

With the Compliments of

" PLANNING FOR PLENTY "

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by

**lt./Lt. Sir William Stampe, C.I.E., R.A.F.V.R.,
Irrigation Adviser to the Government of India**

to

The Institution of Engineers (India)

on

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“ PLANNING FOR PLENTY ”

Index of Contents of an address to be circulated to the Institution of Engineers
(India) by Flt./Lt. Sir William Stampe, C.I.E., R.A.F.V.R., Irrigation Adviser
to the Government of India on November 10th, 1944.

N.B.—The address is *not* to be read at the meeting. It will be circulated to members in advance and the subject will be summarised and explained with the aid of maps and plans by the lecturer's "spoken word" at the meeting.

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ERRATA

Sl. No.	Page	Para.	Sub-para.	Line	
1.	1	2	2	2	<i>Read 'got' for 'ot' between the words 'be' and 'by'.</i>
2.	1	2	2	8	<i>Read 'the' for 'he' between the words 'for' and 'different'.</i>
3.	1	2	2	9	<i>Read 'according' for 'accordng' between the words 'India' and 'to'.</i>
4.	2	4	(b)	4	<i>Read 'many' for 'mny' between the words 'in' and 'alluvial'.</i>
5.	2	5	1	9	<i>Read 'capital' for 'apital' between the words 'higher' and 'outlay'.</i>
6.	2	5	1	10	<i>Read 'development' for 'developmnt' the last word.</i>
7.	4	8	(b)	4	<i>Read '67 inches' for '67' between the words 'area' and 'mean'.</i>
8.	6	9	(a)	16	<i>Read 'identifying' for 'indentifying' between the words 'white' and 'discs'.</i>
			—the SVA		
9.	7	9	(b)	3	<i>Delete ';' after the word 'pumps'.</i>
10.	7	9	(b)	3	<i>Read '(Bihar)' for '(Bhar)' after the word 'tubewells'.</i>
11.	10	11	(iii)	3	<i>Read 'new' for 'now' between the words 'that' and 'irrigation'.</i>
12.	21	12	3	penultimate	<i>Read 'connoting' for 'connecting' between the words 'each' and 'a'.</i>
13.	Graph showing Indian				<i>Population & Yield of major foodgrains—insert the word 'wheat' between the words 'rice' and 'barley'.</i>

“ PLANNING FOR PLENTY ”

An address for circulation to the Institution of Engineers (India) by Mr. Lt.-Col. Sir William Stampe, C.I.E., R.A.F.V.R., Irrigation Adviser to the Government of India.

1. Introduction.—It is an honour to be given this opportunity to address you and through you the engineers of all-India this evening on the post-war planning of irrigation and hydel developments vital to the relief of India's scarcity. These developments by controlling water and co-ordinating its use for power will raise the standard of living and advance the economic uplift of one-fifth of the human race. An inspiring target if ever there was one.

The occasion, too, seems fitting when just as the last bomb thud of the most destructive conflict in human history is shortly to be heard in the west there should be sounding in the east the clear call to this constructive campaign about to open on our dusty plains. I refer to the coming fight with Himalayan forces which must be subdued in order to link these great reserves of mountain power with water which is either seeping silently below the sands of the great plains or flowing down deep-set rivers at too low a level to relieve the cultivator and his tired cattle in the fields. To take even a small part in such a campaign is surely a privilege to those of us who have spent our lives on the plains of India doing what we could with limited resources to serve her agrarian people. This campaign comprises the fulfilment of what I have often called the “Himalayan dream”. First of all let us not underestimate the strength of the enemy—by that wishful thinking which so nearly lost us the earlier western war. In converting such a dream as this into effective action you will on the contrary be up against dame nature in her fiercest moods. Remember the lines:—

“ Though nature red in tooth and claw
With rapine, shrieked against his creed ”.

To train torrents, to convert their wild turbulence into the streamlined flow of modern turbines and tune them again to the rhythmic hum of pumps—that, then, is our task.

2. The target.—In planning a fight against famine we must first “appreciate the situation” in the military sense. It is admittedly essential to increase the total foodgrain production of India, both extensively and intensively, in order to satisfy the needs of its rapidly growing population if India is to survive perhaps the gravest threat that has ever faced mankind. Although this address is intended to outline the principles rather than the details of irrigation planning, a few basic data must be quoted to underline the magnitude of the problem before us—engineers. The population graph (on black board) shows that India's people are increasing by some 5 millions a year. The food-crop-yield graph, moreover, shows a serious lag between the demand for, and the production of, foodgrains. Briefly, therefore, the position is that, by means of new irrigation (aided by artificial fertilisers) and improved methods of agriculture including higher class seeds we have to grow enough additional foodgrains to serve two purposes:—

(a) to nourish the 5 million who are born every year (i.e., to recover the lag), and

(b) to raise the standard of nutrition of the one-third of India's people, say 150 million, who are stated to be under-fed, and, I am informed, require by and large an additional ration of 2 chataks (4 ozs.) of foodgrains daily *per capita*.

For (a) we require an additional 1 million tons of foodgrains yearly, and for (b) 6 million tons or say 7 million tons in all.

I would suggest that in planning, one-third of these additional foodgrains, or say, 2 million tons, should be met by the increased yields that adequate chemical fertilisation and improved agriculture should secure. It will be seen from para. 9 that cheap hydel power for the manufacture of part at any rate of these fertilisers can be produced from the impounded water necessary to secure some of the extra irrigation required. So we may take the irrigation target as 5 million tons of foodgrains yearly. To convert these accurately into acres would involve an elaborate computation of water depths and duties for the different food crops required which vary in India according to the dietetic needs of the respective local populations. We can however assume that throughout India an acre of

land systematically irrigated will produce a quarter of a ton more wheat (and a varied increment of other crops) than a 'dry' acre will produce. Remember that the new mechanised irrigation visualised in the paragraphs below will be applied mostly to the driest areas where often, at present, even grass hesitates to show its head. Hence we arrive at the approximate target figure of $(7-2) \times 4$ or 20 million* acres of new irrigation. How then is it to be attained?

3. The Irrigation Target.—The ideal object of a well-planned irrigation system is two-fold (a) tactical and (b) strategic.

(a) By providing water in the right place in the right quantity at the right time it ensures a yield from 'dry' ground and an increased yield from ground already watered by either (i) intermittent rain, or (ii) other inadequate means. In other words, it equates the rainfall on a tract to the ideal water requirements of the crops thereon.

(b) It secures *all* the crops within the culturable† commanded area (C. C. A.) of the system from total failure in those occasional years (say, 1 in 5) when seasonal rainfall fails, thereby acting as a vast insurance system. Credit is very often denied to an irrigation project in this important respect when assessing its financial return. The value, both to the cultivator and to the State, of such an insurance service against years of short rainfall, is incalculable.

4. Methods of increasing irrigation.—Irrigation can in general be expanded in the following four ways:—

(a) *By new gravity canal systems* taking additional water from sources as yet either (i) not tapped at all, or (ii) inadequately tapped for economic reasons.

(b) *By expanding existing gravity canal systems* by means of (i) stabilising the fluctuating (seasonal) sources of supply by providing *storage*, (ii) increasing the available river flow by pumping into the canals from the sub-soil reservoir where suitable aquifers exist, i.e., in many alluvial tracts, (iii) increasing the efficiency ('duty') of the canal systems by (a) better distribution, (b) reducing percolation losses by (i) lining channels and/or (ii) regrading them.

(c) *By mechanical pumping for local irrigation*, i.e., lifting water from (i) tubewells sunk in the great alluvial belts, e.g., the Gangetic plain, the Punjab extra-canalar tracts, the coastal alluvial zones of peninsular India, etc., (ii) deep-set rivers flowing at a level too low to "command" the high riparian tracts by gravity flow, (iii) power operated open-wells in non-alluvial areas, e.g., Madras, Mysore, etc. The value of tubewells for providing a pure domestic water supply for adjacent villages both for drinking, bathing and washing clothes, and thus reducing epidemics, has been emphasised in para 10 (d) page 9.

(d) *By indigenous methods*, less spectacular but generally applicable throughout India, e.g., open wells, contour bunds and small tanks for impounding surplus monsoon run-off in undulating areas.

As methods (b) and (c) above are capable of yielding the earliest results, my remarks to-night will deal mainly with them.

5. New gravity canal systems.—(a) A glance at the irrigation map of India (on the board) will show that most of the great perennial rivers that command the *dry zones* (where irrigation is most needed) have already been tapped at their most advantageous points, i.e., where they can command the largest dry areas with the least capital outlay on major works. It is natural therefore that as the 'stalls' in the development theatre have already been booked those unlucky provinces (or States) that now stand in the irrigation queue must either remain dry or pay more for their seats! For not only have the best sites gone but owing to the rising cost curve even the inferior sites (the pit!) must inevitably involve higher capital outlay in their development.

* Apart from foodgrains, to secure a balanced diet a large tonnage of other grains, vegetables, fruit, etc., will, of course, be necessary. The acreage required for this will probably be found by rotation within the 20 million acres allowed for.

Again a large acreage, (and water for irrigating it) must be allocated for growing special fodder crops, (including Guinea grass, clover etc.) for maintaining the increased cattle population that will be required (a) for improving the milk and butter diet (b) for the enhanced ploughing and transport of the new foodcrops.

† C. C. A.—In irrigation terminology the "commanded area" is that zone which, lying below the level of the canal (or tubewell), can be irrigated from the source in question over a series of years. The "irrigated area" in a particular crop (or year) is the actual area watered by the canal in that crop (or year).

6. **Post-war prices (P. W. P. F).**—It is relevant here to mention a co-efficient—I have called it the P. W. P. F. (post-war price factor)—which must be applied to pre-war costs to estimate, even roughly, the future cost of irrigation works. This price factor has two aspects—(a) the cost of plant, *e.g.*, hydel (and thermal electric) equipments, sluices, pipes, valves, pumps, etc., and (b) the cost of indigenous items mainly involving labour charges. These factors are of such obvious importance to planners that I must trespass on your time for a moment.

(a) Many engineers (and so-called finance experts) have recently said:—

“ We shall postpone this or that work (involving importation) until prices drop ”.

Have they seen the many air photos of the bombed towns and communications of occupied Europe? Is it likely that plant prices will fall appreciably until the major utilities and factories of Belgium, Holland, China, Poland, the Ukraine, London, Coventry, Paris, Java, Burma, Italy, etc., have been restored, not to mention thousands of bridges, houses, etc.? If India does wait for this economic millennium much water that might meanwhile be usefully impounded will have flowed into the sea and with it the hopes of many expectant millions will have faded away. So if we are to plan for plenty let us plan *with* plenty, in other words, allow a P. W. P. F. (plant) of 160/100.

