab plains. The minimum discharge ever recorded at Kalabagh is 18,870 cusecs. It is unlikely that the river will ever be harnessed for power in the North-West, and it is probable that the cost would in any case be prohibitive. The only possible method of development would be by means of series of lifting dams, as explained in para. 31 of this Report. Here however the maximum flood discharge, reckoned at about one million cusecs, would have to be allowed, for it is exceedingly unlikely that any point could be found where flood regulation would be possible, at least within reach of civilization. The highest discharge in the last 20 years, at Kalabagh, was 800,000 cusecs. In the absence of such regulation the tail waters in flood times would almost certainly rise so that most of the head would disappear. There is information regarding the gradient of the river in Part III of Burrard and Hayden's well known work * from which it appears to average some 17 ft. a mile for hundreds of miles above Attock. If therefore development by lifting dams were *possible* it would provide continuous power on the *minimum* flow of the order of 20,000 kW. per mile run, or over 2 million kW. in the 120 mi. between Attock and the entry of the river into Kashmir territory.

It is interesting to note (from the work cited above) that the great flood of 1841 was caused by the breaking down of a landslip-dam 1,000 ft. high in the Gilgit region, as also happened at Gohna Lake. If such a lake as then existed for a year could be formed *and maintained* lower down it would go far towards flood regulation. This however is a possibility that affects a very large number of rivers in India, and it has therefore been dealt with separately in para. 33 of this Report.

(2) *Kohat Toi.*—It is believed that power can be obtained from this hill stream near Kohat (map 38 O/2, 6, 7) but no information is available.

(3) *Kunhar River.*—This snow-fed river, as noted in the Preliminary Report, page 94, joins the Jhelum (q.v.) on its great bend below Muzaffarabad on the Abbottabad-Kashmir road. It has many rapids and a large perennial flow, and there is little doubt that it could be developed on a series of lifting dams if it were ever necessary. As however neither the minimum flow nor the gradient of the river is known no estimate can be made of its possible power.

* The Geography and Geology of the Himalaya Mountains and Tibet (1907).

(4) *Sinan River.*—This tributary of the Indus had a small plant on one of its own tributaries, near Mansehra, during the Boer War, as noted on page 94 of the Preliminary Report. The Sinan itself could doubtless be developed by means of lifting dams, and there may be sites where other methods of development on higher heads could be used. No information is available however.

(5) *Canal Falls.*—As noted in the Preliminary Report, page 94, the Upper Swat Canal at Malakhand could provide about 20,000 h.p. practically continuously under 230 ft. head, while other canal falls have considerable but unexamined power.

119. Punjab; areas not investigated.—In dealing with this Province the water power is practically all in the Himalayan area, out of the Punjab, and the only logical arrangement is to deal with the "five rivers" and their tributaries, together with such tributaries of the Indus on the W. and the Jumna on the E. as come within the Province. These main rivers are therefore dealt with from W. to E. in the order Indus, Jhelum, Chenab, Ravi, Beas, Sutlej, Jumna; and in each case the Punjab tributaries are in alphabetical order. In this section, in the absence of examination, a good deal of speculation necessarily occurs. There is no doubt whatever that many fine power sites exist, with enormous potential power, but very little of it is actually in the Punjab. Reference to other sections of the Report (Kashmir, North-West Frontier Province, United Provinces) may be made.

The following is a summary of the Punjab rivers with the power that can probably be developed from them, so far as is at present known.

TABLE 50.—*Punjab Rivers.*

Serial.	River.	Tributary.	Site.	Probable power, kWs.
(1)	Indus	..	..	See N.-W. F. Province.
(2)		Haro	..	1,850
(3)		Jablat	..	No information.
(4)		Soan	..	2,000
(5)	Jhelum	..	..	See Kashmir.
(6)	Chenab	..	..	Ditto.
(7)	Ravi	..	Multiple lifting dams	200,000
(8)		Bhadal	Ditto	30,000
(9)		Nai	Ditto	30,000
(10)	Beas	..	Multiple lifting dams, below Largi.	94,000
(11)		Binnu	Reservoir site	Not known
(12)		Gujh	Ditto	Ditto.
(13)		Ool	..	0,000
(14)		Parbati	..	20,000
(15)		Sainj	Above Largi	50,000
(16)		Tirthan	Ditto	10,000
(17)	Sutlej	..	(i) Lower reach to Bhakra, by lifting dams.	60,000
			(ii) Rampur to (i) lifting dams.	100,000
(18)		Arni	Confluence to bifurcation.	000
(19)		Baspa	Raturing gorge	30,000
(20)		Bhera Khad	..	Small.
(21)		Chainre Gad	..	Doubtful.
(22)		Gumber and Gumrola	..	No information.
(23)		Kurpan Khad.	..	Ditto.
(24)		Machha da Khad.	..	Small.
(25)		Nogli River	Above Rampur	1,000
(26)		Sher Khad	A reservoir site	Unknown.
(27)	Jumna	..	..	See United Provinces.
(28)		Pabar River	..	30,000
(29)		Giri River	..	No information.
(30)		Rupin, Supin.	See Pabar	
			TOTAL (say)	692,000 kW. continuous.

(1) *Indus River and Tributaries.*—The portion of this river which runs in the Punjab, or on the boundary between the Punjab and the North-West Frontier Province, is in the plains. The comments under the North-West Frontier Province entry may however be referred to.

All the main feeders of the Indus are out of the Punjab and are dealt with under the North-West Frontier Province. In the Preliminary Report, page 95, mention was made of the two tributaries which may have possibilities in the Punjab.

(2) *Haro River, near Hasan Abdal, Attock.*—There is said to be a fall of 50 ft. which can probably be increased by a lifting dam, and "a good perennial discharge" (map 43 C/5, 9, 13). A private firm enquiring for power believes that 1,850 kW. continuous could be obtained.

(3) *Jablat (or Chablat) River.*—This is near the preceding entry (Haro River) but there is no information whatever regarding it.

(4) *Soan River, near Rawalpindi.*—No information is available regarding this river, but it has been examined under the auspices of a private firm and is believed capable of supporting a plant of 2,000 kW. This may be taken as the equivalent of about 700 kW. continuously, as storage is a part of the project.

(5) *Jhelum River and Tributaries.*—This forms the boundary between Kashmir and the North-West Frontier Province in the latter part of its Himalayan course, and between Kashmir and the Punjab at the lowest part of all. The tributaries rising in the hills are all either in Kashmir or the North-West Frontier Province, to which reference may be made. The lowest recorded discharge of the main river is 2,944 cusecs at Mangla and the maximum (1893) 500,000 cusecs.

(6) *Chenab River and Tributaries.*—The whole of the Himalayan course of the Chenab and its tributaries is in Kashmir; reference to para. 104 will show that it has great possibilities. The minimum discharge recorded was 4,341 cusecs at Marala and the maximum (1893) 713,000 cusecs.

(7) *Ravi River and Tributaries.*—The Upper Bari Doab Canal takes off from the Ravi at Madhupur, and the power possibilities at that point are dealt with under the Punjab Canals. Above Madhupur the river forms the boundary between British India and Kashmir to some way N. of Dalhousie, above which point it is in Chamba State. The catchment area above the canal intake is some 2,500 sq. mi. and runs up to great peaks of 20,000 ft. The lowest recorded flow at Muktesar is 1,334 cusecs and the greatest flood discharge practically 200,000 cusecs in 1908. As in many other cases mentioned throughout this report, if flood regulation is possible at any point (para. 33) then lifting dams can be utilized to harness the river. Its average fall throughout its course of 130 mi. is 115 ft. a mile, and the river is nowhere very remote from the plains. "The Ravi rises in the basin of Bangahal, and drains the southern slopes of the Pir Panjal and the northern slopes of the Dhauladhar. The basin of Bangahal is sixty miles in circumference. Numerous tributaries flow down its inner walls, many of them with steep gradients; the Bhadal rises on the N. at 16,000 ft. and *falls* 314 *ft. a mile for* 35 *mi.*; the Nai, which rises in the mountains known as Kali Devi, has a length of 30 mi. and *an average fall of* 366 *ft.* a mile. The height of the bed of the Ravi at the lowest point (Wulas) of the Bangahal basin is about 5,000 ft. Gathering together all the water that runs off the inner walls of this extraordinary rock cauldron, the Ravi flows out to the W. The gorge by which it escapes from Bangahal may without exaggeration be described as inaccessible; it appears to have been scooped out of solid rock and its sides are perpendicular. After leaving Bangahal the Ravi flows through the valley and State of Chamba in a N.-W. direction parallel to the Dhauladhar range. West of the Chamba capital it makes a sudden bend at right angles and cuts its way through the Dhauladhar to the S.-E. The defile that it has carved through the range is a few miles N. W. of the station of Dalhousie."*

Such a description will appeal at once to the hydro-electric engineer, but only reconnaissance can show what power is actually capable of development. The loop at Dalhousie is probably capable of being short-circuited, with a lifting dam to increase the head. At times of minimum flow the main river is certainly responsible for nearly all the water flowing, though the snow-fed tributary (probably the Bhadal) entering about 16 mi. W. of Chamba may account for about one-fifth of it. Let it be assumed that the main river, above and below this junction, carries a minimum of 1,000 cusecs, averaged along the 60 mi. of its course above Madhupur; the total fall in this 60 mi. may be taken 6,000 ft. using 100 ft. a mile instead of the average of 113 ft. If half of this, or 3,000 ft. can be utilized by means of lifting dam the power available (at multiple sites) is 1,000 ×3,000/15 or 20,000 kW. continuously, with far more except at the rare times of absolute minimum.

(8) and (9) As regards tributaries, nothing is known beyond what is given in the extract above regarding the Bhadal and the Nai. It is however more than probable that they can be developed in the stretches near their junctions with the main stream. On falls of about 300 ft. a mile every cusec of flow will give 20 kW. per mile. If therefore a minimum flow is assumed, in each of these important tributaries, of 150 cusecs only, and 10 mi. of each is taken as practicable—20 mi. in all—a further 60,000 kW. is in sight. This in all probability is *far* below the mark, but the problem is complicated by the distances of transmission. These however are not large; from the great junction 20 mi. E. of Chamba, far above the reaches here considered, it is only 50 mi. to Pathankot and 70 to Hoshiarpur.

(10) *Beas River and Tributaries.*—This river has so far not been utilized directly for irrigation, nor has it been examined for power; the present writer has however been along its course from its rise at the Rohtang pass up to its junction with the Sainj and Tirthan at Largi. In this 75 mi. the fall averages 125 ft. a mile. The river and its main tributaries—the Parbatti and the two mentioned above—are used extensively for timber transport; but by the aid of bear-trap dams or other well-known arrangements this need not be interfered with by power developments. The minimum recorded flow of the Beas at Naushera is 2,500 cusecs and the highest flood 164,300 cusecs at Wazir Bhallur, from a catchment of 5,700 sq. mi.

* Burrard and Hayden; *op. cit.*, page 166.

Below Largi the slope of the river bed drops until, in the outer Himalaya, it is only about 10 ft. a mile. There is a great gorge immediately below Largi, where the river cuts through the Dhauladhar range, after which it widens out. In the 25 or 30 mi. below Largi, in Mandi State, there are certainly considerable possibilities. Parts of this stretch however have a road not very far above high flood level, so that lifting dams might submerge it; this is certainly the case around Largi (where a new road to Mandi is under construction), probably most of the way to the town of Mandi. Road makers do not consider this point when laying out their alignments. Largi is at R. L. 3,140 ft. and 2,000 ft. is reached some 30 or 35 mi. lower down, giving a slope in this intermediate and most promising stretch of about 35 ft. a mile. At Mandi there are known possibilities, which however are unexamined; but Mr. Nicholson records possible storage sites on the main river (i) about 5 mi. upstream of Mandi town, on map 53 A/14; (ii) near Nagan, 10 mi. N.-W. of Mandi, on map 53 A/13; and (iii) 10 mi. W. of Haripur, at long. 79° 0′, on map 53 A/1.

As regards water, discharges were specially taken of the Sainj and Tirthan at Largi, through the kindness of Mr. A. S. Montgomery, Chief Engineer, Roads and Buildings, Punjab, on the 4th and 5th June 1921, during the exceptional drought of this year. They show 950 cusecs for the Sainj, which flows in from the snows to the East, and 325 cusecs for the Tirthan, draining from the South. The corresponding discharge of the Beas alone at this point can certainly not have been below 1,200 cusecs, giving 2,475 cusecs for the combined river. The latent power therefore from Largi downwards, up to where the river flattens out, assuming that half the total fall could be harnessed by means of lifting dams, is $2{,}475 \times 570/15$ or 94,000 kW. continuous.

Above Largi, the Beas itself could not well be developed in the Kulu valley, except high up where its discharge is small. It is interesting to note that the valley of the Beas runs at some 600 to 700 ft. higher elevation than the parallel Sutlej River at corresponding points in the mountains.* Writers in the local engineering papers have suggested tunnelling through the intervening ridge. This is no doubt possible from the engineering point of view, but appears quite impracticable. A tunnel of not less than 20 mi. in length, with two working faces only, would be required apparently to obtain 500 ft. head.

The chief tributaries may now be referred to in alphabetical order.

* Burrard and Haydon, *op. cit.*, page 161.

(11) *Binnu River.*—This flows in on the Right bank at the small loop on map 53 A/9 and Mr. Nicholson records a storage site on it some 2 mi. from the confluence; the elevation is not known at present. He also records a storage site on the unnamed tributary flowing in on the right bank near Dera Gopipur (map 53 A/1, 5) at a distance of 5½ mi. direct from the confluence.

(12) *Gujh River.*—This tributary and the unnamed one immediately to the east of it, on the right bank, flow in from the Kangra Valley (map 52 D/4) and Dharmsala, famous for its slate quarries and its great earthquake. The confluence is far below the stretch of river dealt with above, but the tributaries are of interest as Mr. Nicholson has marked off promising storage sites in both. The dam site in the Gujh is roughly 11½ mi. from Dharmsala, while the second site is 8½ mi. S. E. of the first. These reservoir sites may some day be of importance either for power or for irrigation or for both. Their levels are not known.

(13) *Ool River, Mandi.*—This tributary joins the Beas on the right bank, a few miles above Mandi, flowing immediately under the lee, and to the east of, the spur of mountain from Drang to Jatingra (map 53 A/13, 14). On the 28th May 1921, towards the end of this abnormally dry season, it was found by Mr. Gilbert, Executive Engineer, to be carrying 530 cusecs. The drop of the bed is very steep, and there appears to be a fall from about 6,000 ft. to 3,000 ft. in about 8 or 10 mi. The river can probably be assessed as good for at least 6,000 kW. on a high fall development, and perhaps more; but there is no definite information.

(14) *Parbati River.*—This large snow-fed tributary, flowing in from the high peaks above Pulga (map 52 H/4, 8), has a succession of rapids throughout its considerable length. It may be considered probable that its minimum discharge is of the order of 200 or 250 cusecs, though no information has been received on the point. Timber is floated down it throughout the hot weather, from Pulga. Of the two main branches the N. one appears from the Atlas to have a fall of about 2,000 ft. (from 10,000 to 8,000) in some 10 mi.; the southern or Pulga branch falls more gently. There is however little doubt that the river contains power, capable of development to the extent of some 20,000 kW. continuous. The junction with the Beas is at about 4,000 ft. elevation, more or less.

(15) *Sainj River, above Largi.*—The gauging of 950 cusecs in June 1921 is probably not far from the minimum of this snow-fed tributary of the Beas; 750 cusecs may be taken for security. There are rapids falling 1,000 ft. (4,000 to 3,000) in the 8 mi. above the main confluence, up to the point where the river bifur-

cates, and the whole of this could be developed by an open channel, preferably on the left bank judging from the Atlas sheets and the view from Largi. This would give 50,000 kW. if the data prove correct, and they cannot be very far wrong. Above the bifurcation the fall is exceptionally steep, but the catchment is much reduced.

(16) *Tirthan River, above Largi.*—The gauging of 325 cusecs in June 1921 is here also likely to indicate an absolute minimum of about 250 cusecs in the lower reaches. The stream bifurcates 6 mi. above the main confluence, but the E. branch from the high peaks carries most of the discharge. The fall in this 6 mi. is moderately steep and is of the order of 600 ft., Manglaur being R. L. 3,850 and about 100 ft. above the river bed. The power in this stretch therefore amounts to some 10,000 kW. continuously.

There are other (unnamed) tributaries between Largi and Mandi, especially on the left bank, with fair catchments but not snow-fed. From the known data of corresponding tributaries of the Sutlej, fed from the same hills, it is probable that three of these tributaries can give not less than 1,500 kW. each or 4,500 kW. all together, continuously.

(17) *Sutlej River and Tributaries.*—As regards the "Sutlej River project" and the subsidiary Anu and Nangal projects the reader is referred to para. 90; while the existing Simla scheme is entered in para. 68. These however are merely a small proportion of the total power of this great river. "The mountain basin of the Sutlej lies mainly N. of the Himalaya; this area of the Himalaya proper drained by this river between the great range and the plains of India, consists of an insignificant tranverse strip."* The Giri on the S. and the Beas on the N. are at a much higher elevation at corresponding points and the basin between is only 20 mi. wide (*loc. cit.*).

Reference has been made, under the Sutlej River project, to possible storage sites for regulating flood discharges and augmenting minimum discharges. The minimum discharge in the last 20 years is 2,900 cusecs at Bhakra but Colonel Battye is satisfied that 3,300 cusecs can be depended upon. In fact 3,400 cusecs in the lowest record at Rupar, downstream of Bhakra. The greatest flood in this period is 250,000 cusecs. In the main river Mr. Nicholson has noted such sites (i) 4½ mi. N. of Bilaspur, near Parua, on map 53/A junction of 11, 12. (ii) 8½ mi. E.-N.-E. of Bilaspur, near Chimb, on map 53 A/15. If either of these dams were built the whole reach of the river below, down to the projected tunnel (or rather the H. F. L. of the Bhakra lake) could be developed by a

* Burrard and Hayden, *op. cit.*, page 161.

succession of lifting dams. Between the upper dam site and the projected lake there is a fall of the order of 500 ft., which would give some 60,000 kW. continuously, allowing for only *one-half* of the total fall being used. "The fall of the Sutlej from its source to the plains of India is very uniform, and averages on every section of its length 30 or 35 ft. per mile; the height of its bed is 15,000 ft. near Rakas Tel, 10,000 ft. near Shipki, 3,000 ft. at Rampur, 1,000 ft. at Bilaspur."* There is therefore a further fall of some 1,500 ft. (more or less) between the upper dam site referred to above and Rampur, where the river cuts through the Dhauladhar range; and if one-third of this could be utilized by means of lifting dams (involving a higher flood storage) a further 100,000 kW. is available. Rampur is 60 mi. only from the curve of the foothills, so the whole of this reach is within easy transmission of the plains. Further upstream Khatolu gorge, with a lifting dam and tunnel, offers further power.

Those tributary streams regarding which any information is available may now be mentioned in alphabetical order. It may be pointed out that fairly full information is available regarding the developed Nauti Khad, and that hydrographic data so recorded can be used (with great caution) for other tributaries, especially those on the left bank. The annual rainfall rapidly diminishes as one goes north, the main watershed between the Sutlej and the Giri (*i.e.*, between the Indian Ocean and the Bay of Bengal) passing from Simla along the Hindustan-Tibet road and catching more of the precipitation than the higher ranges on the right bank of the Sutlej. Through the kindness of Mr. A. S. Montgomery, Chief Engineer, Roads and Buildings, Punjab, several of these tributary streams were gauged early in June 1921. Most unfortunately (from this point of view alone) the great drought, which caused record low discharges in the Nauti Khad and Anu Khad, during May 1921, broke up a week before with some casual storms; the effect of these however only lasted for 3 days, when the discharges returned to their former low level.

Anu Khad River.—See Punjab "sites investigated."

(18) *Arni River.*—This flows in on the right bank below Dalash and Luri bridge, with a steep descent from the Jalori pass. A discharge taken at mile 57 on the 5th June 1921, at the end of the exceptional drought, but soon after a casual storm at Simla (40 mi. W.) shows some 36 cusecs. Probably the minimum is not much above 18 cusecs. Local irrigation channels and flour mills show that there is always a fair flow even at the settlement at Ani, above the main

* Burrard and Hayden, *op. cit.*, page 165.

bifurcation. The 4 mi. or so between this point and the main confluence probably have a fall of not less than 500 ft. which indicates continuous power of some 600 kW. only. A casual reconnaissance while in Kulu indicated that the stream has much greater possibilities.

(19) *Baspa River.*—This snow-fed tributary of the Sutlej is somewhat remote, about 90 mi. from the curve of the foothills, but is of importance in that it rises from, and flows between two spurs of, the Great Himalayan range. Its minimum discharge is not known, but will be before the snows begin to melt. On the 16th June 1921, it carried 3,500 cusecs, or more than the minimum discharge of the Sutlej itself! Probably it falls to 1,500 or even 1,000 cusecs occasionally, though it gets more rainfall than the far larger trans-Himalayan catchment of the main river. At Raturing gorge (map 53 I/7) there is a series of rapids amounting to some 500 ft. of fall in half a mile, near Sangla. It is therefore certain that some 30,000 kW. could be obtained continuously here, if not half as much again.

(20) *Bhera Khad.*—This is practically useless, except perhaps for timber sawing. The flow was 11 cusecs at mile 58 of the road on 3rd June 1921, and 36 cusecs on 22nd May 1919.

(21) *Chainre Gad.*—This small nala, 12 mi. W. of Luri bridge on the right bank—the next nala below the Arni—is stated by Mr. R. W. Thick (late Power Station Superintendent, Simla) to have possibilities. The minimum discharge is no doubt of the order of 10 cusecs, from a catchment of some 50 sq. mi., but there is a fall of about 1,000 ft. from Pamlog and Chainre villages, where regulating storage could be built. But as explained in connection with the Anu Khad (para. 90) regulating storage will not appreciably increase the minimum flow over a considerable period of drought.

(22) *Gumber and Gumrola Khads.*—These two neighbouring streams, together with the Ullay Nala, join the Sutlej near Bilaspur (map 53 A/15) on the left bank. They have fairly good catchments to the W. of Simla and Subathu and the main water-parting. Beyond that nothing is known of them at present except that they begin their valley courses at several thousand feet above their confluences.

(23) *Kurpan Khad.*—This flows in on the right bank opposite the Nogli river and below Nirmand. It carried 77 cusecs on 13th June 1921 and may possibly be of some value.

(24) *Machhada Khad.*—This has small power for forestry only. The discharge on 3rd June 1921, at mile 62 on the road, was 19 cusecs and on 22nd May 1919, 110 cusecs.

Nauti Khad.—This is developed ; see para. 68.

(25) *Nogli River.*—This joins the Sutlej near Rampur (map 53 E/11), and is snow-fed from an isolated group of high peaks running up to 20,000 ft. A reconnaissance made by the present writer shows it to be capable of giving some 1,900 kW. continuously, with a long open channel. The minimum discharge is probably about 40 or 50 cusecs ; on the 29th May 1921 it carried 250 cusecs and on 21st May 1919 480 cusecs at its confluence with the Sutlej, at the end of long drought, but probably after a shower. The main river was then carrying 7,000 cusecs.

(26) *Sher Khad.*—This tributary, with a good catchment, joins the river a few miles S.-W. of Bilaspur on the right bank (map 53 A/11) opposite the Gumber. At a point near Gaha and Umrao, 7½ mi. N.-W. of Bilaspur, Mr. Nicholson records a reservoir site ; it is apparently not at any great elevation above the main river, but might be useful as a subsidiary to the Sutlej River main project.

Ullay River.—See Gumber river, above.

(27) *Jumna River Tributaries.*—The Jumna River itself is dealt with under the United Provinces. Of its Punjab tributaries not much is known.

(28) *Pabar River.*—This was gauged on the 15th June 1919, probably after rain, and carried 1,380 cusecs at Rohru, 10 mi. from Kadrala and 74 from Simla. It is partly snow-fed, and with the Rupin and Supin rivers makes up the Tons (map 53 E, F, and I) which forms the boundary between the Punjab and United Provinces. There is very little doubt that all these rivers have considerable power, but the layered Atlas sheets are the only source of information as to falls. Above the main confluence of the tributaries of the Tons there are falls of 1,000 ft. in a few miles. The combined discharge will there be considerably more than double that given above. but this was probably nowhere near the minimum. If the Tons falls to 500 cusecs all told it would appear to have some 30,000 kW. continuous in a small area at the main confluence. What there may be below, on lifting dam development, is a matter for investigation. The confluence appears to be at about 4,000 or 5,000 ft. elevation, while the plains below are at 2,000 ft.

(29) *Giri River.*—This was examined in 1900 below Phagu (Simla Hills) and found difficult to develop. In this neighbourhood (7 mi. from Theog) it carried 73 cusecs on the 11th May 1919, but the minimum is probably nearer 25 cusecs at that point. Lower down it gathers volume and improves, but little information is available. It is worth prospecting upstream from the point, some 20 mi. from the main confluence, where it is joined by two small streams under Kaleog ; here

there is a very long stretch of comparatively level bed, where reservoir sites may perhaps be located.

(30) *Rupin River; Supin River; Tons River*—See Pabar River above.

120. Rajputana; areas not investigated.—*Sirohi State, Mount Abu.*—There are said to be possibilities some 3 mi. E. of Mount Abu, where there is a rapid fall of 2,000 to 3,000 ft. Any project would depend entirely on storage sites being found, as there is a very small catchment. The rainfall however averages 60 in. on the hill. (Map 45 D.)

121. United Provinces; areas and sites not investigated.—(1) *Baur River, Naini Tal District.*—Preliminary Report, page 100. This is unlikely to be of use, as a discharge as low as 9 cusecs is on record. (Map 53 O/7.)