(b) Most major canal works principally comprise labour items such as earth work, brick burning, carriage, etc. The cost of such items varies directly with food prices because 90 per cent. of a labourer's wages usually go in grain. We can roughly estimate therefore that so long as scarcity lasts (*i.e.*, as long as the urge for immediate remedial works lasts) labour costs will, *ex-hypothesi*, remain high. Apart from the much desired oriental El Dorado of a higher general standard of living (that elusive elf!) the cost of earth work will fall *only* when the price of food falls—and by then I fear the urge for planning may have wilted too. So in estimating future costs, I have assessed the P. W. P. F. (labour) at 200 or say double. A general factor of 180—100 for a combined work, such as a mechanical pumping scheme, will probably not be far out in three years time when the bills are due for payment.

7. **Cost of new canal systems.**—In a general address on planning with special reference to mechanical irrigation, it is obviously impossible to do more than adumbrate the possibilities of extending India's major canals, at the same time giving a rough idea of the capital cost per acre in round figures.

Scope for constructing new major gravity canals exists on some of the eastern rivers in the U. P. and in Bihar, also on the lower reaches of certain major rivers in the southern Punjab, Sind and Madras. But as such projects must take several years to prepare and then cannot be in operation for several more years, I have not regarded them as providing an immediate solution of the hunger problem.

8. **Stabilisation of canal supply by storage.**—The discharge (and thus the benefit) of those Indian canal systems that derive their supplies from rivers subject to large seasonal variations are bound to fluctuate accordingly. By a beneficent provision of nature, however, the main Himalayan rivers which are snow-fed yield their *maximum* canal supply in the hottest weather when the demand for early kharif (and cane) crops is highest. On the other hand the Vindhyan rivers of peninsular India, being merely rain-fed, yield their *minimum* supply in the hot weather when the springs almost entirely fail. On the other hand the monsoon discharge of *all* Indian rivers is very much in excess of irrigation requirements. The main object therefore of storage reservoirs is, by holding up a portion of the excess monsoon supplies, to stabilise the ordinary cold weather flow thus maintaining the canal systems at their full capacity. The capacity of such storage depends of course on the seasonal variations of the particular river concerned and must, therefore, be greater in the Vindhyan than in the Himalayan systems. In a short address it is impossible to do more than analyse the economic value of such stabilisation by briefly describing the main features of one storage scheme, *viz.*, the Nayar dam now being projected on a Garhwal tributary of the Ganges under the administration of Mr. A. P. Watal, I.S.E., C.E., Projects, U. P. The same economic principle, if established, can then be applied *mutatis mutandis* to other rivers with known flow characteristics and a general estimate of India's reservoir requirements prepared by the planners concerned.

In passing, I shall presume as being (a) perhaps the oldest irrigation engineer serving in India and (b) one who has lived 36 years mainly on the banks of mother Ganga, to offer a word of caution to those enterprising engineers of the Punjab who propose to subdue certain Himalayan tigers by a frontal attack on their main lairs. Personally in my limited experience I have always regarded discretion in shikar as the better part of valour. In view of (a) the geological instability of the Himalayan set-up, (b) the technical difficulty and danger of dropping stupendous floods on to the unstable river beds, and (c) the appalling consequences that would follow a failure, would not such planners do well to adopt Mr. Watal's 'appeasement' policy of 'catching the cubs first,' i.e., damming the bigger tributaries and thus gaining experience before tackling the tigress herself? However, as my more daring friends have engaged an international tiger tamer, I must leave it at that. These impertinent asides do not of course apply to such tactics in the Vindhya where secure river flanks and floors can be relied upon to resist the fiercest hydraulic forces.

Reverting now to our example on the Nayar the principal hydraulic and economic features are as follows :—

(a) *Economic objects.*—(i) To stabilise the upper Ganges canal flow at 8,400 cusecs (its full capacity) as against 5,860 cusecs its present average *rabi* flow* from November to April. The average minimum flow available at Dhanouri (the U. G. C. gauging point) in February is 4640. This determines (a) the total *rabi* area that can be efficiently irrigated, and (b) the yield from existing areas that can be adequately watered during the critical period when wheat is coming into ear. It is estimated that an additional 175,000 tons of wheat will result from such stabilisation in normal years. Those cultivators whose minor channels will in future operate on an improved roster will, it is believed, endorse this, (ii) to assist maize (and/or sugarcane) sowings and first watering in early kharif in those years (say, 1 in 5) when, due to the prevalence of cool east winds, the river snow freshets in late April and early May are delayed, (iii) to increase the total output of hydel power during the months of low canal supply by maintaining the various power plants at a higher capacity, (iv) to generate 15,000 KW of additional hydel power at the dam itself for feeding the existing Ganges grid which is to be commensurately extended and intensified.

(b) *Features.*—By means of a dam 600' high across a narrow (635 ft.) defile of the Nayar, 0.8 million acre-feet (35,000 million c.ft.) can be effectively impounded out of the 1.38 million acre-feet normally available from the 720 sq. miles of catchment area (67 mean annual rainfall). With the minimum available head of 375' and a minimum discharge of 600 cusecs during the non-irrigation periods, the continuous effective output would be 15,000 KW from an installed capacity of 30,000 KW.

The live storage of the reservoir is anticipated to continue undiminished for 100 years even assuming a silt content as high as 1/700.

(c) *Strategy.*—In preparing the preliminary project the greatest care has rightly been exercised to secure the predominance of irrigation requirements over the interests of hydel. The draw-off from the dam will be regulated accordingly by the Chief Engineer, Irrigation, whose decision will be final. The observance of such a principle cannot be too strongly recommended to other administrations when projecting similar dual-purpose works.

9. *Reconnaissance or large scale research in hydro-electricity.*—Now may I quote two instances of a famous military maxim relevant to our theme—"time spent in reconnaissance is rarely wasted"? One instance, I consider sublime the other you may regard as ridiculous.

(a) *T. V. A.*—Much has been written lately about the T. V. A. whose consultant, Mr. Savage, I am honoured to see here to-night. This authority was set up by the U. S. Federal Government to achieve two main objects : (i) to control the disastrous floods that formerly ravished the Tennessee valley. The river has been curbed by building no less than 13 dams with a large ponding capacity. The average high flood level (H. F. L.) in the valley below has since fallen by four feet ; (ii) to act as a vast hydro-electric (and river) research institute. In the body

The grid system as a whole lifts 2,400 cusecs from the subsoil and 370 cusecs from deep-set rivers for new irrigation, a volume equal to more than half the normal cold weather flow of the Ganges canal at Hardwar.

Hence we have the interesting and beneficial cycle of a great canal irrigating directly some 1.6 million acres and, also, by means of its water power irrigating an additional 800,000 acres in tracts hundreds of miles beyond its own command. It has been shown in para. 8 above that by stabilising the fluctuating cold weather supply in the Ganges canal by means of the Nayar storage dam in the Himalaya the direct irrigation can be increased by 700,000 acres and the power output by roughly 40 per cent thereby enabling 600 additional tube-wells to be energised. If, as I hope to show, similar results can be achieved elsewhere, what vast possibilities can we not visualise in India as a whole ?

To correlate the grid prices outlined above, which relate to the 1931-40 period, to post-war construction it is necessary to apply the "P. W. P. F." of 180 as arrived at in para. 6. It has been computed that at estimated post-war construction values the Ganges Grid would have cost 6.48 crores and the average price per unit to produce an equivalent net return (7.0 per cent) would be 1.05 annas instead of 0.66. But in such a computation, allowance must be made for the fact that instead of providing an average net return of 7.0 per cent on the capital, as had actually been the case, a future Government will avowedly be content with 3 per cent as a net *direct* return. Thus if the figures are adjusted accordingly the average cost per unit delivered at sub-stations would be of the order of 0.68 anna for future canal operated schemes under similar conditions—a highly significant figure. In arriving at this basic figure I have increased the actual pre-war establishment charges by 50 per cent to cover (i) additional cost of more highly trained staff and (ii) the scarcity allowance which is likely to continue for some years. Your careful attention to the comparative financial schedule (Appendix B) is invited. It will be seen that the Ganges grid has yielded a net return higher by 0.8 per cent than the project figure forecasted in 1935.

(a) *The S. V. A.*—From these fields of fact, limited as they at present are, I ask you to fly in imagination with me over the Sone valley where thousands of kilowatts now thunder to waste pending our decision to exploit them in the service of man. Taking off from Allahabad we shall cross the semi-arid tail areas of the half starved* Ganges canal and visualise the coming colour conversion from khaki to green K/G as the canal supply is gradually increased from the slowly rising NAYAR dam now to be built away in the Garhwal Himalaya. In the meantime the 'K/G ratio' can be improved by constructing more feeder tube-wells (see para. 10) in the Meerut district. Crossing the Tons river meandering below its Vindhyan ridge we see the site of the pumping station which could, with the aid of cheap power from the 'S. V. A.' transform the Jumna-Tons doab from brown to green and also energise KARCHNA tehsil. Entering the Sone Valley below Rewa we fly over at least four power sites that can be developed economically for the Sone grid. This is not an occasion to describe these in detail but a reference to the RIHAND site in particular is relevant to this review. Circling at 2,000' over the narrow (300') gorge with its steep rocky flanks and granite bed the white indentifying discs are not necessary for us to pinpoint this obvious site for an ideal storage dam. The site offers the following advantages: (a) secure flanks with a wide flat sloping bed up-stream opening out into a reservoir basin of immense capacity (410,000 m.c.f.) for a dam height of 300'. (b) A rocky catchment area of 5,000 sq. miles on this tributary alone, with a mean annual rainfall of the order of 50". (c) Possibility of power expansion by stages as, one after another, the various dam sites† are exploited when the load develops as it inevitably must with such a vast potential market existing all around. (d) Proximity to large cement works and local availability of good stone, sand and other construction materials.

* The lower Ganges Canal is at present notoriously short of water for its existing command let alone for the tail areas that it could irrigate if suitably reinforced.

† In addition to the four sites so far pin pointed, there are several others which, as seen from the air, appear to be suitable.

With a total catchment area of 28,000 sq. miles and a stable (50%) rainfall the Sone Valley as a whole presents unique opportunities on its various tributaries for 'stage' scheme to develop energy on a vast and expanding scale.

The following latent loads present scope for the economic* utilisation of Sone power (see also para. 15):—

(a) *Urban and industrial utilities.*—(1) U. P. Cawnpore (245 miles), Lucknow (290), Allahabad (125), Mirzapur (75), Benares (110), Ghazipur *via* Benares (155), Gorakhpur (245) and Ballia (190). (2) Bihar: Dehri on Sone (90), Patna (170), Gaya (140), Daltonganj (80). (3) C. P.: Jubbulpore (250), Katni (195), Satna (140).