(2) *Dabka River.*—Near the Baur, and the same remarks apply. (Map 53 O/3.)

(3) *Garai River, Mirzapur District.*—There is a fall of 180 ft. but no further information is available. It flows into the Kaliganga (q. v.).

(4) *Garrah River, Bareilly District.*—This was gauged in the plains near Sandi and found to carry:

	cusecs.
15th April 1919	226
15th May "	214
7th June "	193

This gives no indication of the hill discharge; the stream is not identified.

(5) *Gaula River, Naini Tal District.*—This is under examination.

(6) *Jagei Lake, Garhwal.*—(Preliminary Report, page 101.) This has not been examined, but the remarks on the Gohna Lake, para. 93) probably apply here also.

(7) *Kalaunia Nadi.*—(Preliminary Report, page 101.) This is under examination, but reports have not yet come to hand.

(8) *Kaliganga River, Garhwal.*—(See Preliminary Report, page 101.) This has not yet been examined at the Launsari site previously referred to.

(9) *Kanhar River, tributary of Sone.*—(Preliminary Report, page 101.) This has not yet been examined. (Map 63 P/3, 7, 8.)

(10) *Khajuri, Dahwa and Jargo Nadis, Mirzapur.*—(Preliminary Report, page 101.) These have not yet been examined. (Map 63 K/12.)

(11) *Khoh River, Garhwal.*—Possibilities were indicated in the Preliminary Report, page 102, at a point 4 mi. above Dogadda. Ropeways are proposed in the district. No examination has yet been made. (Map 53 K.)

(12) *Mussoorie.*—The various small sites mentioned in the Preliminary Report (page 102), as offering possible extensions for the Mussoorie Dehra scheme (Table 16) have not yet been examined. (Map 53 J.)

(13) *Nandhaur River, Naini Tal District, and*

(14) *Nayar River, tributary of Ganges, Garhwal.*—These rivers (see Preliminary Report, page 102) have not yet been reported on, but are under examination.

(15) *Pindar River.*—This snow-fed tributary of the Alaknanda is under examination. See Preliminary Report, page 102; map 53 N.

(16) *Rer River, tributary of Sone.*—This promising river (see Preliminary Report, page 103) has not yet been examined. (Map 63 L and P.)

(17) *Tons River, tributary of Jumna, Dehra Dun.*—This should not be confused with the river of the same name in Rewah. The site at Kalsi, where the Tons joins the Jumna, has not yet been examined. The catchment area, as shown in Burrard and Hayden's great work,* is larger than that of the main river. If a minimum discharge of only 500 cusecs is assumed, and a fall of 500 ft. developed by lifting dams, the power will be of the order of 16,000 kW. continuous.

(18) The *Giri* tributary is not likely to show much power as its discharge runs low.

122. Native States of India; areas not investigated.—So far as is known, comparatively little investigation has been made of the water power resources of many of the Native States and Territories adjoining British India. In previous tabular statements certain working plants and projects are included, and these need not be referred to further here. No doubt other sites have also been either examined or suggested by those immediately concerned with them; and in some cases detailed investigations may have been made, of which no details have reached the survey. Nothing whatever is known regarding Hyderabad (Deccan) or Baluchistan, and very little regarding the many States comprised in the Central India Agency or Rajputana. In the latter, however, two possible sites have been mentioned in Udaipur.

(1) *Dhebar Lake, Udaipur.*—It is not known whether by raising the level of the Dhebar Lake, 30 mi. S.-E. of Udaipur City, any power possibilities would be found; the lake is of great area however.

(2) *Sabarmati River, Udaipur.*—There appear to be possibilities in the Wakal River, tributary of the Sabarmati, either near Bansiwara or Manpur (Atlas sheets, map 45 H, left half), and possibly in the other tributaries or the main river, which crosses the boundary between Bombay and Udaipur in this area. The rainfall is scanty, about 25 in. but reservoir sites may be available. The bed level where the Manas and

* Geography and Geology of the Himalaya Mountains and Tibet

Wakal Rivers join, at Bansiwara, is 1,440 ft. while at the junction of the Wakal and Pamri R., 25 miles downstream, it is 941 ft.—see 1 inch map 43 H/3, 7 old No. 143 Bombay and 120 C. I. and R. A tunnel through the intervening ridge on this large hair-pin bend would reduce the distance to 9 miles, but the uncontoured maps do not show what length of tunnel would be required. Or, again, there appears to be a possibility of w r king either from Bansiwara or from Manpur (at the turn of the bend) down to the South East, where the drop to the plains could be developed (Map 45 H/4, 8; old 144 Bombay and 121 C. I. and R.) Whether any storage sites exist is unknown, as also is the discharge, but the hill catchment is considerable.

Chapter 15.—Useless sites.

123. Reasons for rejection.—The following pages deal with the Provinces in alphabetical order and give a list of the sites in each which have been examined to a sufficient extent to enable them to be pronounced useless for power purposes. This is sometimes on account of the total run-off being insufficient, in small catchments; sometimes because storage sites sufficiently large to carry over the dry season are not available; or because the cost of the development would be prohibitive. Where the last factor is the deciding one, time may prove the verdict wrong, as fuel becomes scarcer and more costly; but no project has been condemned on grounds of excessive cost that is not clearly out of the question at present. The following is a summary :—

Table 51.—*Summary of useless sites.*

Reference.	Province or State.	Number of useless sites examined.
Paragraph 124	Assam	2
„ 125	Bengal	2
„ 126	Bihar and Orissa	8
„ 127	Bombay	8
„ 128	Burma	21
„ 129	Central India	3
„ 130	Central Provinces	17
„ 131	Madras	3
„ 132	United Provinces	5
	Total	69 useless sites examined.

124. Assam; useless sites.

(1) *Ka Yeng River.*—This tributary of the Jatinga R. (q.v.) joining at the proposed dam site of the latter, is almost certainly useless.

(2) *Loobah River, at Loobah Charra, Sylhet.*—This was examined and reported as useless. It had been stated that a good site existed, where large storage could be obtained. This appears to be true, but there is very little fall. The site is on map 83 C/8 (available in ½ in.) above Kanairghat; the Surma River comes out of the hills here and the Loobah (or Luba) is a tributary stream. The catchment area at site is 49 sq. mi. with a rainfall of about 200 in., so that the annual run-off is enormous. With a dam 100 ft. high it is reckoned that 1,000 m. c. ft. of useful storage could be impounded above draw-off level, the huge surplus spilling over the dam. The dam site is at Kuddum, which is not in the map. Between here and Kanairghat there is a gradual fall of 115 ft. only. The maximum power on the above basis would only be 27 cusecs on 115 ft., or say 200 kW. The site is therefore clearly useless.

125. Bengal; useless sites.

(1) *Bansloe River; Brahmini River; More River.*—These three rivers flow out of the uplands of the Santhal Parganas (map 72 P), in Bihar and Orissa, into Bengal. In the latter province there appear to be no possibilities in the rivers, which are referred to again under Bihar.

(2) *Barakar River; Damodar River; Usri Nala.*—As noted in the Preliminary Report, p. 69, a flood regulation project in the Damodar River was then under consideration; but, as recorded in the Second Report, p. 61, all the three rivers named have been examined by the Irrigation Branch of the Bengal Public Works Department and found impracticable. Power requirements would in any case have to be subservient to the main purpose of the storage reservoirs.

126. Bihar and Orissa; useless sites.—Of the sites suggested in the Preliminary Report, pp. 71 *et seq.*, or brought to notice later, the following have been examined and reported useless.

(1) *Durgaoti River, Shahabad.* (Map 63 P/14.)

(2) *Harnagarha.*—No indication is given as to where this place is, but a fall of 250 ft. has been examined and reported useless because there is no good storage site.

(3) *Kakolat fall, Gaya.* (Map 72 H/10.)

(4) *Kao River, Shahabad.* (Map 72 D/1.)

(5) *Murhu falls, Ranchi District.*—These falls (river not mentioned) are about 100 ft. and cannot be increased artificially. There is a good catchment but examination shows no storage sites.

(6) *Nindi River.*—Reported too small to be of any use. (Map 73 A/7.)

(7) *Papaharan River, Sambalpur.*—Definitely useless —no catchment. (Map 64 P/1.)

(8) *Phulwaria River, Shahabad.* (Map 63 P/9.)

127. Bombay; useless sites.—The following sites have been examined and (for the reason given) written off as useless, in the Bombay Presidency.

(1) *Barda River and Borkhet Nala Hydro-Electric Project, Surat-Dangs.*—Map 1″ Topo Sheet No. 46 H/9 & 13. The storage sites are situated on the Barda River at a sharp bend about 20° 48′ N. by 73° 46′ E., due south of Sadunia village, and on the Borkhet Nala at point about 20° 46′ N. by 73° 45′ 20″ E. near the village of Borkhet. Both can be reached, except during the monsoon, from Kala-Amba Railway Station on horseback or in bullock tonga *viâ* Ahwa, a distance of 26 and 23 mi. respectively. The catchment areas above the storage sites are 9 sq. mi. on the Barda River and 6·5 sq. mi. on the Borkhet Nala (also called Kapri Nala on the maps). Both areas are mainly of steep hills covered with teak and bamboo forests. Both streams cease to flow in January, and therefore any project must be worked on monsoon flow aided by storage. In the 10 years 1910-19 the aggregate rainfall at Ahwa was 681·76 in., giving an estimated run-off of 409 in. From statistics available for other parts of the Presidency, it appears that in the last 30 years the decade of lowest rainfall was 1899-1908, when it was about 79 per cent. of that in the decade 1910-19. It is estimated, therefore, that the rainfall at Ahwa for the decade 1899-1908 was about 538 in. or an average of 53·8 inches per annum, giving an estimated run-off of 27 in. The proposed full supply level of the Barda River Lake is R.L.1,509, giving an area of about 600 acres and a capacity of about 950 m. c. ft., while that of the Borkhet Nala Lake is R.L. 1,551, giving an area of about 350 acres and capacity of about 700 m. c. ft. The Dam on the Barda River as proposed would be 148 ft. high (R.L. 1,361 at base and R.L. 1,509 at crest) and 4,020 ft. long. It would contain about 7·3 m. c. ft. of masonry which at Rs. 55 per brass of 100 c. ft. would cost Rs. 40·15 lakhs. It would impound between F.S.L. and minimum working level (R.L. 1,401) about 950 m. c. ft. of water at a cost of Rs. 4,226 per m. c. ft. There would be available after allowing for evaporation, absorption, etc., a yearly supply of 421 m. c. ft. The dam on the Borkhet Nala as proposed would be 125 ft. high (R.L. 1,426 at base and R.L. 1,551 at crest) and 5,700 ft. long. It would contain about 10·7 m. c. ft. of masonry which at Rs. 55 per brass would cost Rs. 58·85 lakhs. It would impound between R.L. 1,551 and R.L. 1,466—*i.e.*, between F.S.L. and minimum working level—about 630 m. c. ft. of water at a cost of Rs. 9,341 per m. c. ft. There would be available, after allowing for evaporation, absorption, etc., a yearly supply of about 304 m. c. ft. A canal about 3½ mi. long would lead from Barda River dam to a forebay situated on the hill on the east side of the Barda River, at a point about 20° 49′ 10″ by 75° 45′ 27″ E. This canal could be much shortened probably economically, by tunnelling. Another canal about 2½ mi. long would lead from the Borkhet Nala dam and connect to the first canal near the Barda River dam. The pipe line would lead from near the forebay down the hill in a westerly direction to the power house, situated at a convenient place close to the Barda River, into which the tail water would flow. The Barda River lake would supply 421 m. c. ft. per annum or 13·4 cusecs and the Borkhet Nala lake, probably about 304 m. c. ft. per annum or 9·6 cusecs making a total of 23 cusecs. The fall from the forebay to the Barda River would be about 410 ft., therefore the continuous power will be some 629 kW.

Assuming the cost of coal to be Rs. 24 per ton, the power factor 40 per cent, and a 50 mile transmission line, it will be seen that the probable admissible of hydraulic cost development per E.H.P. installed is Rs. 511.

Therefore the total admissible cost is some 10 lakhs.

As the cost of the dams alone would amount to Rs. 99 lakhs it is obvious that this project is not admissible.

(2) *The Dhodar River, a tributary of the Purna River, Surat Dangs.*—Map 46 H/13. The site of the suggested storage work is 1¼ mi. above the junction of the Dhodar and Purna Rivers, 23½ mi. from Navapur station on the Tapti-Valley Railway. The catchment area above the dam site is 58 sq. mi. and lies in the area where the average rainfall is between 50 and 75 in. There is no flow in the river during the cold months, so if any project was possible it would be based on monsoon flow aided by storage. By taking off a canal from the dam site on the right bank, and by running across country to a point 1 mi. N.E. of the village of Ghana where the Purna River makes a big bend, a fall of 174 ft. is available. Under existing circumstances this fall is not sufficient to allow for the construction of a storage work for a power scheme, and as water is not required for irrigation in this part of the country, there is no possibility for a combined scheme. This scheme, therefore, is not worth investigating under present conditions.

There are, however, rapids on the Purna River, near Mahal Chikhla and Meheskatri—Map 46 H/9—where, if a storage work was in existence higher up the valley, additional falls of some 50 ft. at each place could be utilized for power.

(3) *The Hadaph River, a tributary of the Panam River Baria State.*—46 J/1 & 2. The site is on a small plateau 3 mi. E. of the village of Umria some 10 mi. south-east of Limkhera Station on the B., B. and C. I. Railway main line. The catchment area is about 10 sq. mi. and is situated in the region of average rainfall of 50 in. No rain gauges are in existence in the immediate vicinity of the site, and the flow of the river has not been gauged. A fall of about 200 ft. is available below the proposed dam site, which is situated on the Kariol River 3 mi.

above the point where the junction of the Kariol and Jhot rivers form the Hadaph River. The project was examined at the request of the Baria Darbar and for reasons given below it has been included in the list of projects not suitable for detailed investigation :—

(*a*) The fall available is lower than is generally considered necessary to give a paying hydro-electric project based on storage.

(*b*) The catchment area is too small, in a year of minimum rainfall the run-off will probably not be more than 6 in., giving a volume of 139·4 m. c. ft., sufficient for a constant discharge of only 4 cusecs. Thus the constant power available would only be some 50 kW.

(*c*) The canal or pipe line from the storage site to the power station would be expensive.

(*d*) The combination of an irrigation project for this discharge would not materially improve the outlook of the project.

(4) *Kapri Nala, tributary of Ambika.*—Possibilities were forecasted in the Second Report ; but this is the same as the Borkhet Nala above, and is useless.

(5) *The N/arbada River at Mokhadi, Rajpipla State.*—Map 46 G9 & 13. The Narbada River, between Mokhadi and Ghora, in a distance of 5 mi., passes over rapids which give a total fall of 21 ft. The minimum gauged discharge of the Narbada is 586 cusecs so that if it was possible to utilize this fall some 820 kW. could be generated without the help of a storage work. As unfortunately the H.F.L. at Ghora, where the power station would have to be situated is 45 ft. above low water level, it does not appear likely that any way can be found of utilizing this discharge except at a prohibitive cost. The project is, therefore, classed as not suitable for detailed investigation at the present time.

(6) *The Ramchand Nala, a tributary of the Khapri River, Surat-Dangs.*—Map 46 H/10 & 14. There is a possible dam site near the village of Ramchand 4 mi. from Awah, the capital town of the Dangs. The catchment area above the dam site is 24·5 sq. mi. and lies in the region where the average rainfall is between 50 and 75 in. There is no flow during the hot months, so a storage work is necessary to supplement the monsoon flow. From the dam site by means of a right bank canal about 3 mi. long to a point about ¾ mi. south of the village of Karanjwa, a fall of 277 ft. can be made available. Further rapids and falls of 75 ft. between Wadthal and Sonda (map 46 H/10) and 100 ft. between Chichpara and Dungarda (map 46 H/9) are found on the Khapri River, where, given the existence of a storage work upstream, weirs could be built and the falls made available for power purposes. The project seems likely to be far too expensive to pay under present conditions and prices, and therefore is classed as being not worth investigation.

(7) *The Tapti River at Bhusaval, East Khandesh District.*—Map 46 O/16.

(i) The Tapti River at Bhusaval has a perennial flow, which may fall to not more than 24 cusecs in the hot weather. Just below the G. I. P. Railway Bridge over the Tapti River a series of rapids are found aggregating 61 ft. in a distance of 5 mi. There is an excellent site for a pick-up weir about ½ mi. above the Railway Bridge, near the village of Sudgaon, but unfortunately the cost of this weir and of a canal 5 mi. long through difficult country to a possible power house site below the rapids could not be contemplated on a minimum flow of 24 cusecs. The Tapti has been examined in this province for a storage site, in which the 1,824 m. c. ft. storage required to guarantee a constant flow of 200 cusecs can be held up.

No feasible site exists and therefore, until a storage work on the Tapti or its tributaries in connection with one of the Central Provinces hydro-electric schemes is constructed, the tail water from which would increase the hot weather flow of the Tapti, it will be impossible to put up a paying scheme for this River in the Bombay Presidency. Detailed surveys in connection with this work are practically complete and prove the impossibility of the project under present conditions. (Statements showing the flow of the river are recorded.)

(ii) The site of the Haran Falls or rapids on the Tapti is at Bhilpada, near the village of Raygad, 18 mi. from Nandurbar station on the Tapti Valley Railway ; map 46 K/3 and G/15. The fall of the river in a distance of 3 mi. is 64 ft. An excellent pick-up weir site exists immediately above the head of the rapids, and a canal line on the left bank leading from the weir to a power station site below the rapids would be easy to construct. Unfortunately, as in the case of the other Tapti site at Bhusawal, the minimum flow available is too small to give a paying project, and nothing can be done until some means of increasing this minimum flow can be devised.

(8) *Tarla River, a tributary of the Krishna River, Satara District.*—Map 47 G/14. The Tarla River raises on the same plateau as the Vena and Urmodi Rivers, and near the village of Chalka has a catchment area on the plateau of some 5 sq. mi. in the region of average rainfall of 100 in. The run-off in the worst year would probably amount to 20 in., so that, assuming that the project is developed on the worst year's rainfall, and that the above run-off amounting to 232·30 m. c. ft. can be stored with a reasonable height of dam, a continuous discharge of 7 cusecs can be obtained. The fall available is about 800 ft. so that continuous power of the

order of 370 kW. could be developed. The site is some 16 mi. as the crow flies from the town of Satara, where no industries exist at present. As the Urmodi scheme will be a considerably cheaper one than this, and will suffice for the lighting of Satara, this project is put on the list of projects not worth detailed investigation at the present time.

128. Burma ; useless sites.—Comparatively few streams have as yet been examined and found useless for power considering the total number of " possibles " ; the following alphabetical list gives these :—

(1) *Heinza Chaung, Tavoy.*—The reported falls N.E. of Yebyu (Preliminary Report, p. 77) have been struck out as useless.

(2) *Kaladan River, Akyab.*—This river with a catchment of 3,000 sq. mi., was mentioned as a possibility in the Preliminary Report. It has been examined to near the border and found useless (map 84 C, D, H and 85 A).

(3) *Kelaung River, Mandalay.*—The site near Wetwun (Preliminary Report, p. 78) is struck out as useless.

(4) *Laimaw River.*—This has been struck up from the list in the Preliminary Report, p. 78, as apparently it refers to the Balu Chaung (q.v.).

(5) *Lenge Chaung, Meiktila.*—This has been struck out.

(6) *Magyi Chaung, tributary of Madaya.*—This has been struck out and probably is entered under the Madaya.

(7) *Menyan River.*—Struck out ; not identified.

(8) *Monghang River, S. Shan States.*—This has been struck out locally.

(9) *Nam Kaw, tributary of Salween.*—This has been struck out locally.

(10) *Namkwe Lake, Yamethin.*—This has been struck out locally.

(11) *Nam Lang.*—The lower reaches have been examined and found useless. The upper reaches are called the Nam Et, which is entered under sites not examined. Map 93 F/4, 8.

(12) *Nam Laung, tributary of Myitnge.*—Struck out.

(13) *Nam Tay, tributary of Salween.*—Struck out ; probably this may be the Nam Teng.

(14) *Pang River, tributary of Salween.*—Struck out as useless.

(15) *Payagale Chaung, Pegu.*—Struck out as useless.

(16) *Pyinpongyi Chaung, Pegu.*—Struck out as useless.

(17) *Taungdwin Chaung, Myittha.*—Struck out as useless.

(18) *Teng River, S. Shan States.*—Probably misnamed in Preliminary Report.

(19) *Tonbo River, Mandalay.*—Struck out.

(20) *Ye River, Pagyi.*—Struck out.

(21) *Yezin Chaung, Meiktila.*—Struck out.

129. Central India ; useless sites.

(1) *Indore ; Narbada River.*—This was examined at the Maheswar rapids below Mandleswar, on map 46 N. The cold weather fall of 21 ft. disappears in the rains, when the river may back up 50 or 60 ft. from its passage through the Satpura range lower down. No barrage is possible, as it would submerge whole tracts of country during abnormal floods.

(2) *Patalpani Fall.*—This has no catchment and is useless. (Map 46 N/14.)

(3) *Rajgarh ; Newaj River.*—This river was examined by Mr. Bull near Rajgarh. It was found that the storage which could be depended upon was too small and precarious for utilization under the small head obtainable. It is however possible that better conditions may be found elsewhere on the river.

130. Central Provinces ; useless sites.—The following alphabetical list gives a short summary of the results of reconnaissances of a number of sites in the Central Provinces which, for one reason or another, appear not to be worth further examination. Some of the rivers mentioned (*viz.*, the Narbada, the Tapti, and the Purna and Moga) also appear in the list of sites requiring investigation, the sites or method of development being different. The original reports on these sites are with the Chief Engineer, Hydro-Electric Survey. The reconnaissances were carried out under the direction of Mr. Powys Davies, Officer in charge in the Central Provinces during 1920.

(1) *Aran River at Masni, Magrul Taluk, Akola District.*—(See Preliminary Report, page 84.) This has been examined and is pronounced " certainly useless." The river is not perennial, so storage would have to be depended upon ; the dam site is ½ mi. North of Masni, 7 mi. South-East of Karanja, and 15 mi. North-East of Magrul, near Sangwi Railway Station. A fall of 45 ft. only would be obtainable by means of an open channel some 2 mi. long from the dam to the forebay. The catchment area is 315 sq. mi. A raingauge station is in the area at Mangrul Pir and shows the following results :—

Total in 7 dry months, average 3·6″ minimum, *nil*.
Total in 5 wet months, average 33·1″, minimum 10·5″.
Maximum fall in one day, 8·3″.
Probable annual run-off in a minimum year 446 m. c. ft.

With a masonry dam 1,300 ft. long and 53 ft. high (apparently this is the mean height) a total capacity of 2,176 m. c. ft. could be impounded if it were available, while the effective capacity is estimated to be 1,310 m. c. ft. Neither storage nor fall can be augmented so that 42 cusecs only could be obtained.

This on 45 ft. head gives only 130 kW. continuous power. (Map 55 H/7, 11.)

(2) *Aran River at Rutanpur, junction with Arna River.*—This has been examined by the local officers and a good reservoir site was found, at the entrance of a gorge, ¾ mile downstream of the junction of the rivers, and not far from where they flow into the Penganga. The H.F.L. of the backwaters of the Penganga reaches R.L. 821 at Manusdari Village and the low water level of the reservoir would be at R. L. 850, so not more than 30 ft. head could be depended on. Therefore, although the catchment area is 1,712 sq. mi. it is clear from the preceding entry relating to this river that the site is useless for power purposes.

(3) *Bhajee (or Bhanjee) River, joinging the Muran (q.v.) Betul District.*—This was examined 23 mi. from Chicholi (map 55 F/42) where a fall of 200 ft. could be obtained by a long open channel and long pipe line. The stream is not perennial and the yield of the small catchment, if all stored, would only give some 8 cusecs at prohibitive expense. The site is therefore useless. (The Narbada itself is at about 1,000 ft. elevation and the site 1,400 ft. so that no possibilities exist lower down on this or the Muran River.)

(4) *Bina River Rahatgarh, Saugor District.*—(See Preliminary Report, page 84; second Report, page 72.) Mr. Batchelor estimated this river to be worth 5,000 e.h.p. at each of two sites. A detailed reconnaissance was made, with the result that only 750 kWs. continuous power, could be obtained at prohibitive cost. The site examined is just upstream of Rahatgarh, map 55 I/5 & 6, 25 m. W. of Saugor. A fall of 135 ft. is obtainable by means of an open channel from the storage dam. The river dries up in May, so power would depend entirely on storage. The catchment area is 421 sq. mi., mostly cultivated, with some forest and high land. Rainfall records at Khorai, the nearest station, show the following results :—

Total in 7 dry months, average 2·3, minimum *nil.*
Total in 5 wet months, average 42·5, minimum 19·4.
Maximum fall in one day 9·0 in.
Probable annual run-off in average year (44·8), 6,445 m. c. ft.
Probable annual run-off in minimum year (21·8), 2,500 m. c. ft.