(b) *Irrigation Pumping.*—(i) Tons pumping scheme (*via* Allahabad) (150 miles) (ii) Ghogra pumping station (8,400 KW, 260 miles), (iii) Sone canal tail feeder pumps; (Bihar) (3,000 KW, 130 miles), (iv) Dehri-on-Sone tube-wells (Bihar) (1,500 KW, 90 miles).

(c) *Sone Canals.*—Reinforcing the Patna and Arrah canals by increasing the dry weather flow in the Sone river by 6,000 cusecs (from the Rihand reservoir alone). At present the dry weather flow falls to 500 cusecs against a canal capacity of 6,000 cusecs.

(d) *Drainage Pumping.*—Vast areas, extending ultimately to millions of acres await the advent of really cheap power (0.3 anna per KWH at pumps) for dewatering flooded lands in North and South Bihar as well as in S. E., U. P. for extending paddy cultivation and providing pasturage for cattle by means of low-head drainage pumps (see also para. 17).

Roughly speaking, 1 KW can dewater 20 acres† of flooded rice land against a head of 8' in time to save a paddy crop from the rising flood water due to the heading up of the local drainage cuts by the rising Ganges—the main outfall of Central Bihar. Thus the provision of 10,000 KW throughout the monsoon would secure the dewatering of about half a million acres to assist hungry Bengal.

Flying over these localities lately we were forcibly struck by the demand for cheap power both in the dry season for irrigation pumping and in the monsoon for drainage of millions of acres of flooded but fertile soil.

(e) Then there is the improvement in the navigational conditions on the Bihar-Bengal rivers below Patna that must result from the perennial tail waters emanating from the power stations in the Sone valley. The Rihand plant alone contributes 6,000 cusecs continuously.

(f) Finally, but here, like the rice crops, I am out of my depth, there is the scope for fertiliser manufacture at factories to be located on the E. I. Railway at say, Moghal Sarai, a point sufficiently adjacent both to the coal fields and to the depleted lands of the over-populated districts in the east U. P. and west Bihar.

Some time ago in an air inspection note, I advocated the immediate formation of a quasi-State authority 'the S. V. A.' under regional control to develop the power resources of the Sone valley. The potentiality is great, the need for the economic relief of the people is even greater, the situation thus calls for early exploitation in the interests of the needy populations toiling in the plains below. I beg therefore that the Central Government will give a lead to India by forming the S. V. A. as a regional enterprise at no distant date.

* It is shown in para. 15 on 'zoning' that the local cost of grid power is affected less by distance of transmission than by cost at source.

† Assuming that the rice land is flooded with 1 ft. depth of water and the lift involved is of 8 ft., power required per cusec lifted with pumping sets of 60 per cent overall efficiency—

$$\frac{62.5 \times 8 \times 100 \times 3 \text{ KW.}}{550 \times 60 \times 4} \\ = 1.1 \text{ K. W. say } 1 \text{ K. W.}$$

∴ 1 K.W. will suffice for lifting 1 cusec-day or 2 acre-feet per day, i.e., 20 acre-feet in 10 days.

10. The Ganges Valley Tubewell Irrigation Scheme, U. P.—(i) *General description*.—The Ganges scheme in the U.P. (1935-37) under which some 1,600 wells (of 1 1/4 cusecs each) were installed in 3 years to command 1 1/2 million acres of (mainly) arid but fertile land, of which 800,000 acres have since been irrigated yearly* has shown that the ground water in selected alluvial tracts can be successfully exploited for commercial irrigation provided that certain essential conditions prevail. These include (a) that the flow in the coarser grained subsoil 'aquifers' tapped by the tube strainers is adequate to meet the surface demands, thus ensuring a stable water table (b) that the depth to this table does not generally exceed 50 feet (c) that irrigation demand prevails over a wide tract for an average period of not less than 3,000 hours in the year and (d) that a cheap† source of power exists—or can be created—in the form of a rural network over the irrigated area. (It is shown in para. 9 above that, provided widespread demand does exist, the construction of a power network can be commercially justified, from a hydel or thermal source). In the upper Ganges valley where the depth of the water table averages 22 feet, the aquifers are such that 80 to 100 feet of 6" strainer can be located in a total depth of boring of 250'—300', yielding 1 1/2 cusecs (33,000 g. p. h.) with a depression of 15 feet. In the lower valley where the sands are finer, 'cavity' ‡ wells are being installed.

The pre-war cost of a standard strainer tube-well with sump, pump-house 12 1/2 H. P. motor pumps, 3 miles of distribution channels, approach road and a share of the 'general' expenses (e.g. offices, inspection houses etc.) was 10,000. The present day cost (including R. C. pipe distribution and other improvements) is roughly 40,000. For estimating purposes the pre-war cost may be taken as 25,000.

(ii) *Cost of irrigation*.—Tubewells lend themselves to a system of payment for water by volume which ensures greater economy both in distribution and in its application to the fields. The cultivator who thus scores in a wet year pays more in a dry one when his crop is more valuable. There is also less drain on the water-table.

Water is sold at a standard rate of (i) 38,000 gallons per rupee for food crops and (ii) 26,000 gallons for sugarcane. The average cost per acre-watering (90,000 gallons) for wheat is Rs. 2-4 and for sugarcane (115,000 gallons) Rs. 4-4. In years of normal rainfall wheat takes 2 1/4 waterings (Rs. 5-4 per acre-crop), and sugarcane 4 waterings (Rs. 17-6). These rates compare favourably with 5 and 15 per acre respectively on the adjacent "open-canal" system.

(iii) *Tactical advantages of tubewells*.—In suitable areas where the above defined conditions prevail, tubewells offer certain tactical advantages as a means of irrigation:—

(a) They can be located initially on the highest suitable ground, the wires skipping over the lower zones, thus securing the maximum command of *selected* areas. The less favourable sites can then be developed later by the interpolation of a second batch of wells (the black squares of the chessboard) after the first series (white squares) has succeeded. In this way an undulating but fertile tract of alluvium can be rapidly§ and economically exploited.

(b) Tube-wells lend themselves to the development of a tract by 'stages' thus avoiding the heavy outlay on certain essential major works inherent in large canal schemes (e.g. headworks, aqueducts, etc.).

(c) The introduction of cheap electric power over a wide area is *ex-hypothesi* justified by irrigation as a base load thereby opening up a tract of country for minor

*See Appendix C showing development of irrigation.

†The price of energy should not exceed 3/4 anna per unit (low tension) at the tubewell. In the U. P. the cost is 80 per H. P. year, or 1/2 anna per unit at the existing load factor of 32 per cent for tube-wells.

‡ A plain 6" pipe is sunk with its lower orifice opening into the sandy aquifer below a strong clay layer of sufficient thickness to span the cavity created by pumping out the sand. The sand is then pumped out until the slopes of the cavity form a cone with sufficient perimeter to supply the necessary discharge (usually 1 1/4 cusecs). The cavity is then in hydrostatic equilibrium.

§200 interpolated wells sanctioned in July 1943 are now being completed in U. P. in one year and, it is believed, will irrigate 100,000 acres during 1945.

and agricultural industries *e.g.* cane crushing, cotton ginning, flour milling and the like. If the machines are worked in the off-peak (*i.e.* non-pumping periods) a very cheap rate can be offered (*e.g.* 1/2 anna per K. W. H.).

(d) Various domestic amenities can be provided *e.g.* (i) pure water supply—tanks can be cheaply constructed on the roofs of tube-wells adjacent to villages—bathing tanks (ii) cattle troughs (iii) radio loudspeakers (iv) fruit and fuel trees can be grown round wells and looked after by the operator.

(iv) *Canal feeder tube-wells.*—Apart from their value for local irrigation in alluvial areas, tubewells have proved fruitful on the Ganges canal system as a means of supplementing the fluctuating river supplies by pumping from the subsoil either:—

(a) Into the main canal for carriage of the ground-water to distant areas where tube-wells cannot be sunk for geological reasons. 100 cusecs are thus being pumped from 30 large wells* installed along the main canal bank a few miles from Delhi for utilisation on new canal extensions in the Muttra district 120 miles away from the wells themselves, or (b) directly into distributaries which can then be cut off from the main canal system, thereby releasing water for utilisation in areas far beyond the tube-well zone. The Daurala distributary in Meerut district thus releases 90 cusecs of Ganges water† for less fortunate areas elsewhere.

Similar extensions at economic rates on a large scale are possible here and elsewhere. A vast dual-purpose project of this type, now to be undertaken in the Punjab for irrigating nearly a million‡ new acres, is described in para. 16.

11. (i) *Underground water as a strategic source of irrigation supply.*—In para. 10 above it was postulated that in order to locate a subsoil irrigation system the underground flow in the aquifers of the tube-well tract should be adequate to meet the surface demand for water. Whilst flying over India lately I have frequently asked myself why the tube-well system which has proved so successful in the upper Ganges valley should not be applied to other alluvial tracts in the arid plains below. To answer this rational question it is necessary to examine for a few moments the origin of ground water supply. Let us trace these sources in the Ganges valley first and then apply the same principles, *mutatis mutandis*, to other—often less favoured—areas. The alluvial deposits in the great Gangetic trough between the Vindhyan and Himalayan ridges consist of alternating layers of soil (on top) clay and sands of ever varying thickness and texture. These layers being lenticular are non-continuous, at any rate in the upper valley as far south as, say, Aligarh. South of this the aquifers tend to become finer and more regular in their set-up. In the centre of the upper trough there is a depth of 2,000 ft. or more of such deposits of which perhaps a third (or say 700') comprises water laden sands (aquifers) which are suitable for strainers. Then there is the finer sand in other places, also water laden but with a lower transmission coefficient which, as shown in para. 10, is suitable for installing cavity wells, provided it is overlaid by a roof of clay thick enough to span the cavity safely. The water in these aquifers, which is derived from the sources discussed below, is not static but is seeping very slowly under the ever decreasing force of gravity towards the Bay of Bengal. This hidden river, the Saraswati of Hindu Mythology, is the basic source of *all* the deep well water required for cultivation in the plains above. It thus constitutes a vital asset in our post-war plans. To arrive at a quantitative estimate of its discharge would involve a difficult and wearisome analysis of factors far too complex in their inter-relation to discuss to-night. The following valuation, however, is illustrative even if inexact. Taking the depth of the aquifers as say 700' and the interstitial space of the sand as 40 per cent., the cross

With a capital cost averaging Rs. 3,96 per cusec and energy at 80 per B. H. P. year or 1/4 anna per unit, at the existing load factor, the cost of pumped water is of the order of 4/4 per cusec-day of demand, or, say, Re. 3/3 per acre irrigated allowing for transit losses. Assuming a 'P. W. P. F.' of 180 and post-war energy at say, 0.3 anna, the cost for future extensions of this type may be estimated at Rs. 2 per acre.

†At a capital cost of Rs. 6,994 per cusec and energy at 1/4 anna, the pre-war cost of released water was Rs. 4/8 per cusec-day, or, say, Rs. 3/6 per acre of extended rabi irrigation.

‡At present day plant prices with the cost of canal-generated energy at 0.14 anna per unit, water can thus be pumped into the Punjab canals at a lower cost than the normal flow rates for gravity irrigation.

sectional area of the Saraswati would be 148 million sq. ft. for a width of trough of say 100 miles between the Vindhya and the Himalayan foothills. Again, assuming the average rate of flow in the Hardwar—Aligarh zone at half a mile or 2,640 ft. per year, the underground discharge may well be of the order of 12,500 cusecs (or 18 cusecs per foot of aquifer), as against 5,000 cusecs the minimum surface flow of the Ganges at Hardwar. I hope my critics will not regard these fantastic approximations as more than mere mental castles on the sand! They will, however, perhaps serve to prompt the pertinent question "how, if the total underground flow available through each 100 feet of aquifer is only 1,800 cusecs, can a total of 2,500 cusecs have been pumped out of the ground by a system of some 1,800 tube-wells for 9 successive years without substantially lowering the water table?" To answer this, we must remember (a) that the tubewells are designed to operate for only 3,000 to 4,000 hours in the year and (b) that the Saraswati receives important reinforcements along its course to the sea. These are threefold (a) from rainfall (and irrigation) on the tract itself—perhaps 15 to 20 per cent. of this water reaches the water table, the fraction depending on (i) the degree of surface vegetation, (ii) the ground configuration, (iii) the intensity of rainfall (and irrigation) and (iv) evaporation.

(b) From rainfall on the flanking hills to the north and south, a portion of which seeps into the water-table from the porous submontane hillsides and Tarai swamps.

(c) From the rivers entering the great plain from the north and south e.g. Ganges, Jumna, Sardah, Gogra, Betwa, Ken, Sone, etc.

It is impossible, as I have said, to evaluate these reinforcements quantitatively but it can be stated that source (c) alone furnishes an important field for expansion of tube-well irrigation.

It has been rightly argued that, as the Ganges meanders southwards towards the sea, its sands become finer in texture and thus less suitable for tube-well development. But each tributary, especially those from the laterite hills to the south in Bihar, contributes its own quota of coarse sand which forms a suitable 'delta' of considerable area for local exploitation. In Bihar for instance the Sone 'delta' near Dehri, the Morhar, and the Panchani near Bihar Sharif have already yielded copious supplies of subsoil water.

(ii) *Necessity for a Central Subsoil Research Panel.*—Systematic reconnaissance over India is likely, in my opinion, to reveal further sites both in the Ganges and in other valleys where agriculture can be aided by subsoil irrigation. The necessity for the early formation of a Central Panel on the lines I have frequently recommended for prospecting and co-ordinating such data cannot, thus, be over-emphasised. Let it be remembered that in the early days of the pioneer scheme in U. P. there were countless critics who first of all denied that tube-wells would succeed at all and later foretold loudly the early exhaustion of the underground supplies.

The fact is that in dealing with "unseen" hydraulic forces, exact formulæ cannot be applied and some degree of initial risk must inevitably be incurred if irrigation is to be advanced. One is reminded of the lines:—

"There's far more faith in honest doubt,
Believe me, than in half the creeds".

Let us pass on after quoting a remark by the chairman of the U. P. tube-well conference in 1934 when the expansion of the Ganges scheme had been discussed at great length—"Well, gentlemen, we have heard a lot about these tube-wells lately both for and against, let's sink them and see"!

(iii) *Post-war installations.*—An analysis of the cost of a vast hydel-operated tube-well system to cover 3,000 sq. miles of typical alluvial country irrigating 1 million acres of food-crops, indicates that now irrigation can be effected at a capital cost of Rs. 30 per acre and an operating cost of Rs. 3-8 per acre including (i) energy at 0.5 anna per K. W. H. (ii) depreciation @ 6 per cent. and (iii) establishment, repairs etc.

The scope for systematically exploiting India's alluvial ground-water by large scale tube-well installations is thus shown to be considerable.

12. *Power pumping from deep-set rivers.*—(a) *General considerations.*—Experience in river pumping on the Ganges grid has shown that water can be

economically lifted from deep-set rivers on to high bluffs commanding local areas by means of suitably aligned canals, provided that certain conditions are fulfilled. These include :—

- (i) That the lift does not in general exceed 50' [see 10 (i) (b)].
- (ii) The price of energy at 50 per cent. load factor, does not exceed a certain value—normally $\frac{1}{2}$ anna, at the pumps—for irrigating ordinary crops.
- (iii) The cost of the river control works (if any) and pumping station layout is not excessive in relation to the discharge pumped.

Broadly speaking, if the latter is small compared with the river flow no weir is required and a cheap layout results. Again, cheaper control can obviously be secured in the rocky ravines of the Deccan than in the broader alluvium of the Ganges plains. Instances are given in sub-para. (c) below.

(b) *Advantages of river pumping.*—(i) As in the case of tube-well irrigation [para. 10 (a) and (b) pp 8-9] greater flexibility can usually be secured by locating a series of pumping canals along a river system than is the case with a gravity canal where command of the water-shed can usually be obtained only by incurring heavy outlay on major works e.g. drainage crossings and (usually) a long unremunerative canal head reach. The cost of the power system (or part of it) and the capitalised generating charges (if thermal) must of course be off-set against any such saving in the headworks layout. In suitable alluvial areas it will sometimes be found cheaper to install tube-wells for direct irrigation than to pump water from large rivers. On the other hand, in peninsular India especially on rivers where the flow has been stabilised by hydel storage dams (see para. 8) pumping from the tail water (even on to areas with lifts up to 80') will often be found economic* especially for valuable crops e.g. sugarcane and vegetables.

(ii) Economy in time of construction, which is usually proportionate to the saving in outlay, is important especially in the case of short term projects, provided of course that an economic source of power (e.g. a local grid or an *ad hoc* 'pilot' thermal station) is available.

(iii) As in the case of tube-wells [10 (c) p. 9], the introduction of cheap power into a tract with pumping as a base-load opens up the district for minor and agricultural industries enabling, *inter alia*, the cultivator to process his own produce, thus improving the local agricultural economy.

(c) *Economic considerations.*—The relative economy of hydel operated pumping installations can best be illustrated by outlining typical instances on the U. P. grid.

(i) *Sumera.*—A flow of 100-140 cusecs is lifted 22' by 4—100 H. P. pumps from a local stream (Kali Nadi) into a small feeder (6 miles long) to supplement the Ganges Canal. The capital cost (1929) was Rs. 4,11,229 including a control weir 120' long and a pumping station, or Rs. 3,576 per cusec. The grid tariff in force is a fixed charge of Rs. 80/- per year per B. H. P. installed equivalent to 0.5 anna per unit on the average L. F. (34%) obtaining. The all-in cost per cusec day pumped is Rs. 3/6.

(ii) *Nadrai.*—A discharge of 50 cusecs (of regeneration flow into the Kali Nadi bed, 50 miles below Sumera) is lifted 32 feet into the lower Ganges canal by a (Sulzer) axial flow pump contained within an extended pier of the famous Nadrai aqueduct. The capital cost including a small pick-up weir was Rs. 1,64,123 or Rs. 3,282 per cusec of average discharge.

The grid tariff in force is 0.5 anna per unit. The all-in cost per cusec day pumped is Rs. 4.55.

(iii) *The Ramganga Scheme.*—The Ramganga river discharge usually decreases from 600 cusecs in November to 200 in April and 80/100 in June. Of this, 200 cusecs are lifted (by 4-50 cusec Sulzer vertical axial flow pumps installed in each of 2 pumping stations, 12' and 24' heads) into the main canal against a total head of 36 feet. The canal which commands 96,000 acres was designed to irrigate 34,000 acres in rabi and 8,200 acres of sugarcane. Whereas the cane area is attained yearly, owing to climatic reasons the maximum area yet realised in rabi has been only 23,000 acres. Power is supplied from the grid at 80 per B.H.P.-year on a maximum demand

* Please see Appendix D giving approximate cost of pumping by diesel engines from 30'—80' for each 10' lift.

of 1,000 K. W. The canal rates had to be pitched somewhat high *viz.* 7 per acre for wheat and 15 for sugarcane. The abstraction of the total (rabi) discharge necessitated an expensive weir with training works and several minor river crossings the outlay on which has reacted adversely on the economics of the scheme which is thus classed as a 'protective' rather than a 'productive' work. The all-in cost of pumping is Rs. 4/5 per cusec-day.

(iv) *The Fyzabad Pumping Canal.*—160 cusecs are pumped 35 feet from the Ghogra, a major river with a minimum flow of 6,000 cusecs, designed to irrigate 25,440 acres in rabi and 17,808 acres in kharif out of a commanded area of 101,761 acres. There are three Escher-Wyss axial flow pumps each of 360 H. P. Energy is taken from an adjacent (thermal) power station (2,500 K. W. output) which also supplies a small local grid. At an energy charge of 0.8 anna per unit generated the cost of pumping (including fixed charges on the cost of the pumping station) is Rs. 5/8 per cusec-day or Rs. 3 per acre of actual rabi irrigation (15,000 acres). This canal which was opened in 1938 has demonstrated the economic possibilities of power pumping even by thermal electricity.

(v) *Sultanpur pumping Canal project (U.P.).*—An important project is under preparation in the U. P. whereby 2,100 cusecs are to be pumped 40 feet from the Ghogra river at a point 7 miles below the Elgin bridge (see index map) for commanding 1.4 million acres of high fertile land between the Ghogra and Gumti rivers at present lacking systematic irrigation. The canal will irrigate about half a million acres yearly at a roughly estimated cost of Rs. 2.8 crores. Power to the extent of 8,400 KW will be derived either from the Sardah Canal falls (175 miles) or from a cheaper but more distant source, the SVA beyond Allahabad (250 miles). It is interesting to note that this project can command by pumping a tract that the so-called "Lower Sardah" Scheme of 1870 could not protect by gravity owing to the difficulty of conveying water from the Ghogra above its confluence with the Sardah. If Sone Valley power can be supplied at the Ghogra pumps at 0.33 anna per K.W.H. (at 50% LF), the cost of delivering water into the canal against 40' lift will be Rs. 2/13 per cusec-day or Rs. 2 per acre of rabi irrigated.

Various other major pumping projects are under consideration in the east U.P. whereby 1 million acres can be irrigated at economic rates yearly out of a total C.C.A. of 2.7 million acres. All these must await the development of an effectively cheap source of power which fact alone furnishes a strong reason for expediting the construction of the Rihand dam in the Sone Valley (S.V.A.).