The run-off is based on Mr. Barlow's method. The main dam site is 350 ft. upstream of the fall in the river 2 mi. S. of Rahatgarh; in addition to the main dam 5,700 ft. long and 116 ft. deep there would have to be three subsidiary earthen dams. Taking into account the monsoon rainfall of the two consecutive driest years the effective capacity of the reservoir is estimated to be 2,580 m. c. ft. against a total storage of 3,000 m. c. ft. The land submerged is mostly good cultivated soil and contains 18 village sites. The compensation alone rules the site out practically. A concrete lined channel of 5,000 ft. would be required from the W. end of the main dam to a forebay 1 mi. S. of Rahatgarh, with a pipe line thence of 2,700 ft. to a good power house site 6 furlongs W. of Rahatgarh, 5 ft. above H.F.L. and near the river which would take the tail race discharge. The reservoir supply would be valuable for irrigation purposes in the future—there is no irrigation at present—but while the draft of water for power would be required continuously that for irrigation would be intermittent. The combination is therefore inadmissible as a commercial proposition unless the power could be used almost entirely for high level irrigation. On a continuous 24-hour basis the above effective storage would give 84 cusecs (74 in report) which on 135 ft. fall is equivalent to 750 kW. The cost of the hydraulic development *alone* would be over 42 lakhs of rupees, so that the scheme could not conceivably compete with other forms of power. (The Report is accompanied by plans and full details.)

(5) *Chandrabhaga River, Melghat Taluk, Amraoti District.*—This is one of Mr. Batchelor's sites, mentioned on page 84 of the Preliminary Report (map 55 G/7). It was examined above R.L. 1,800, where a fall of 500 ft. would occur to the plains at R.L. 1,250; but a 20 mi. channel would be required. In two consecutive dry years it was estimated to yield under 200 m. c. ft. from the catchment area of 26 sq. mi. Considerably more storage could be impounded above this site; but even allowing for the provision of large (and expensive) carry-over water the site could by no possibility be economically utilized for some 200 kW.

(6) *Chargad River, tributaryo f Wardha, Morsi District, Amraoti.*—(See Preliminary Report, page 84.) This site has now been examined and pronounced "certainly useless." The rainfall at Morsi varies between 29 and 9 in. and the river is not perennial. No large storage is possible at Udkheir and there is no fall available other than what would be formed by a "lifting dam." (Map 55 G/15.)

(7) *Katni River, near Murwara and Katni, Jubbulpore District.*—(Map 64 A/5, 6.) This river was investigated at the instance of the Electrical Engineer, Central Provinces Government, who required no more than 100 kW. for Katni. There is however no natural fall and no fall can be created of any value. The river is perennial but drops to about 10 cusecs. Storage would submerge valuable agricultural land and villages, at prohibitive cost. The site in question is therefore definitely useless.

(8) *Moga (or Arna) Nullah, Ellichpur, Amraoti District.*—See Preliminary Report, page 85. The site near Malni, suggested by Mr. Batchelor, was examined and found useless. The catchment is 42 sq. mi. With a channel, including a long tunnel, and a pipe line 3 mi. long, it is reported that a fall of 500 ft. could be obtained. The power available might be of the order of 400 to 800 kW. and the cost of development would be prohibitive. See however the Purna River, in the list of possible sites, where a combined scheme of possible utility is suggested along with the Moga.

(9) *Muran (or Morum) River, near Chicholi, Betul District.*—This river, a tributary of the Gangal and Narbada, was examined 21 mi. N.W. of Chicholi (map 55 F/12), where a fall of 200 ft. could be developed with a pipe line a mile long and at considerable expense in tunnelling. The stream however is not perennial and is dry by the end of April, and not more than 1,200 m. c. ft. could be impounded at the dam site examined, where the catchment is 121 sq. mi. and the rainfall of the two driest consecutive years 18 and 37 in. respectively. It is clear that less than 500 kW. would be obtainable at prohibitive expense; and the site is useless. (The Narbada itself is at about 1,000 ft. and the site at about 1,400 ft., so that no possibilities exist on this stream or its tributaries lower down.)

(10) *Narbada River.*—In the Preliminary Report, page 86, mention was made of the Dharighat Falls, 6 mi. N. of Ponassa Forest Rest House, in Nimar District, map 55 B/7. These falls and neighbouring rapids were examined and it is reported that the dry weather fall (9th February 1920) was only 25 ft. and not 50 ft. as conjectured in the above report. The fall completely disappears in the rains. In 16 miles above here the cold weather fall of the various rapids was only 98 ft. all told. The single fall at Dharighat is clearly useless for the reasons given when dealing with the Maheswar falls in Indore, further West, on page 63 of the Second Report. Similarly the accumulated fall of 98 ft. could only be utilized by tunnelling the whole 16 mi., as the banks are very high on both sides; and a diversion dam would be required. A proposal to use a high dam at a site found 1 mile below Sakur Ghat (2,300 ft. long and 180 ft. high), and to utilize this fall in addition to the natural fall, has also been suggested; but this would also involve similar tunnelling. The afflux behind such a dam in the case of a flood such as is recorded near Maheswar (*loc. cit.*) has not been calculated, but would almost certainly put the idea out of count. For the same reason the proposal to use a lifting dam alone at this place is likely to prove impossible, though with this method of development a much lower dam would clearly suffice. This method presupposes rapids so that the afflux would not reach far back. The good fall below Sakur Ghat would however probably enable the tail waters to get clear away in flood times. This last proposal is just conceivably possible, but would in all probability be prohibitive in cost; it requires calculation to be made of the discharge, based on the flood record referred to, and the afflux effect of that discharge behind dams of various heights. The flood levels at the Hoshangabad-Budni Railway bridge are no doubt known and enter the problem. On the whole it is not worth while to continue the investigation here. See however the Narbada River site at Mandla, entered among sites for further investigation.

(11) *Purna River, Amraoti and Betul Districts.*—See Preliminary Report, page 86. This river was suggested by Mr. Batchelor as suitable for development. It was examined at Junapani, 15 mi. due N. of Sirasgaon, where the catchment is 80 sq. mi. A channel of 16 mi. over difficult country, with tunnels and aqueducts, and a pipe line ¾ mi. long would give a fall of 500 ft. The yield would be some 700 m. c. ft. in a dry year giving say 20, or with carry-over perhaps 25 cusecs. Some 600 to 750 kW. continuous power might therefore be obtainable at great cost. It is therefore practically certain that this site should be relegated to the category of useless sites. See however the combined scheme for the Purna and Moga rivers, in the list of Central Provinces sites for further investigation.

(12) *Pus River, Marsul, Yeotmal District.*—(Maps 55 H/8, 12 and 56 E/5, 9.) A possible storage site was examined on this river, just S. of Marsul village and 44 mi. from Darwha Railway Station, Yeotmal Branch. It is pronounced "certainly useless." The river is not perennial, so storage would have to be employed. By means of an open channel from the dam site a fall of 90 ft. could be obtained. The reservoir site is large; but only some 1,300 m. c. ft. of water could normally be obtained, and the effective storage would be 888 m. c. ft. in bad years, giving 29 cusecs continuously. The cost of the storage would therefore be out of all proportion to the 150 kW. or so obtainable.

(13) *Sapan (or Sarpin) River, Melghat and Ellichpur Taluks, Amraoti District.*—See Preliminary Report, page 86. (Map 55 G/7.) This is one of Mr. Batchelor's sites. Near Wajar there is no suitable site for storage and the fall available with a very long pipe line is 300 ft. The yield, if it could be stored, is estimated to be dependable for only 9 cusecs in a bad year, from a catchment of some 44 sq. mi. The small natural fall of 30 ft. is useless alone and the stream is not perennial; it carried only 2 cusecs on 24th January 1920. The stream rises rapidly to an elevation of several thousand feet, but splits up into many branches with insignificant catch-

ment areas. The whole stream appears to be useless.

(14) *Shahnur River, near Anjangaon, Amraoti District.*—In the Preliminary Report, page 86, this site was mentioned on the authority of Mr. Batchelor, who recorded several sites as worth investigation, and who believed a reservoir could be made with a fall of 600 ft. available below it. (Map 55 G/3, 7, 8.) A reservoir site was found between Moragarh and Raipur, but the available fall at this place is only from R.L. 1,350 to 1,250 or 100 ft. The stream is not perennial and dries up in March, and from the catchment area of 45 sq. mi. only 335 m. c. ft. could be expected. A site higher up was also indicated by Mr. Batchelor, where the total fall to the plains would be 500 ft.; this would therefore be above R.L. 1,800 and the catchment area is less than 30 sq. mi. There is no storage site here to take the small yield, and a channel of many miles in length would in any case be necessary. Higher up still is Mr. Batchelor's third site, referred to above, with a catchment area of 12 sq. mi. only. By means of a channel some 20 mi. long a fall of 600 ft. could be obtained; but the total water available in a bad year would be under 80 m. c. ft. or say 2½ cusecs giving under 100 kW. This river is near, and similar to, the Chandrabhaga and Sapan Rivers. All appear equally useless.

(15) *Tapti River, above Burhanpur.*—The whole river was examined to the E. of this point up to the junction with the Tawa and Ambhara (55 K/2), as it was indicated in the Preliminary Report (page 88) to have possible power sites. The result is disappointing, and the circle officer recommended no further action. There is one natural fall of 50 ft. at Dhanora (55 G/14) and seven others from 8 to 20 ft., which probably disappear in the rains. The sites examined are as follows :—

Site 1.—Half a mile below junction with Tawa on square 2 of map 55 K/2. The catchment here is 204 sq. mi. with a probable effective yield in the two driest consecutive years of 826 m. c. ft., giving 23½ cusecs. There is however storage capacity capable of impounding a very large carry over, and there is a substantial flow except at the end of the hot weather. The available fall, including the Dhanora water fall, is only 105 ft. so the power would be not worth considering. At Dhanora fall itself the catchment is only 250 sq. mi. and though some channel would be saved the site is equally useless.

Site 2.—Further downstream at Bothi Sehar, 10 mi. S.W. of Badnoor town, map 55 G/13. Here no useful head is capable of development, and the conditions proved unsatisfactory.

Site 3.—At Ratamati; square 3 of map 55 G/9, below junction with the Betul River. The catchment here is stated to be 848 sq. mi. and the probable effective yield 8,250 m. c. ft., giving a discharge of 176 cusecs. A fall of only 60 ft. can be obtained, so the site is useless. Two possible dam sites were examined, one being 1 mi. N.E. of Ratamati and the other 1½ mi. upstream. Both would be prohibitive in cost.

Site 4.—At the junction with the Labada Nadi, on square 3 of map 55 G/5 near Ankhi. The catchment area and yield below the Ratamati site are given as 485 sq. mi. and 3,980 m. c. ft., giving an extra 86 cusecs or 262 cusecs in all. A fall of only 60 ft. is obtainable, so this site also is useless on account of the cost of the impounding dam. There is however a good channel line through the saddle enclosed by the loop of the river, and there may be unsuspected possibilities here.

Site 5.—At Rangobeli, square 4 of map 55 G/2. The catchment, additional to that at site 4, is 535 sq. mi. with an effective yield calculated as 6,500 m. c. ft., equal to say 185 cusecs or 447 cusecs in all. A fall of 45 ft. only is obtainable—presumably exclusive of the dam lift, though this is not stated.

It is elsewhere in this report pointed out that the river might possibly be developed by means of lifting dams.

(16) *Waghari River, Yeotmal District.*—This non-perennial stream runs parallel to the Aran, but has a far smaller catchment area. There is a fall of 15 ft. near Waghari Takli village, but no reservoir site was found by the investigating engineer. In any case, as will be seen from the Aran River, there would be no chance of commercially developing power from storage on so small a head and with so low a yield. (Map 55 I/5.)

(17) *Wardha River, near Pulgaon, Wardha District.*—(See Preliminary Report, p. 88.) Mr. Batchelor estimated this site to be good for 1,000 e.h.p. It was examined locally and pronounced "certainly useless." There is a fall of about 10 ft. a short way downstream of the G. I. P. Railway bridge (map 55 L/6), but no suitable storage site was found. The discharge as early as December was found, in 1920, to be only 6 cusecs; and it is clear that on so low a head (even if it were possible to increase it considerably by means of a channel) no amount of storage would give power consonant with the cost.

131. Madras; useless sites.—The following sites in Madras have been examined and pronounced useless.

(1) *Chandravauki River, Ettipotata Fall (Etipotla), Guntur District.*—A reconnaissance was made by Mr. Sneyd who found this site near Macherla useless owing to lack of flow and excessive cost of storage. (Preliminary Report, page 89.)

(2) *Palni Hills, Madura District.*—The Gundar River was examined by Mr. Sneyd and reported useless except possibly for a very small plant for Kodaikanal. In view of the Pinjikave site (q.v.) and other practicable developments in these hills the Gundar may be written off. The minimum flow is about 5 cusecs and no storage site is available. With a head of 800 ft. only 250 kW. continuous are available, at heavy cost.

(3) *Siruvani River, tributary of Bhavani, Nilgiri Hills.*—See Preliminary Report, p. 92. This project was fully investigated and found wanting, in view of other finer sites in the neighbourhood, *viz.*; Kundah River and Pykara River (q.v.). The dam site was unfavourably reported on and the river will probably be used for water supply to Coimbatore.

132. United Provinces; useless sites.

(1) *Darma River and Sobla Lake.*—What power exists here is too remote to be of any use. Site not identified.

(2) *Ghagar Nadi, Mirzapur.*—(Preliminary Report, p. 101.) There is reported to be no fall above the canal headworks which could be utilized for power.