13. (a) *Improved distribution of water and (b) Lining of Canals.*—Experience in the remodelling of many of the older canal systems, notably in the U. P. has shown that a large increase of 'duty' (acreage per cusec) can be attained by (i) improving the distribution of canal water and (ii) remodelling defective channels thereby enhancing their hydraulic efficiency. (i) comprises, *inter alia*, (a) the correct allocation of supplies at times of demand thereby reducing wastage of water in tracts that, owing to local rainfall, etc., cannot utilise such supplies efficiently and (b) improving outlet distribution and field 'rosters'.

(ii) comprises mainly the regrading of silted beds and adaptation of the widths accordingly. Recent research into the silting of channels (Mr. G. Lacey's researches into channel flow deserve mention) and the designs of silt extractors, non-silting heads etc., have contributed to these important improvements.

Whilst it is difficult to assess quantitatively the increased area thereby attained it can be said that an increase of 10 to 20 per cent. of existing acreage could be effected by such means on the older canal systems of India.

(b) The lining of canals with cheap materials is sometimes an important source of economy of water especially in sandy reaches. The capital cost of lining major canals and the larger branches is however usually too high in relation to the saving effected to justify the outlay. The lining of watercourses with cheap concrete—especially on tube-well systems where there is also scope for the use of pressure pipe-lines in undulating lands—can usually be justified in porous soils where demand is intense.

14. *Electric versus animal power for open well pumping.*—In any large scale plan for increasing India's production the possibility of improvements

in lifting water from open wells must play an important part in view of the immense* area which such wells serve. Moreover if water can be drawn from open wells by electricity a service will have been rendered to agriculture by releasing bullock power for more intensive ploughing and/or transport purposes in the additional area thus irrigated. Attempts to lift water by means of oil engines from open wells (and often, too, from tube-wells) have usually proved un-economic for small cultivators except for special crops. The incidence of the cost of oil, labour and depreciation on the price of the water pumped has generally proved too high and the difficulties of maintaining isolated oil engines too great. Widespread electric power if it can be established over an intensively cultivated tract may however prove an effective and economic solution.

The economics of open well pumping are affected by three main factors.

(a) *The yield* of the well which can often be increased by sinking pipes (and/or strainers) below the well to tap a more copious supply at a great depth. In general it is not economic to pump from a well yielding less than 2000 g.p.h.

(b) *Lift*.—If the lift, including "depression" during pumping, exceeds 60' to ground surface it is usually un-economic to pump for any but valuable crops such as potatoes and vegetables in suburban areas.

(c) *The cost of energy*.—It has been shown in the U.P. grid scheme and also in Madras and Mysore, that, with moderate depths, open well pumping by electricity is economic with current costing less than one anna per unit low tension at the pump. The problem, therefore, depends largely on whether energy can be delivered at this rate at thousands of small pumping stations scattered over the country-side. Much depends on the source of supply and the existence (or otherwise) of a number of larger and more paying load points on the system which would assist in justifying the introduction of power into a wide rural tract. In the Ganges grid area of U.P. for instance, there are a number of concentrated pumping loads (50-100 H.P.) and a far greater number of medium size tube-well stations (12 H.P.) to justify the transmission system apart from more than 100 urban sub-stations which assist in lowering the cost. In a system comprising some 3,000 miles of 11 K. V. rural lines already justified by the tube-well demand it is a comparatively easy matter to connect even two or three hundred scattered 5 H.P. open well pumps. At present day transmission costs, however, I cannot visualise any large new net-work of rural lines for open well pumping proving an economic proposition without the support of other loads of larger dimensions.

The importance of increasing open-well irrigation (and relieving bullock power) in rural areas is however so great, especially in tracts not irrigated by canals that every attempt should be made to reduce the cost of lifting water by (a) increasing the yield of wells and also (b) the systematic study of the economics of electric pumping. The Central Sub-soil Water Panel (C.S.W.P.) which is, I hope, now to be formed should be equipped with a special section for exploring such possibilities by means of (i) installing vertical pipes and strainers and/or (ii) inserting horizontal strainers in non-alluvial tracts, to intercept new sources of underground water.

At the same time research should be carried out for improving the mechanical means of lifting water wells. Centrifugal pumps with their high speeds and difficulties of procurement are not always an ideal solution. The indigenous 'harat' or persian wheel if it could be adapted for power drive would probably be more effective owing to its slower speed. My own primitive attempts to electrify persian wheels in the early days of the Ganges grid proved a failure but this was due more to lack of mechanical skill than to any inherent defect in the system.

The subject is of sufficient importance to an India about to be widely electrified to warrant a brief description of Mr. W. G. Came's ingenious (EMAC) device. I would refer my listeners to the outline sketch (on the blackboard) of a typical open well in Bihar. The yield of the well would of course first be reinforced by means of one or more strainer tubes tapping the lower aquifers in order to secure an enhanced supply commensurate with the outlay on the lifting device.

* Area irrigated by open wells—12½ million acres (*vide* Agricultural Statistics of India 1937-38 Vol. I).

I must first emphasise a difficult hydraulic characteristic being encountered in tube-well construction in Bihar and elsewhere. Due to high rainfall (and poor surface and sub-surface drainage) the water table in the alluvial tracts of Bihar has an exceptional range* of variation between the dry and wet seasons. Hence to secure the motor-pump from submergence during the monsoon when rice is often irrigated it is necessary either (a) to employ the vertical or 'borehole' type of pump installed at ground level—an expensive expedient—or (b) to construct a deep watertight sump (also a costly alternative) for locating the electric horizontal pump at a sufficiently low level to enable it to operate equally well under dry and wet weather conditions.

The usual conditions of irrigation operation in the dry and wet seasons in Bihar are as follows: In the dry season when the depth of the water table (including depression) is say, 28 ft., wheat and potatoes are the principal crops irrigated, the H.P. required to lift 33,000 G.P.H. against a total head of 28 feet with 65 to 70 % overall efficiency is 7.5. In the paddy season i.e. from July to October the rise in water table reduces the total lift from 28 to 14 ft. but the amount of water required for irrigation is roughly doubled. Mr. Came ingeniously uses this fortunate circumstance of 'double the water and half the lift' as the basis for his persian-wheel design. Briefly the machine comprises (a) an electric motor of 10 H.P. running at 1440 R.P.M. geared to (b) the horizontal shaft of the double persian-wheel which runs at 7-1/2 giving a bucket speed of 1.87 feet per second. The special feature of the design is its dual purpose operation. In the Rabi season when less water is available (and required) one of the (double) chains of buckets is dismantled. Each bucket (which is specially designed to give a stream-lined entry to the water in the well and has also an equally ingenious emptying device) has a capacity of one cft. thus giving a discharge of 33,000 gallons per hour or 1.5 cusecs. During the paddy season when the total lift is reduced to 14 ft. the second chain of buckets is installed on its pulley and operated at half the head giving double the discharge for the same horse power, thus meeting the increased requirements of the paddy crop. Like all big ideas this device appears extremely simple when once it has been evolved! The only non-indigenous working part is the gearbox which for the present at any rate will probably have to be made overseas. The motor which should preferably be of a low speed type can easily be made in India and so of course can be shafts and buckets. The EMAC machine is now being manufactured for extensive tests in Bihar.

The results of these tests must be awaited for a final opinion but *prima facie* the machine appears to meet Bihar's local hydraulic conditions admirably and I for one anticipate important results.

I am informed that in Madras electric pumping for irrigation is confined to small holdings having pumps from 3 to 20 H.P. The total number connected now exceeds 2,000, and the equivalent horse-power about 12,000. Pumping sets, when required, can be obtained on the hire purchase system and are the property of the cultivator. The rate of energy is 0.90 anna per unit. In Mysore a similar system prevails, but the rate is 0.50 anna per unit. Larger pumping units, also the property of the cultivator and averaging 50 H.P. per set, are used in Travancore, where the conditions differ. The rate is one anna per unit.

15. Zoning for hydro-electric power distribution.—It has been shown above (para. 8) that the storage of surplus monsoon water by means of the construction of large dams on our major rivers (especially in peninsular India) can attain the double object of (a) stabilising the seasonal river flow for establishing and/or increasing perennial canal irrigation and (b) cheap power development at suitable locations. Assuming that the power to be generated at such dam sites is effectively cheap, the question often arises in planning as to the maximum distance to which such power can be economically transmitted. Considerable confusion of thought is liable to occur on this point. Some enthusiastic amateurs have attempted to zone their provinces by dividing the map into distribution areas in relation only to their *proximity* to the various sources of hydro-electric power supply as if adjacency were

* As much as 26 feet in the Bihar-Sharif area!

the ruling economic factor. There is a tendency, I think, to attach too much weight to the proximity of the area of demand to the source of supply and too little to the cost of power per unit *at source*. Whereas proximity is often very attractive especially for the young and magnetic it does not always lead to economic results. To show how relatively unimportant the cost of transmission per unit is on a modern grid system at high load factors (L.F.'s), I have prepared a graph (on black board) showing the approximate relation of transmission cost per unit to load factor. The transmission cost; for a given load factor depend of course on the incidence of the annual 'fixed' charges *e.g.* (i) interest on capital (ii) depreciation on lines and transformers and (iii) maintenance charges. It will be seen from the graph how relatively cheaply energy can be carried to distant zones of demand even at present day costs. *Per contra*, on the generation side it can be shown that the difference in cost of power per unit (at the same load factor) generated at two sites, one a good site with a short high dam 200 miles away and the other an expensive but adjacent site (with a long low dam or a series of dams), usually exceeds the extra transmission cost per unit from the distant (but more economical) station.

The economic history of the Ganges grid system has already shown [*vide* para. 9 (b)] that by a judicious combination of pumping loads with other demands, both urban and agricultural, a widespread network can be efficiently loaded so as to secure the maximum benefit to the community as well as a substantial return on the outlay.

In zoning a province, therefore, a very careful appreciation of both generating and distribution costs is an essential preliminary.

16. **Anti-waterlogging measures for safeguarding "India's granary".**—One of the gravest engineering problem facing all-India to-day—and as the Punjab is India's granary I use the word 'all' advisedly—is now being examined by the irrigation engineers of the Punjab—notably by Mr. F. F. Haigh, Chief Engineer (North). A reference to the Punjab waterlogging problem is therefore relevant.

Waterlogging—and its associated evil 'thur' or soil alkalinity—is a phenomenon caused by various factors far too complex in their interaction to be analysed in a brief address on irrigation. Suffice it to say that due mainly to (a) the diversion of 24,000 cusecs (the aggregate flow of the canals in the Ravi-Jhelum tract alone) from the river bed to the uplands and (b) certain subtle and adverse characteristics of the local subsoil (which I shall refer to later), the ground water-table in this zone has risen steadily for the last 20 years and over a tract of many thousand square miles is now dangerously near (only 7' or so below) the surface! I am reliably informed that as a result some 50,000 acres are going directly out of cultivation and worse than that—due to alkalinity—the yield is declining seriously over a very much larger * area. Owing, however, to the increasing irrigated area commanded by *new* canals the dangerous extent of this deterioration was not fully realised for some time. No wonder that the Punjab authorities who have built up this vast canal system with such enterprise are now gravely alarmed.

To those of us who traverse the Punjab occasionally especially by air the surface evil appears more striking than it does perhaps to the local residents, as is the case when infrequent visits are paid to a slowly sickening patient.

I have referred publicly before to the contrast one experiences when flying from the disturbed air over the west U. P. tube-well area (water table—40') to the still air over central Punjab with its shining surface. Why this ominous stillness? Uplift in an aircraft depends largely on air density which at a constant height varies (apart from the effort of extraneous currents) with ground temperature. Thus when the latter is stabilized by large masses of adjacent water steady flight ensues as when flying over the sea.

* The yield of several hundred thousand acres is said to have fallen by 75% in the last 10—12 years.

Turning now to the cause of the waterlogging trouble it can be stated in general terms that the stability of the water-table is regulated by two main factors, (a) the rate of inflow into the subsoil, firstly by percolation from the vast volume of canal water referred to above and secondly but to a less degree, from absorbed rainfall and (b) the rate of outflow or subsurface drainage.

(a) The average rainfall in the western Punjab being 15" or only about half that in the west U. P. and the rate of evaporation being high, this component may for the moment be neglected in our diagnosis. Absorption of canal water occurs in 4 ways—

(i) from the main canals themselves comprising probably 50% of the total absorption.

(ii) from distribution comprising perhaps 20 per cent.

(iii) from watercourses say 5 to 10 per cent.

(iv) from field irrigation, etc., contributing the balance.

It has been recently computed that in the Ravi-Sutlej zone a volume of some 6,000 cusecs passes from the canal system as a whole through these various media into the subsoil reservoir for perhaps 270 days in the year equivalent to an annual increment of 140,000 million c.ft., a contribution of the first magnitude.

(b) Turning now to outflow *through* the subsoil, or what may be called underground drainage, it has already been shown that in the more fortunate terrain of the Ganges valley a continuous underground stream is seeping through the aquifers towards Bengal. As far as is known no underground impervious barrier exists to check this flow, at any rate between Ambala and Darjeeling. Hence the danger, if any, lies in the risk of *over-pumping* rather than of waterlogging by irrigation.

In the Punjab on the other hand nature has been more generous in her supplies of river water than in her provision for subsoil drainage. Apart from local patches of 'hard pan' which occasionally obstruct the vertical flow, geodetic surveys have disclosed the presence of an underground ridge of impervious rock known to scientists as a "crustal structure line" running roughly N. E. in continuation of the Aravallies (or Delhi ridge) south of Ambala and north westwards below Lahore to near Sargodha. There is another such ridge running roughly N. E. through Ambala to the hills. These 'warp lines' which have an important strategic bearing on the case are shown on the index map (No. 1). Acting like the watertight bulk-heads of a ship it seems probable that these ridges by preventing the flow of subsoil water towards the south contribute to the steady rise of the water table fed as it is by the lavish canal system to the north. This conclusion is corroborated by the evidence given before an Enquiry Committee over which I presided in 1939 at the instance of the Jodhpur Government to examine the possibility of installing tubewell irrigation in that State. The weight of scientific opinion was that the inflow of subsoil water from the Punjab underneath Bikaner into Jodhpur was cut off by the presence of this hidden ridge.

If this theory of waterlogging is to be accepted, as I think it must be, then the various solutions for saving the central Punjab from a major disaster are (a) to reduce the volume of irrigation water applied by the canals (b) to improve the *surface* drainage thereby preventing as much canal (and rain) water as possible from entering the subsoil reservoir (c) to line the main canals and branches in their more porous lengths in order to reduce absorption losses, and/or (d) to pump out of the subsoil reservoir by means of tubewells as large a proportion as possible of the water being contributed by canal absorption. The question is of such importance, both locally and for application elsewhere, that I propose to discuss these alternative measures at greater length.

(a) Is a negative solution which would obviously reduce proportionately the areas cropped; it would only be adopted therefore if all other methods fail. As a palliative, however, it is suggested that every possible economy in water distributions should meanwhile be exercised. The revision of water 'duties' by modulating might result in reduction of 'depths' (delta) in certain over-generously irrigated tracts.

(b) Surface drainage can be carried out in two ways (i) by digging *shallow* gravity drains leading into the rivers. Such drains are now being extended. They are however too shallow to have any great strategic effect and must be regarded as partially preventive, rather than curative. Moreover, the water thus drained away is lost to that particular canal system, (ii) by deep arterial drains graded from the low ground between the canal branches into deep sumps located along with canal banks from which the resulting flow would be lifted into the canals by large electric pumps (5 to 10 cusecs). Such a system of pumped drainage would obviously yield the double advantage (i) of covering a deeper and wider area thus being strategic in effect and (ii) enhancing the canal supply thereby largely replacing what has been lost by percolation and enabling the head discharge to be proportionately reduced and/or the area of irrigation to be extended. Pumping for drainage is now being extensively adopted in the Cambridge fens, in the Pontine marshes and in Egypt.

(c) Lining is highly expensive and if carried out on an extensive scale would involve digging duplicate canals as there would not be time to line an appreciable length of canal in each year's short closure. Further a great waste of land would be involved. Lining to a minor extent is now being carried out, however, in certain wasteful reaches.

(d) *By large scale subsoil pumping.*—The chief engineer proposes to sink a series of tube-wells along the canal banks in the worst reaches* each yielding 2 cusecs and operated by electric pumps. The water thus removed from the subsoil would be pumped into the canal. The actual spacing of the tube-wells along the banks, usually 5 per mile, will depend upon the estimated amount of water percolating out of the canal system in that particular reach. Assuming that the aggregate absorption losses in the canal systems of the Ravi-Jhelum tract are of the order of 6,000 cusecs, the proposal is to pump 68 per cent. of this volume out of the subsoil in the first stage of the scheme (i.e., 4,100 cusecs) by means of 2,050 2-cusec wells. By other ingenious methods, such as more scientific re-distribution, reduction of losses, etc., it is anticipated that an increase of 750,000 acres in the total cropped area will result from the combined river discharge *plus* the subsoil pumping system. Power to the extent of 22,000 K. W. for the operation of this scheme will be generated at a hydro-electric station to be located at Rasul on the upper Jhelum canal where a fall of 70/85 ft. is available between the upper and lower canal systems. High priorities are being given for procuring the necessary plant and it is anticipated that the whole installation including 2,050 tubewells will be completed within 3 years.

An alternative suggestion for dewaterlogging the tract in question is to adopt deep drains aligned between the various canals and graded so as to flow from the low ground across and against the transverse slope of the country towards the canals. The drainage water, thus intercepted, would be lifted by means of deep-set pumps located along the canal bank. This latter or 'area' treatment might well prove more effective than the former alternative, i.e., pumping from the subsoil along the canals thus confining the abstraction of water to *lines* instead of areas. It is suggested that *both* the systems should be tried simultaneously. As the construction is to extend over 3 or 4 annual stages, the scheme lends itself to progressive research into these important phenomena.

17. *Increasing cultivation by drainage.*—Another method that suggests itself during an all-India air tour for increasing eastern India's food cropped area—especially in the great plains of Assam and East Bengal where the pressure of population† on the available soil is very great—is by the partial drainage of the larger swamps. Obviously if water can be either drained or at any rate controlled to the extent necessary to enable (i) more rice to be sown and/or (ii) the growing rice to keep its head above water, much valuable land could be restored to cultivation. The problem can be tackled in two ways (a) tactically, by minor measures (to be briefly described) and (b) by long term or strategic schemes.

* i.e. where the water table is within 10' of ground surface. See red lines on map (on black board).

† 640 × 1½—800 Souls per mile.

(a) These comprise local village works such as, firstly, small field embankments (i) to check the onrush of the rising floods (ii) to retain water for irrigation of the adjacent lands; secondly, drains to enhance the rate of run-off after the monsoon and thus ensure the earlier growing of 'boro' paddy for the spring crop. These measures which are now being carried out on a tentative scale in both Bengal and Assam are capable of increasing the annual paddy yield by perhaps 100,000 tons but they hardly call for examination this evening by an august body of engineers. As I recently pointed out to the Governments concerned, however, they do require both systematic local planning and careful supervision if the results in rice are to be commensurate with the broadcasted outlay. A further local complication must be mentioned—the necessity for retaining a proportion of the swamps (i) for inter-village navigation (there are few roads) (ii) as fishery reserves. Let us pass now to (b), i.e., large scale or strategic (and more scientific) remedies for a desperate food situation. Are they practicable or not? To answer this question—or to attempt to do so—let us take a concrete example—the Surma Valley—part of which I have recently seen both from the air and the ground. The hydrological conditions in the Surma Valley, whilst generally typical of the problem, are so adverse that a solution, if practicable there, can, *a fortiori*, be applied almost anywhere else. The two principal hydraulic factors that determine drainage in a given tract are (i) inflow and (ii) outflow and it is the relationship between these that decides the degree of flooding. If, as will be seen to be the case, the inflow is large and the exit capacity is relatively small, ponding must occur until the relationship can be improved. (i) Inflow: A glance at the index map (on the blackboard) and the (approximate) rainfall incidence will indicate the magnitude of this factor. The Surma is fed from the north by the stupendous run-off from the Khasi Hills with an annual average fall ranging from 430 inches at Cheraponji (above Sylhet) to 90 in the Naga hills further east and 110 in the Lushai hills to the south. Not content with pouring in this volume from roughly 700 miles of hilly perimeter, nature deposits 150 inches on the 9,000 sq. miles of the Surma plain itself. I doubt if even the German 7th Army in the Falaise pocket was assailed by such a bombardment as this! Very approximately, taking the catchment areas from the map and averaging the rainfall as 150", the flood discharge might well be of the order of 500,000 cusecs! No wonder the Surma with its feeble slope of 1/10000 gave up the unequal contest and split into two main channels between Silchar and Bhairab Bazar. The interflow, or lack of flow, between these waterways seriously complicates the local problem.

(ii) *Outflow*.—The rate of outflow or discharge from any valley much inevitably depends upon two determinable factors, firstly the cross sectional area of the exit/river(s) and secondly the slope to the sea which fixes the velocity. A glance at the map will show that the Surma is by no means a 'free' stream, rather it takes but a poor place in the eastern river queue—the Meghna, the Bramhaputra and finally the Ganges delta. The fact that the average cold weather water surface at Sylhet bridge is only 40 ft. above sea level (the foundations actually go well below it), and the distance to the sea is 220 miles, indicates how terrific is the task of improving the outflow. To remodel by dredging the Meghna-Bramhaputra system with its high silt content is in my opinion a measure beyond Indian experience and to obtain advice on such a problem I have suggested that the Assam Government should invite Mr. Savage (the well known reclamation engineer from U. S. A.) to visit the valleys by air and then recommend a drainage expert of international reputation. In the meantime various palliative but long term steps can be taken—and I recommend these—such as the prevention, or at any rate the control, of 'jhooming' in the adjacent forest hills.