(3) *Gohna Lake, Garhwal.*—This is almost certainly useless; but Mr. Lyle's inspection note is printed under "Sites investigated" in the United Provinces.

(4) *Gori River, tributary of Sarda.*—This river joins the Kali at Askot. Mr. Lyle examined it up to Dawani, but found no good site. It is in any case too remote to be of use. There are practically no roads in this tract.

(5) *Sarasvatiganga River, Garhwal.*—Owing to its inaccessibility, beyond Badrinath and at an altitude of some 11,000 ft., the site referred to in the Preliminary Report, p. 103, may be written off as useless.

APPENDIX I.

Useful Hydraulic and Hydro-Electric Data (in round numbers generally).

Flow of water.

1 cusec flow = 1 cu. ft. per second = 62·4 lbs. per second,
= 60 cu. ft. per minute = 3,744 lbs. per minute,
= 374 gallons per minute,
= 3,600 cu. ft. per hour,
= 86,400 cu. ft. per day,
= 2·6 m. c. ft. per month,
= 31½ m. c. ft. per year.

Gallons per minute = cusecs × 374

$$\text{Cusecs} = \frac{\text{Gallons per minute}}{374}$$

1 cubic metre per second (or m^3) = 35·31 cu. ft. per second.

Regulating Storage.

100,000 cubic feet stored will give	1·16	cusecs for	24 hours
" " " " "	2¼	" "	12 "
" " " " "	4½	" "	6 "
" " " " "	9¼	" "	3 "
" " " " "	27¾	" "	1 hour

Catchments and Reservoirs.

1 acre = 43,560 sq. ft.
1 acre of water 1 foot deep = 43,560 cu. ft.
= 1 acre foot.
1 square mile = 640 acres = 27·88 1 m. sq. ft.
1 square mile of water 1 foot deep = 1 sq. mi. ft.
= 27·88 m. c. ft., which will (in practice) give a flow of about ¾ cusec for 12 months, 2¼ cusecs per 4 months or 3 cusecs for 3 months.
1 inch of rain = 100 tons per acre or = 3,600 cu. ft. per acre.
= 64,000 tons or 2·33 m. c. ft. per square mile.

In practice, however, only a percentage, and often a small percentage, will reach the reservoir; see paragraphs 20 to 24 of Report.

A continuous fall at the rate of 1 in. in 1 hr. gives 1 cusec per acre of catchment (100 per cent.).

Main storage.

31½ m. c. ft. 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 m. c. ft stored will give	30	cusecs continuously for a	year.
" " "	40	" "	9 months.
" " "	60	" "	6 "
" " "	90	" "	4 "
" " "	120	" "	3 "

Power from flow.

On the practical basis assumed throughout this report

$$\frac{\text{Cubic feet flow} \times \text{head in feet}}{11} = \text{electrical horse power.}$$

If 15 is the divisor, the result is in kilowatts.
On small projects 12 and 16 may be used.

Power from storage.

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

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

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

If the divisor is 500, the result is in kW. years.
Millions cubic feet × head in feet × 17 = B.O.T. units
One cusec-day = 24 units for every 15 ft. of head.

MODEL FORM OF AGREEMENT FOR GRANTS FOR WATER POWER DEVELOPMENT.

CONTENTS.

HYDRO-ELECTRIC SURVEY OF INDIA.

Draft Model Form of Agreement for Grants for Water Power Development.

Form of agreement for grants of Water Power development,	*Notes on the draft.*
primarily from storage works and not from rivers or canals.	A. These reference letters A. B. C. are used throughout where a clause or a phrase is applicable to one or the other
from Rivers, with or without storage.	B. case.
from Canals.	C.
Preamble.	*Preamble.*—Taken from the Jumna River agreement.
THIS INDENTURE made the.................day of 19 , between the Right Hon'ble the Secretary of State for India in Council (hereinafter called the grantor) of the first part,* and..	* If a Native State is concerned with the agreement the addition of a "grantor second party" may be necessary and the grantees will be "of the third part." See cl. XXXII.
together forming an Association/Company known as the ....,	
............Association/Company having an address at..........	
(hereinafter called the grantees) of the second part.	
WHEREAS the grantees being desirous of carrying out a scheme for generating electrical energy by means of utilizing the water	A. B. C. following according to nature of project.
(to be) stored in a reservoir or reservoirs (to be) constructed by Government/them at or near the locality shown.	A. According to whether an existing reservoir constructed by Government is to be used or not.

Draft agreement.	Notes on the Draft.
of the River........between the point...........and the point..........these points being marked by the letters.....	B.
of the........Canal between the point......and the point..........these points being marked by the letters........	C.
on the plan hereto annexed, have applied to the Government of........(hereinafter called the local Government) for a grant for water power development	
in the locality aforesaid	A. } Alternatives.
between the points aforesaid.	B, C. }
AND WHEREAS the local Government, with a view to encourage commercial enterprise and the development of the resources of the country by means of electrical power, has determined that such a grant as is asked for by the grantees may properly be granted.	
[and* whereas the said reservoir site to the following extent, that is to say...........................	A. * Where there is a "grantor second party"—see note on previous paragraph—the extent to which the site is within the jurisdiction of that party should be mentioned here, and also the agreement of that party to the indenture, as shown between the square brackets. In that case the form should be examined for other clauses where the grantor second party may appear.
said River in the portion of its course referred to above namely the portion between the letters........and...... on the plan hereto annexed.	B.
said..........Canal in the portion of its course referred to above namely..................	C.
adjoins (falls within) the territories of the grantor second party and the said grantor second party has agreed to become a party to this indenture in the manner on the conditions and to the extent hereinafter appearing].	

IT IS HEREBY AGREED AND DECLARED AS FOLLOWS:—

These headings are put in for convenience of reference and will not necessarily form part of the agreement.

Grantees to include permitted assigns.

I.—Throughout these presents the expression "grantees" wherever it occurs means the grantees specified in the preamble hereof and includes where the context so permits or requires or after the transfer contemplated in clause XX hereof their permitted assigns.

Clause I.—Taken from the Jumna River agreement. Transfer of grant to a Company.

Grant subject to certain Rules.

II.—The grant hereinbefore expressed to be granted is in so far as it relates to territories for the time being administered by the local Government granted subject to the rules prescribed by His Majesty's Secretary of State for India and published by the Government of India as Resolution No. 933

Clause II.—Taken from the Jumna River agreement, with additions from the Periyar concession.

Draft agreement.	Notes on the draft.
of the Department of Finance and Commerce dated the twentieth day of February 1894 as subsequently amended; and the sanction of the authorities concerned to the granting of the grant as required by the said rules, has been signified in writing under the hand of the Secretary to the Government of India in the..........Department in letter No......... dated..................	
Exclusiv eright to water power at site named.	
III.—Subject as is hereinafter mentioned the grantees shall have the sole and exclusive right from the date of these presents to use the water power.	*Clause III.*—Taken from the Jumna River agreement, modified
within the limits named	A.
of the River..............	B.
of the.......................Canal.	C.
in the manner above mentioned, but only for the purpose of the generation of electrical energy.	
PROVIDED ALWAYS that the grantors shall not be liable for any loss, damage or inconvenience which may happen to the grantees by reason of any deficiency in the water arising otherwise than as the direct consequence of any action taken by them or by the local Government:	
PROVIDED ALSO that after the expiry of...........years from the date of these presents the Government of......... shall be at liberty to grant to any person or persons other than the grantees, grants in respect of such proportion of the water flowing in the said.........as the grantees shall not till then have utilized.	Ten or twenty years is suggested. B or C. River or canal.
Purchase of works by the State.	
IV.—After the expiration of a period of (50) years from the date of this grant, and after giving not less than two years' notice of his intention to the grantee, the grantor shall have the option of purchasing the whole of the works constructed in pursuance of the powers herein given and, if the grantor elects to purchase, the grantee shall sell the said works to the grantor on payment of the then value of all the lands, buildings, works, materials and plant, such value in the absence of agreement being determined by arbitration on the basis of a going concern.	
Restriction on neighbouring grants.	
V.—Subject and without prejudice to the provisions of the Indian Electricity Act, 1910, or any statutory modification or re-enactment thereof, no grant shall be granted by the local Government to any other person or company for the construction of any works for generating electrical energy from water power within a radius of.......miles of the site referred to in this indenture until the option of taking such a grant on terms not less advantageous than those proposed to be granted to such other person or company shall have been offered to the grantees and either declined by them or not accepted within six months from the date of the offer.	*Clause V.*—Taken from the Bari Doab Canal agreement, clause 10, modified.

Draft agreement.

Right to construct works.

VI.—The grantees shall be at liberty for the purpose of carrying into effect the above-mentioned scheme to erect power houses in the locality and within the limits named and to construct such weirs, reservoirs, channels, tunnels, pipe lines and other works within the said limits as may be necessary for the purpose of the said scheme ; but the grantees shall not, except with the sanction of the local Government, construct such works in a manner which will render the site incapable of full development at a later date, if a partial development only is contemplated in the first instance :

PROVIDED ALWAYS that the erection and construction of all the works above-mentioned both as regards number, situation and design shall be subject to the inspection and approval of the local Government and no works shall be commenced by the grantees without the permission of the said local Government to be signified in writing under the hand of the Chief Engineer,............Branch first had and obtained.

Use of Canal water power.

VII.—As soon as the grantees are ready by means of their works constructed under this grant to undertake the generation of electrical energy the local Government will instruct the canal officer responsible for regulation at the head of the said canal to maintain, and there shall thereafter be maintained, subject to the conditions hereinafter in this clause contained, a continuous supply of water to the power channel in accordance with the requirements of the grantees from time to time but subject to a maximum limit of......cusecs. Every endeavour will be made on the part of Government and its officers to prevent interruption of the supply but Government shall incur no liability whatsoever to the grantees for or in respect of—

(*a*) Interruption of supply due to circumstances beyond the control of Government and its officers ;

(*b*) Emergent interruptions of supply considered necessary by the canal officer responsible for regulation at the head of the canal (whose certificate to this effect shall be conclusive) in case of floods or for urgent repairs ;

(*c*) Any interruption due to the mistake or error of judgment of a Government servant while acting in good faith ;

[(*d*) Interruptions of supply during the customary period of the annual closure of the canal for repairs, of which due notice will be given to the grantees ;

(*e*) Interruptions of supply at times when the canal is closed owing to water not being required for irrigation purposes, it being agreed that the use of the said canal for the generation of electrical energy is subsidiary always to the use of the same for its prime function of irrigation] :

PROVIDED ALWAYS that Government shall not be required to provide a greater measure of security against interruptions of supply than is afforded by the system of river works considered sufficient by Government for the protection of the public interests in or depending upon irrigation and that if further security to this end is required by the grantees and Government shall be able and willing to afford or furnish such

Notes on the Draft.

Clause VI.—Taken from the Jumna River agreement,* with additions to works enumerated.

* Clause II of Agreement.

Clause VII.—Taken from Clause 6 of the agreement with the Punjab Power Association for the use of the power of the Bari Doab Canal, with additions as noted.

C only.

Sub-clauses (*d*) and (*e*) have been added to meet cases where the canal is normally closed for the reasons given. They do not appear in the Bari Doab Canal agreement.

Draft agreement.	Notes on the Draft.
security the grantees shall pay the cost of additional works necessary for affording or furnishing such security.	
Canal Works.	Other special canal clauses may have to be added here; but see clause VIII.
VIII.—The plans and designs of all works and channels which will fall within the canal boundaries shall be submitted by the grantees for the approval of the Chief Engineer, Irrigation Branch, and be approved by that officer before work is commenced on them, and the local Government may at its discretion undertake the construction of any such works, the cost thereof including the Departmental charges in force being borne by the grantees and certified by the said Chief Engineer whose certificate both as to such cost and approval or disapproval of any plans or designs submitted to him under or in pursuance of this clause shall be final and binding on the grantees.	*Clause VIII.*—Taken from Clause 4 of the Bari Doab Canal agreement.
The Chief Engineer shall, when communicating approval of the designs submitted, state which works, if any, are to be constructed by Government and such works, if any, as are constructed by the grantees shall be constructed under such supervision as may be considered necessary by the Chief Engineer and to his satisfaction in all respects.	C only.
Navigable Rivers.	For draft clause as to Navigation rights see the supplement at end. Such a clause will not usually be required in Canal concessions and never for reservoir schemes.
Return of water after utilization.	
IX.—The grantees shall return all water utilized by them in the working of the said scheme to the .... without pollution or diminution except unavoidable loss from absorption or evaporation.	*Clause IX.*—Taken from the Jumna River agreement, clause II. The stream or canal into which the tail race will discharge should be specified. Ordinarily this will be the river or canal from which the water was taken, or the stream draining the valley dammed. Cases will however occur where a watershed is tunnelled and the discharge is in a different catchment.
Timber flotation.	Special clauses dealing with this (applicable to rivers) will be found in the supplement at the end, and will probably be placed here where necessary.
British Standards of pressure and frequency.	
X.—The grantees in carrying out the works contemplated by this grant shall employ exclusively the British Standard electrical pressures and the British Standard frequency of 50 periods per second or the subsidiary standard frequency of 25 periods per second.	*Clause X.*—It has been generally agreed that in future only British Standard pressures and frequencies should be permitted. The only exception is that hitherto the British Engineering Standards Committee has not standardized pressures beyond 11,000 volts and that higher pressures such as 15,000, 33,000, 66,000, and 132,000 volts are used for transmission of power.
Tenders for Plant.	
XI.—Before the grantee invites tenders for plant in connection with this grant the specifications of the plant required shall be furnished to His Majesty's Trade Commissioner in India; and the date on which the said tenders shall be dealt with shall be so fixed as to give manufacturers in the United Kingdom sufficient time to submit tenders.	
Leasing of Government land to grantees.	
XII.—The grantors shall lease to the grantees if in the opinion of the local Government (or of the..........as the case may be) it is practicable and desirable to do so such lands in the possession of Government (or of the said.......... respectively) as may in the opinion of the local Government be	*Clause XII.*—Taken from the Jumna River agreement, clause VII. ( ) This phrase is to cover the case where a Native State is involved as grantor second party—see Preamble.