To sum up, in my view—but I am not a drainage expert—there seems to be no real strategic salvation for these deltaic regions—they are unlucky: in R. A. F. language the Surma Valley "has had it"!

Now all this must strike you as a negative—almost defeatist—attitude. As constructive engineers can we not bring some scientific remedy—even if it is only in the nature of a local manipulative operation—to the relief of these mortal cases? It has been briefly shown that nature in her most violent mood has assailed Assam with an unparalleled run-off thereby causing these adverse hydraulic conditions. I have recently suggested to the Assam Government that this very phenomenon

should be utilised to supply cheap power for dewatering some of the marginal zones of the great 'haors' by hydel-operated pumps. Whereas admitting that the main river drainage cannot be strategically improved appreciable areas of gently sloping ground along with northern perimeter of some of the larger lakes can, I believe, be drained and the water lifted therefrom on to the terraces towards the hills to the north (and south) thereby achieving the double objective of draining low land for cultivation and irrigating adjacent high fields at present lying fallow for lack of water.

This is not an occasion to discuss details but in an appendix (E) to this address it is (very) approximately computed that for a capital expenditure of perhaps Rs. 100 per acre and a recurring cost of Rs. 12 per acre appreciable areas of paddy land can thus be reclaimed in certain perimeter zones. This assumes that hydel power can eventually be broadcasted from the Cherapunji (or other adjacent) falls at a local cost, low tension, of 3/4 anna per unit.*

Perhaps this idea of dual-purpose pumping strikes you as fantastic. I understand that in the coastal belt of Travancore—that enlightened State—where the human pressure on the soil is even greater than in the Surma Valley, land is being simply dewatered by oil-engine-pumps at a commercial rate. If hydel current can be substituted for Diesel engines—and the benefits of adjacent irrigation added—surely the cost per acre can be brought within the range of commercial possibility in Assam—as long as *scarcity prevails*. At any rate there is, I feel, a *prima facie* case for a fairly large experiment operated initially with thermal electric power in the form of temporary (or 'pilot') stations. Before we leave the subject of drainage I would mention the latent possibilities that exist in Western Bihar for cheap hydel pumping as a means of increasing paddy cultivation. The Sone Valley (S. V. A.) has already been referred to (para. 9) as a regional source of cheap power. Within its economic transmission range lie vast areas that are (and must continue to be) submerged by the Ganges which backs up the local streams in time of flood. The problem here is easier, as with the lower rainfall (40") and increased ground slopes, the volume to be pumped and therefore cost per acre is less. I would respectfully recommend to the authorities concerned that, assuming the 'Broadcast' cost of S. V. A. energy to be 1/2 anna per unit in the field, an experimental project be prepared for dual-purpose pumping in the riverain rice tracts south-east of Patna where it is believed that much benefit can thereby be rendered to an over-burdened soil.

18. Soil conservation measures.—In the course of a talk on post-war irrigation planning, a brief reference to measures required for restricting erosion and its reaction on the regime of rivers is not out of place. Anyone who has seen, especially from the air, hundreds of miles of the Siwaliks in northern India being carved into deep ravines by the rapid run-off of intense annual rain-fall (40 to 100 inches) will appreciate the importance of this subject. For it is not only the direct loss of valuable forest soil that is going on year by year but, even more important, the subtle deterioration of the river systems in the plains below in regard to (a) the reduction in their cold weather surface flow (b) the diminution of the subsoil seepage and (c) the interference with their navigation regime. I ask you first to accompany me on a rather 'bumpy' flight of the imagination from Delhi to Hardwar, over the west Hindan tube-well† area where 85,000 acres of food crops waist high now grow on lands which less than ten years ago were mere sandy wastes. The subsoil water supplies for these wells are derived largely by seepage from the sub-montane zones to the north. The water-table, at places already 40' deep, is slowly sinking as a result of the intense demand for tube-well water which has already exceeded by 10% per cent. of the estimated draw-off.‡ Any interference with the sources of subsoil supply must therefore inevitably react on the ultimate economy of the tube-wells themselves. Similarly, further west in the Punjab we shall see on our return journey the increasing lengths

*In the rural areas covered by the U. P. Ganges grid scheme a lower rate than this (80 per H. P. year) has been commercially achieved for pumping.

†170 tube-wells were installed in the sandy tract between the Ganges and the Jumna Canals in 1935-37 which now irrigate 85,000 acres yearly.

‡Tube-well pumping was estimated to operate at the rate of one cusec per sq. mile of commanded area for 3000 hours in the year. Actually the period has averaged 6500 hours yearly in this tract.

of the bullock-well ramps necessitated by the gradually falling water-table, particularly in the Jullundur-Hoshiarpur districts. I need hardly emphasise further these resulting phenomena ; let us rather discuss some possible causes and remedies. During a recent flight along the foot of the hills with the Secretaries of the Labour and Planning Departments, we noticed the interesting phenomenon that, not only are the intervals between the streams closely correlated to the degree of erosion in the hills above but so also are the sizes of the 'deltas' of the Sewalik torrents. In fact, at points where the hills were capped by cloud, one could judge the degree of hill de-forestation by the areas of the sandy deltas that projected like sterile tongues into the plain below. One may recall Swinburne's lines :

“ Till the slow sea rise and the sheer cliff crumble,
Till terrace and meadow the deep gulfs drink,
Till the strength of the waves of the high tides humble
The fields that lessen, the rocks that shrink ”.

We noticed when flying above Hoshiarpur recently a striking example of an effective anti-erosion treatment. In the forest hills there was a green oasis a few miles long to which the response in the plain below was instant. Instead of the long brown 'deltas' visible elsewhere, the wedge of alluvium had already withdrawn towards the mouth where a little blue ribbon meandered from the ravine into the sand. Another colour contrast—the more 'green' above, the less 'brown' below. Here surely lay a solution of one of India's greatest problems. In a few years, we were told, forest erosion has been checked by the exercise of strict control on the following lines : (a) stoppage under strict penalties of grazing and the substitution of stall feeding, (b) cutting of 'bhaber' grass by villagers after it has flowered, (c) construction of thousands of tiny 'check-dams' in the ravines to conserve the monsoon flow, reduce the local erosion and cause the accumulation of absorbent sand, which, acting like a sponge, feeds the sources of the sub-montane springs. The initial capital cost of these measures amounts roughly to Rs. 8 per acre or Rs. 5,000 per sq. mile of country treated. The measures are it is believed almost self-supporting as the resulting additional fodder and grass for paper will give more profit to the countryside. I would strongly recommend that, in the interest of land conservation and irrigation strategy, such measures be vigorously expanded throughout the whole length of the Punjab Siwaliks and be adopted by adjoining administrations.

Whilst it is realised that such measures are necessarily but long term remedies for a deteriorated water-table situation in the plains below, and also in regard to their effect on river regime, it is recommended that, in the meantime, various palliative steps of a more immediate nature be taken. These include, *inter alia*, the prevention of 'jhooming' which is being extensively carried out in certain provinces for creating new cultivation at the expense of afforestation, in Assam for instance. It strikes an observer, especially from the air, as doubly incongruous that the smoke of burning forests should be intermingled with the spray of torrents tearing from the hills.

19. Administrative aspects.—After suggesting the tactical lines on which this campaign be fought I must allude to the question of staff-work. Technically I have no doubt whatever as to the capacity of our Indian engineers to take their full share of the burden. To take a local instance, how could I think otherwise of those capable young men, who trained and ably guided as they were by a mere trio of more senior British engineers, bore the heat and burden of the Ganges grid campaign for 14 years in the U. P. ? In passing, I would like to pay a tribute not only to those young engineers but also to their trainers and in particular to the late Mr. Walton to whose capacity and unswerving devotion the Ganges grid so largely owes its success. It is no exaggeration to say that Eric Walton, who was all along suffering from a mortal disease, gave his life in furtherance of this pioneer work. I always salute his photograph in spirit when entering the control room at Roorkee. His influence still inspires the staff he trained.

In regard to advance design, modern hydro-electricity—especially grid transmission—has recently developed at such a rate that advice must in my opinion be obtained for some time from western countries until our own engineers can be adequately trained. The Government of India have wisely decided to form immediately a Central Technical Power Board which will assist those provinces and States who may require advice in drafting their plans and in the coordination thereof with other administrations. For the detailed planning and execution of electricity schemes must inevitably devolve mainly on the permanent staff of the administrations concerned suitably supplemented as necessary. The larger Provinces and States, *e.g.*, Madras, U. P., Punjab, Mysore, Travancore, etc., have already carried out major undertakings and will probably merely require consulting assistance in certain special aspects such as high dams, E. H. T. networks, switchgear design, etc. The Central Board will moreover be useful to *all* Provinces and States in matters of regional liaison especially in regard to schemes deriving power from border rivers such as the Sone, Jumna, Cauvery, etc. If I may offer a word of advice to provincial administrations, I would suggest that wherever the construction of large schemes involving the development of power and irrigation on one or more rivers is contemplated, a joint irrigation and power Board should be formed at an early date for co-ordinating these vital activities in the best interest of provincial development. It has already been shown for instance that storage for stabilising the flow on a river not only vitally affects (a) the amount of direct irrigation on the canals and (b) the operation of hydro-electric power plants on the river and/or canals but also (c) the utilisation of the power for pumping from (i) the sub-soil and/or (ii) the enhanced river supplies resulting from the storage. The U. P. Government have, I believe, recently decided that these vital interests can be most effectively co-ordinated by the constitution of such a technical Board on which the senior engineers of irrigation and electricity as well as agricultural experts will serve. I would make bold to recommend consideration of this principle to other administrations when planning their post-war developments. Such boards which can later be linked with those of other provinces across the rivers might well form the nucleus of the electrical federation of India which is bound to follow.