Draft agreement.

necessary for the purposes of the undertaking of the grantees upon such terms and conditions as to payment of rent and otherwise as shall be mutually arranged between the parties, such terms in the case of dispute to be settled by the local Government, whose decision shall be final and binding upon the grantees.

Acquisition of land.

XIII.—(In the event of the transfer of this grant to a company with the permission of the Government of......as contemplated in clause XX hereof) the local Government shall, subject to any conditions as to it may seem fit, acquire in accordance with the provisions of the Land Acquisition Act, 1894, or any statutory modification thereof and transfer to the company such land within the territories for the time being administered by the local Government as may in the opinion of the local Government certified as aforesaid be necessary for the purposes of the undertaking of the grantees on payment of a lump sum amounting to the whole amount of the purchase money and the expenses of the acquisition thereof together with twenty-five times the amount of the land revenue remitted on the land so acquired.

(The acquisition of the land situated within the territories of the grantor second party by such company shall be the subject of mutual agreement between the company and the grantor second party.)

Demarcation of acquired land.

XIV.—The grantees shall maintain at all times the outer boundaries of any land, acquired by them by purchase or otherwise for the purposes of this grant demarcated in a conspicuous manner.

Royalty for use of water.

XV.—The grantee shall pay to the grantor a royalty upon the following scale, for all power which he may develop in connection with this grant, *viz*:.........................

....

Rent for use of Works of the grantor.

XVI.—In consideration of the direct or indirect use by the grantees for the purpose of their works of the reservoirs, canals, canal headworks, regulators and other hydraulic works, the property of and constructed by the Government as irrigation works and particularly indicated on the annexed plan the grantees shall pay to the grantor an annual rent to be calculated on the capital value of the said reservoirs, canal head works, regulators and other hydraulic works so far as these lie within the area immediately connected with the grantees' works and are utilized by the grantees for the purpose of their works, such annual rent to be charged at the rate of..........per cent. per annum on the capital value of the said works:

PROVIDED that no part of a canal at a distance exceeding one hundred yards from the point where the grantees shall divert the water of the said canal to their works or a like distance from the point where the grantees shall return the water to the same after utilization shall be taken into consideration in the computation of the annual rent payable under this clause.

Notes on the Draft.

Clause XIII.—Taken from the Jumna River agreement, clause VIII.

NOTE 1.—The opening phrase of this clause does not take into account the amendment of the Land Acquisition Act, 1894, by section 57 of the Indian Electricity Act, 1910. This amendment *inter alia* allows the acquisition of land for a person *not* being a company. The clause, however, being in every case a matter of legal drafting, has been left in its original form.

NOTE 2.—The acquisition of land by a person or a company seeking a grant should invariably be the subject of a *separate agreement*, which can be so drawn up as to be completed at the same time as the main agreement. Otherwise great delay will invariably occur.

( ) To cover the case where a Native State is involved.

Clause XV.—No royalty should be charged in the case of natural sites or of power used for electro-chemical or metallurgical processes in the initial stage of operations.

Clause XVI.—It appears legitimate, where existing irrigation works are utilized, the cost of which would in other cases have to be borne by the grantee, that he should pay some royalty on the value of these works. On the other hand, any such payment inevitably becomes a tax on the electrical energy supplied or (on the merchandise manufactured by it) so that it is questionable whether it is to the interest of Government to make more than a nominal charge. A rate of one per cent. is suggested as of the right *order*, though in the case of large dams this would be excessive. In any agreement the works enumerated in the clause should be confined to those actually used.

C The limits suggested are arbitrary and based on no precedent; but a strict limitation is evidently necessary. It will perhaps be preferable to define the limits by reference to the plan.

Draft agreement.

Share of profits of grantees.

XVII.—When the income, upon which the company formed by the grantee under clause XX hereof shall be assessed for the purposes of income tax under the provisions of the Indian Income-tax Act, 1918, or any statutory modification thereof, shall in any year exceed ten per centum of the aggregate paid up capital of the said company, the following provisions shall have effect, namely :—

(*a*) If the said income shall be more than ten per cent. and not more than 12 per cent. of the said capital the grantee shall pay to the grantor one tenth part of the excess income over ten per cent. :

(*b*) If the said income shall be more than twelve per cent. and not more than fifteen per cent. the grantee shall pay to the grantor one fifth part of the excess income over ten per cent. :

(*c*) If the said income shall be more than fifteen per cent. and not more than twenty per cent. the grantee shall pay to the grantor one third part of the excess income over ten per cent. :

(*d*) If the said income shall be more than 20 per cent. the grantee shall pay to the grantor one half of the excess income over ten per cent. :

The said payments (if any) shall be made by the grantee to such officer as the local Government shall nominate in that behalf within three months from the date on which the said assessment for income tax is made :

PROVIDED ALWAYS that the grantee shall be at liberty to make such reductions in the prices charged by him for electrical energy as will limit the said income in such manner as he may think fit.

Liability for damage.

XVIII.—The grantees shall be responsible for all loss or damage arising through the escape of water from their reservoirs, channels and pipe lines due to the bursting or collapse of, or leakage from the said reservoir, channels or pipe lines and for all loss or damage caused by any overflow of water over the banks of the said.........which is due to any dam or other obstruction erected in connection with this grant and for all loss or damage which is due to the failure of any of the works constructed in connection with this grant provided that such loss or damage does not arise from an earthquake or other convulsion of nature or any act of the King's enemies, and shall further indemnify the grantor against all actions, suits, claims and demands on account of any such loss or damage as aforesaid.

Accounts to be kept.

XIX.—The grantees shall keep true and accurate accounts of all expenditure and shall publish such information at such times and in such form as the local Government may demand and shall pay all royalties and other charges payable by them under the terms of this grant at such times as they may become due and shall permit the grantor* or his officers, servants or agents duly authorized in that behalf at all times during the hours of daylight to enter upon the premises occupied by the grantees for the purpose of this grant and to view the same and the works carried on there and shall fur-

Notes on the Draft.

Clause XVII.—This clause is an attempt to make a fair sliding scale of profits and royalty. By taking the income tax assessment (rather than the dividend) as the basis questions of depreciation and reserve funds need not be taken into consideration. A similar basis is used in the Periyar concession. Ten per cent. is a fair "standard dividend" in India. An alternative method of profit sharing has been suggested.

The payment would be made on the profits of the previous year.

It is preferable that the excess profits should go to the consumer rather than to the Government. In the case of a grantee using power for industrial purposes this proviso would need modification to apply to the manufactures produced.

Clause XVIII.—Taken from the Mansan Falls and Kanbauk mine agreements.

River, stream or canal.

This addition is taken from the original clause "Accounts" next following from the Jumna River agreement.

Clause XIX.—Taken from the Jumna River agreement.

* First party, if there are two grantors.

Certain matters dealing with damage and compensation that appeared in the original of this clause have been transferred to the preceding clause dealing with "Liability for damage."

Draft agreement. | Notes on the Draft.

nish all such information in relation thereto as may be required by the grantor or his officers,* servants or agents authorized as aforesaid:

PROVIDED that the grantor † and the local Government may use all such information as may be furnished under this clause without limitation for their own purposes:

PROVIDED ALSO that the information so furnished shall not be made public by the grantor † or by the local Government without the consent of the grantees save in so far as publication of such information may be required under the provisions of any law from time to time in force or of any rule made thereunder.

† First party, if there are two grantors.

Transfer of grant to a company.

XX.—The grantees shall within........years from the date of this indenture form and register under either the English or Indian Company Laws a limited liability company with a capital and with a memorandum and articles of association to be previously submitted together with the terms of sale to the company for approval by the local Government for the purpose of taking over and working the grant hereby granted and the local Government if satisfied with the capital, memorandum and articles of association and terms of sale will authorize the transfer to the said company of the rights and liabilities of the grantees under this indenture:

PROVIDED ALWAYS that the transfer of the rights and liabilities conferred and imposed by this indenture shall not relieve the grantees of liability in respect of anything done or omitted by the grantees which would attach to the grantees but for such transfer.

PROVIDED ALSO that if such limited liability company be not formed in the manner aforesaid within the prescribed period it shall be lawful for the grantor to cancel the concession hereby granted without notice to the grantees.

Clause XX.—Taken from the Periyar agreement. This form is preferable to the similar one in the Jumna River agreement in which the obligation to transfer is relegated to a proviso to a clause forbidding the sale, lease, mortgage, etc., of the undertaking, such as follows next in this draft. See also clause " Determination of Grant."

The period specified in the Periyar agreement is 1½ years.

Prohibition against sale, lease, etc., of grant without consent.

XXI.—Save as herein otherwise provided the grantees shall not sell sub-lease mortgage transfer or assign in any way whatever their rights or obligations hereunder except with the previous consent of the local Government.

This should perhaps be incorporated with the preceding clause.

No right to licence conferred.

XXII.—The said grant shall not confer upon the grantees any right or claim to the grant of any licence under the Indian Electricity Act, 1910, or any statutory modification or re-enactment thereof, and nothing herein contained shall restrict or affect the power of the local Government under the said Act or any statutory modification or re-enactment thereof and the rules thereunder, which is hereby expressly reserved, to reject any application for such a licence or to grant any licence subject to all or any provisions or conditions which under the said Act may be made applicable or attached to or comprised in any such licence and the grantees will not be entitled by virtue of this concession to claim damages or compensation from Government or the grantor on the ground or in respect of the refusal or revocation at any time of any such licence notwithstanding anything done by the grantees in the exercise of their rights or in virtue of their obligations under this grant. No licence shall however be refused on the ground alone that the construction of the

Clause XXII.—Taken from the Jumna River Agreement clause XIV. The grant of a licence must be considered on its merits under the Act and rules relating thereto; but (as in the case of land acquisition *supra*) steps should be taken to ensure simultaneous consideration of all applications connected with the grant.

Draft agreement.

works for the generation of electrical energy contemplated in or by the grant is in itself independently of the manner of such construction inexpedient.

Security deposit.

XXIII.—The grantees shall within thirty days of the execution of this agreement deposit with the Secretary to the Government of........Government Promissory Notes of the value of Rupees........as part security for the due fulfilment of each and all of the conditions of this agreement and the said Promissory Notes shall be liable to absolute forfeiture to the grantors as part indemnity in the event of the determination for any sufficient cause of this agreement by the grantors before the expiry of the term for which it is granted but otherwise shall be surrendered in full to the grantees at the expiration of the full term of this agreement or the sooner determination thereof by mutual consent. All interest accruing on the said Government Promissory Notes prior to the forfeiture thereof to the grantors or surrender thereof to the grantees as above provided shall be payable to the grantees through the as it from time to time accrues and becomes due. The grantees shall by way of further security give to the grantors a bond for the sum of Rupees.......... to be executed simultaneously with these presents for the due performance of each and all of the said covenants such bond to be deemed and taken to be for the performance of a public duty or act in which the public are interested within the meaning of the exception to Section 74 of the Indian Contract Act, 1872.

Determination of grant.

XXIV.—This grant may be determined by Government in any of the following events:—

(*a*) In the event of the revocation in whole (otherwise than by consent) under the Indian Electricity Act, 1910, or any statutory modification or reenactment thereof of any licence or licences which may have been granted to the grantees thereunder in connection with this grant:

(*b*) In the event of the grantees making default which in the opinion of the local Government (whose decision as expressed in writing by the Secretary to such Government shall be final and binding against the grantees) is wilful or unreasonably prolonged in the construction of the works hereinbefore contemplated and in the commencement of the generation of electrical energy:

(*c*) If at the end of .. years from the date of its formation and approval the company formed under clause XX hereof shall not have commenced to execute works for the utilization of the water power referred to in Clause VI hereof or if at the end of .. years from the same date the company shall not have installed at the site of the works in complete working order plant capable of generating not less than .. brake horse power at the turbine shafts or if such plant shall not be maintained in good working order:

(*d*) In the event of the grantees ceasing for a period of .. months during the continuance of this grant

Notes on the Draft.

Clause XXIII.—Taken from draft agreement between the Punjab Government and Punjab Sugar Works.

While substantial security should be deposited by the grantee (or by the applicant) to ensure his carrying out the works (as demanded by Clause I of the Schedule to the Indian Electricity Act) the actual agreement should provide for the repayment of the deposit in the case of public utility companies when the supply begins.

In the case of concerns primarily industrial the Government would have no power of compulsory purchase and security should be held as a guarantee that if the works are abandoned other persons can use the power.

Clause XXIV.—Taken from the Jumna River agreement, clause XV; but modified as noted.

Clause (*c*) is taken from the Periyar agreement, clause 2. Periods of one and four years are suggested as reasonable.

The period in the Jumna River agreement, clause XV, is two years, but this is unnecessarily long. Six months or less is

Draft agreement.

after the date of commencement of the generation of electrical energy, to generate such energy (and to offer it for public supply):

(e) In the event of the grantees becoming bankrupt or entering into liquidation:

(f) In the event of the grantees failing to pay any sum or sums of money that may be due from them to the grantor under the terms of clauses .. hereof within a period of six months from the date of a written demand by Government for such payments made after they have fallen due or in the event of the non-compliance by the grantees with any other of the terms and conditions hereof. Otherwise the grant shall endure for the same time as the licence or licenses to be granted as aforesaid and shall determine whenever such licence or licences determine.

Liabilities not affected by determination of grant.

XXV.—In the event of the determination of this grant under any of the provisions hereinbefore contained such determination shall be without prejudice to any liabilities incurred by the grantees to the grantors hereunder or any claim or demand by the grantors in respect thereof all which shall remain unaffected and the grantees shall not have any right against the grantors for any compensation or otherwise in respect of any expenditure made liabilities incurred or things done in respect or in consequence of or under this grant.

Disputes.

XXVI.—In the event of any dispute or difference or question arising between the parties hereto as regards this indenture or the interpretation or construction of any of the terms or provisions hereof or any matter connected herewith or with the operation hereof or the rights, duties or obligations of either of the said parties in relation to the premises and whether during the subsistence or after the determination hereof such dispute or difference shall be referred to the arbitration of two arbitrators one to be appointed by each party. In the event of disagreement between the arbitrators the dispute or difference shall be referred to an umpire to be chosen by them whose decision shall be final or the matter shall be referred to an officer to be nominated by the Government of India whose decision shall likewise be final.

Stamp Duty.

XXVII.—The stamp duty hereon shall be borne by the grantor.

IN WITNESS WHEREOF the parties hereto have hereunto set their hands the day and year above written

Signed by

Secretary to the............. for and on behalf of the........ acting in the premises for and on behalf of the Secretary of State for India in Council in the presence of

Witness

Witness

Grantor.

Signed by

Witness

Witness

Grantees.

Notes on the Draft.

suggested; so long a cessation is unknown in electrical supply. This should usually be a condition but not necessarily in case of works for purely industrial purposes.

Clauses dealing with royalties and other payments: see list of contents.

Clause XXV.—Taken from the Jumna River agreement, Clause XVI.

Clause XXVI.—Taken from the Kundah River agreement.

Clause XXVII.—This is common to many of the agreements.

Draft agreement.

Supplementary clauses.

Notes on the Draft.

B. The following clauses, dealing with navigation rights in rivers, flotation of timber, and the jurisdiction of the grantor second party, will not generally be required and are therefore kept separate.

Navigation rights to be maintained in rivers.

XXVIII.—The grantees shall so construct their work that the navigation in the River.........may be carried on as heretofore, or by means of locks lifts or other devices, at the sole cost of the grantees, and no toll or other charge whatsoever shall be levied upon any person navigating the said river. The plans of all works to be erected on navigable rivers shall be subject to approval by the local Government.

B. *Clause XXVIII.*—This clause will only be required for navigable rivers. It is not based on any existing agreement, and is inserted as a reminder to meet cases as they arise.

Timber transportation by other parties.

XXIX.—The grantors hereby agree with the said grantees that the grantors, when entering into contract deeds for forest produce transported by the River......and passing the grantees' works, will insert in all such contract deeds that if the party or parties to whom such contract deed may be given transports his or their produce so that such produce will or may reach the head works of and belonging to the said grantees on or between the.....and the..... in each and every year during the existence of the said contract such transportation will be at his or their own risk and neither the grantors nor the grantees will be responsible for any delay that may occur.

B. *Clause XXIX.*—Taken from the Jumna River agreement, clause IV, with "transport" substituted for "export" to make it more general. Where no such transport of timber by the river by outside agency is practised the clause will not be required.

The dates in the Jumna concession are 1st September and 15th February, but will naturally vary with the locality and circumstances of each case.

Facilities to be provided for timber transportation.

XXX.—Subject as is hereinafter mentioned the grantees shall at all times take such steps as may be necessary to ensure that all sawn or marked timber .... proceeding by flotation down the said River.......shall pass without avoidable let hindrance or detriment over that portion of the river affected by the grantees' works and more particularly—

Clause XXX.—Taken from the Jumna River agreement, clause V. It will only be required in the case of rivers used for the transport of timber by the Government or by Native States whose territories are above the works. Particulars or limitations on size may be inserted here.

(*a*) shall make all possible arrangements within reason to define and keep clear the main stream of the river .... within their limits by blasting rocks and by confining the water to one channel:

(*b*) shall make and maintain a riparian pathway where required by the Divisional Forest Officer .... Division, to facilitate the movements of the gangs employed on flotation within those limits:

(*c*) shall at all times allow a minimum quantity of water of .....,cusecs to pass through or over their weirs:

Sub-clause (*c*) may not always be necessary or desirable.

(*d*) on or between the.......and the........they will give flushes of water in order to assist floating within their limits when required by the Divisional Forest Officer.......Division (or the Conservator of Forests.........), provided that the quantity of water in the river permits this to be done without curtailing the quantity required by their works:

The dates here entered in the Jumna agreement are the same as those mentioned in the note to the preceding Clause XXIX, *viz.*, 1st September and 15th February.

This phrase is to cover the case where another Administration or a Native State is involved.

(*e*) after the.......and up till the commencement of the rainy season they will give extra flushes of water whenever required by the Divisional Forest Officer .....Division (or the Conservator of Forests .....)

The date here entered in the Jumna concession is the later date mentioned in sub-clause (*d*), *viz.*, 15th February.

See note to Sub-clause (*d*).

(*f*) that they will provide boats when required to do so by the Divisional Forest Officer.......Division (or the Conservator of Forests.......) to assist in the passage of timber through their reservoir:

See note to sub-clause (*d*).

Draft agreement.

(g) if after the..........and before the rainy season any batch of timber consisting of not more than ....pieces approximately is delayed within the grantees' limits by any cause other than one for which they are not clearly responsible, such as a landslip or the scattering of the batch by a freshet, for more than twenty days counting from the date on which the tail of the batch passes into the grantees' limits to the date on which the tail passes out of the grantees' limits the grantees will be subject to a fine not exceeding.....per diem for each day that the tail of the batch remains within their limits in excess of .....days at the discretion of the Forest Officer,....... Division, and subject to appeal to the Committee provided for in sub-clause (h). The amount of such fine shall be paid to the said Forest Officer within one month of the order imposing it, and that officer shall decide the method of disposal thereof:

(h) any difference or difficulties arising between the parties with regard to flotation shall be decided by a Committee composed of the Superintending Engineer, Irrigation Branch, the Manager of the Hydro-Electric Works, and the Conservator of Forests, ...Circle (or the Conservator of Forests....) according as the timber has been brought from the forests of the local Government (or of the .... State) and the decision of the majority of the Committee shall be final.

Flotation of timber not marked or sawn.

XXXI.—Timber which may be brought down by the river to the works of the grantees but is neither sawn nor marked need not be passed through the works or down the river by the grantees. But if it is removed from the river by the grantees it shall be kept by them at the disposal of the Government and notice shall be given periodically at such intervals as may be required by the local Government or any of its Forest Officers of the removal of drift wood from the river and its retention at any point by the grantees, provided that the grantees if they so desire instead of removing such timber from the river may trim it so as to make it pass easily through their works or down the river and allow it to proceed.

Jurisdiction of grantor second party.

XXXII.—It is hereby further agreed and declared that nothing hereinbefore contained shall be so construed as to affect in any way the jurisdiction of the grantor second party over any portion of his territories to which this agreement may become applicable.

Notes on the Draft.

As in sub-clause (e).

Fifty rupees in Jumna agreement, clause V (g).
Twenty days in Jumna agreement.

Required only when a second Administration or a Native State is involved.

But see clause XXVI.

Clause XXXI.—Taken from the Jumna River agreement, clause VI; see first note to preceding clause.

Clause XXXII will only be required where a second Administration or a Native State is involved as a party. It is taken from the Jumna River agreement.

Model form of Application for a Grant for the utilization of water power for the generation of electrical energy.

I..
of.......in the district of.......in........of........ nationality............... do hereby make application for a grant for the utilization of the following described waters:—

1. The source the water of which it is proposed to utilize is..... .....situated in.........taluk (sub-division, etc.) in the district of ....

Name and address of applicant in full. Town Presidency or State.

If the applicant is a Company state date and place of incorporation.

Name of river, stream or other source.

Draft application.	Notes on the Draft.
2. The point of diversion of the required water will be located... ...and is shown approximately in the map attached by the letter......	
3. The proposed power station will be located at......... and is shown approximately at the point......... in the map attached.	
4.	Here give particulars of any observations with results on discharge of the stream or source of which it is proposed to utilize the water.
5. It is understood that the whole of the water utilized shall be returned to...................... at the location described in clause 3 above without pollution or diminution except unavoidable loss from absorption or evaporation.	Name of stream.
6. The amount of water it is proposed to divert in the first instance is (*a*) Continuously.........cusecs, (*b*) Discontinuously.........for.................. Eventually it is proposed to divert.........cusecs.	Here state maximum and minimum discharges required and periods (yearly and daily) for which they are required.
7. The head to be utilized is approximately........... feet.	
8.	State whether the unutilized flow of the stream will be stored if necessary and if so, whether it will be impounded by the diversion dam or by a separate work.
9. (*a*) Nature of storage works (masonry dam; earthen bund, etc.)...........................	If it is proposed to construct a main storage work particulars should be given.
(*b*) Capacity of storage work.......million c. ft.	
(*c*) Location of storage work...............	
(*d*) Height of dam will be......feet.	
(*e*) F. T. L. will be......... feet above bed at site of dam.	
(*f*) M. W. L. will be.......feet.	Depth and height to be those above deep bed at site of dam.
(*g*) The material to be used in the dam will be	
(*h*) The area submerged at F. T. L. will be approximately .... square miles.	
(*i*) The area submerged at M. W. L. will be approximately........square miles.	State whether the areas given above have been obtained from an actual survey or from a Survey of India Atlas or Standard sheet.
(*j*)	State ownership of land (Government, Zamin or private) submerged at F. T. L. giving approximate areas.
(*k*)	State ownership of land submerged (Government, Zamin or private) at M. W. L. giving approximate area.
(*l*)	State if it is desired that the Government of............. shall acquire under the Land Acquisition Act, 1894, any of the areas enumerated in (*j*) and (*k*) above, giving reasons for this request.
10.	If it is proposed to construct regulating storage works (not included under head 9 and other than a forebay) state their position, nature and capacity approximately.
11. Ownership of land.	Here state ownership (Government, Zamin, private and if private whether applicant is owner) of the land on which it is proposed to locate each of the following works :—
(*a*) Diversion work (*b*) Open channel (*c*) Forebay (*d*) Pipe line (*e*) Generating station	
12.	State for what purpose or purposes the power is to be generated.
13. It is agreed that British Standard pressures and frequencies will be used exclusively and that, before	

Draft application. Notes on the Draft

tenders are called for, a description of the plant required will be furnished to His Majesty's Trade Commissioner in India, in order to ensure that opportunity is given to British firms to tender; also that the date up to which tenders may be received shall be so fixed as to give firms in the United Kingdom time to submit their tenders.

14. It is understood that I may not sell, sub-lease, mortgage, transfer or assign in any way, any rights or obligations that may be granted to or incurred by me except with the written consent of the Government of....

15. The following periods from the date of the grant of the concession are required for the following purposes:—

(a) To form a company..........................

(b) To commence construction of works.............

(c) To generate electrical energy ....

(d) Free water.................... ....

Signature of applicant.

Date of application.

Application received by Government on...................

Note.—It is not essential that every item in this form shall be fully and completely filled in. Where exact details are wanting the fact may be stated.

INDEX.

The more important entries are printed in small CAPITALS.

C—*concld.*

D

D—*concld.*

E

F

F—*concld.*

G

G—*concld.*

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R

R—*concld.*

S

S—*contd.*

S—*contd.*

V

W

W—*concld.*

Y

Z