Technical Training. A review of power and irrigation possibilities, however inadequate, would be incomplete, without a brief reference to the advisability—in my opinion the immediate necessity—of founding one (or preferably three) first class all-India engineering training institutions. I can assure the Governments concerned that if even a third of the projects recently reviewed by the Power Conference in Calcutta, are to be efficiently carried out in the near future, as they must be if India is to survive, a very large and early increase in the provincial (and States) engineering cadres will be imperative. It has been my experience—and it is not a short one—that as far as possible the civil and electrical engineers who are to execute these combined works should ideally be trained together. I visualise therefore as part of the 'Himalayan dream' the immediate organization of at least one combined College furnished with the most modern laboratory and workshop equipment and staffed in the higher ranks with professors of international reputation. The stinting of salaries of such key staff would surely be the most sterile form of 'economy'. I have recently submitted a note on this subject suggesting that as a start a federal college of this type be located forthwith at Roorkee. Having been associated with the Thomason College and its engineers in various capacities throughout my official service of 37 years I can testify to its suitability as a venue for such an institution. The old spirit of co-operation and service still actuates its engineers wherever they may be and a great tradition abides in its spacious buildings. Whenever in a tight corner I used to ask for Roorkee men and it is a pleasure to see many of my "old guard" here to-night. I have reason to believe that the administrations of the northern provinces would support such a proposal which I earnestly request may be examined forthwith. Finally have you noticed, Sir, that the word 'hydel' (now in the Oxford dictionary) has no hyphen? Its evolution is interesting, it is also 'symbolic'. When we first took up hydro-electricity in the U. P. in 1928 it was expressed by two hyphenated words each connecting a separate—if linked—idea. Gradually we all got together on the rope and within two years the hyphen disappeared and efforts were blended into one

strong pull to drag the cultivator with the aid of electricity a little further from the economic abyss. May that spirit long continue to actuate the staffs of India. Adapting Tennyson's lines :—

“ Let knowledge grow from more to more
 But more cooperation dwell,
 That east and west according well
 May make one music as before.”

20. Plea for early action.—A study of the history of human effort would I think disclose that more opportunities have been lost through inaction than through taking some action even if it is not necessarily the ideal one. Two instances of indecision may be quoted :—(i) At the Suvla Bay landing in Gallipoli in August 1915 after effecting a complete tactical surprise a certain commander hesitated on the beach for 12 hours whilst a unique opportunity to capture, unopposed, a vital ridge slipped away—an act of indecision which contributed largely to the failure of the campaign. (ii) The simple but all too familiar modern case of an air pilot coming in to land when his engine ‘cuts’ at 200 feet, a quarter of a mile short of the boundary. Instead of instantly putting his nose down to the gliding angle and ‘landing short’ how often has a fatal hesitation seized the pilot who ‘holds off’ stalls, spins and crashes?

Similarly how many opportunities for helping India in the past 20 years have been allowed to pass through endless debates and departmental indecision? The famous Meares-Barlow hydro-electric review of 1918-19 was allowed to ‘stall’ unfinished; the Inspector-General of Irrigation was removed and many great projects that could have been co-ordinated by central effort have wilted away.

“And thus the native hue of resolution
 Is sicklied o'er with the pale cast of thought
 And enterprises of great pith and moment
 With this regard their currents turn awry
 And lose the name of *action*”.

One cannot but feel that had Hamlet lived with us in these ‘Committee’ days he might well have been awarded the freedom of the Secretariat perhaps even with oak leaves!

But now the rustle of a new resolution is stirring the still air and we can hope that formulae and files will at last emerge into fruitful facts; that the welfare of the farmyard will supersede the sanctity of the yardstick.

In regard to our own particular subject, the food target has been indicated as well as some of the methods by which our aim can be achieved. Remember that these short term solutions have already succeeded in principle notably in U. P. and Madras and are now again being put into effect in U. P. and elsewhere. It is only a matter of degree as to the extent to which they can be expanded both there and in other parts of India where similar hydrological conditions prevail. ‘it can be done’ is the hydel motto; may we not then proceed to constructive action without further ado?

APPENDIX A

*Summary of Specifications for various types of transmission lines in the Ganges Grid U. P.***66 K. V. Lines.**

66 Kilo volts overhead transmission line, 3 phase, 50 cycles, consisting of 0.06 square inch (7/115") Cadmium Copper Conductors and one 7/12 S. W. G. earth wire, supported on steel towers, 55'-10" high, 8 per mile, complete with suspension insulators (6 discs per string) galvanised earth plates and all fittings and foundations.....Rs. 7,300 per mile.

37.5 K. V. Lines.

37.5 Kilo volts overhead transmission line, 3 phase, 50 cycles, consisting of 7/104" Copper Conductors and one 7/14 S. W. G. earth wire, supported on tubular steel poles, 40' long, 7 1/2" x 6 1/2" x 5 1/2" dia. fitted with C. I. finals, 18" square buckled steel base plate, 12 to the mile, 'U' shaped cross arms complete with ohio brass pin insulators, earth plates, all fittings and foundations and painted.....Rs. 4,000 per mile.

11 K. V. Lines.

11 Kilo volts overhead transmission line, 3 phase, 50 cycles, consisting of 0.03 square inch (7/074") Stranded H. D. B. Copper Conductors one 7/16 S. W. G. earth wire supported on 90 lbs. rails 36' long, 4" x 3" x 4'-6" long salwood cross arms, 14 poles to the mile, complete with pin insulators, earth plates, all fittings and 1'-6" x 1'-6" x 6" Cement Concrete foundations.....Rs. 2,500 per mile.

11 K. V. (Rural) Lines.

11 Kilo volts, overhead transmission, 3 phase, 50 cycles consisting of No. 8 H. D. B. Copper Conductor, one 7/16 S. W. G. earth wire, supported on 90 lbs. rails or salwood poles, 36' long, 4" x 3" x 4'-6" long salwood cross arms, 16 poles to a mile complete with pin insulators earth plates and all fittings.....Rs. 1,500 per mile.

APPENDIX B
The Ganges canal hydro-electric scheme
Comparative financial schedule
 (Figures in lakhs of Rupees)

Years	Capital outlay to end of the year		Gross Revenue (including unrealised assessment)		Working expenditure		Depreciation		Net Revenue		Interest on Capital		Net Profit		Percentage of net revenue to capital	
	Project Figure	Actual	Project Figure	Actual	Project Figure	Actual	Project Figure	Actual	Project Figure	Actual	Project Figure	Actual	Project Figure	Actual	P. F. Col. 10	Actual Col. 11
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1934-35 . . .	185.14	178.44	19.14	15.64	5.21	5.72	4.10	3.95	9.83	5.97	10.08	8.27	-0.25	-2.30	5.30	3.84
1935-36 . . .	232.60	227.10	24.16	18.50	5.36	4.44	4.11	4.08	14.69	9.98	12.35	8.93	2.34	1.05	6.30	4.40
1936-37 . . .	292.43	310.52	29.53	20.56	7.44	5.19	4.12	4.02	17.97	11.35	14.51	10.64	3.46	0.71	6.2	3.7
1937-38 . . .	331.84	344.48	35.28	28.78	10.13	5.97	4.53	4.46	20.62	18.35	15.57	12.47	5.05	5.88	6.2	5.3
1938-39 . . .	334.90	352.05	39.60	42.61	19.98	9.59	5.83	5.71	22.79	27.31	15.79	13.41	7.00	13.90	6.8	7.8
1939-40 . . .	337.31	360.64	43.71	38.04	11.25	9.87	7.96	7.98	24.50	20.19	15.84	13.74	8.66	6.45	7.3	5.6
1940-41 . . .	337.31	365.81	44.29	46.96	11.25	11.70	9.00	9.72	24.04	25.53	15.84	14.00	8.20	11.53	7.1	6.98
1941-42 . . .	337.31	373.99	44.65	46.56	11.25	13.21	9.24	6.40	24.16	26.98	15.84	14.24	8.32	12.74	7.2	7.21
1942-43 . . .	337.31	377.60	45.02	47.49	11.25	12.93	9.29	6.64	24.48	27.92	15.84	14.45	8.64	13.47	7.3	7.39
1943-44 . . .	337.31	382.90	45.02	52.95	11.25	14.40	9.29	7.55	24.48	31.00	15.84	14.63	8.64	16.37	7.3	8.02

APPENDIX C

Development of Irrigation on U. P. Tube-wells

Year	No. of Tube-wells in operation	Acreage kharif	Acreage Rabi	Rainfall inches
1	2	3	4	5
1932-33	30	Not available	Not available	Not available
1933-34	80	Do.	Do.	41
1934-35	200	Small	40,000 (200)	27
1935-36	400	50,000	120,000 (300)	51
1936-37	900	80,000	130,000 (144)	56
1937-38	1,350	135,000	270,000 (200)	19
1938-39	1,400	150,000	430,000 (307)	17
1939-40	1,450	200,000	430,000 (296)	27
1940-41	1,520	220,000	480,000 (316)	26.5
1941-42	1,700	230,000	550,000 (324)	19
1942-43	1,700	200,000	440,000 (280)	Not given.

NOTES.—(a) Figures in brackets in column 4 indicate rabi area per well.

(b) The acreages in columns 3 and 4 are approximate only taken from a graph.

(c) The number of wells in operation (Column 2) includes those wells just completed at the commencement of a particular year. It will be realized that in 1936-37, 1937-38 and 1938-39, the proportion of brand new wells in each year was high. Hence the facilities for irrigation were not fully developed.

The average sale rate for wheat during the period was Rs. 3 per maund in the market and considerably less in the field.

Sugarcane was a rival crop during the years in question and thus detracted from the rabi value of the tubewells.

APPENDIX D

RIVER PUMPING SCHEMES FOR IRRIGATION

Statement showing the approximate "varying" and "fixed" charges per acre-inch at canal head with Oil engine driven pumps

Sl. No.	Discharge in cusecs	Head			H. P. absorbed (pump efficiency 75%)	H. P. absorbed 7½% drive losses Col. (6) + 7½%	Site rating allowing 20% for altitude, temperature and humidity at pumping site Col. (7) + 20%	Fuel oil at ½ lb. per hour on Col. (7)	Fuel oil cost per hour at Rs. 150 per ton Rs.	Fuel oil cost per acre-inch Col. (10). Col. (2) Rs.	Lubricating oil cost per inch 10% of Col. (11) Rs.	Total varying charges per acre-inch Col. (11) + Col. (12). Rs.	"Fixed" charges per acre-inch from page 27 Col. (15) Rs.	Total cost at canal head per acre-inch - Col. (14) + Col. (15) Rs.
		Static ft.	Friction maximum 10% of Col. (3) ft.	Total ft.										
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
<i>5 Cusec Pumping Sets</i>														
1	5	30	3	33	25	27	32	13.5	0.90	0.18	0.02	0.20	0.29	0.49
2	5	40	4	44	33	36	43	18	1.21	0.24	0.02	0.26	0.32	0.58
3	5	50	5	55	42	45	54	22.5	1.51	0.30	0.03	0.33	0.37	0.70
4	5	60	6	66	50	54	65	27	1.81	0.36	0.04	0.40	0.41	0.81
5	5	70	7	77	53	62	74	31	2.08	0.42	0.04	0.46	0.42	0.88
6	5	80	8	88	67	72	86	36	2.41	0.48	0.05	0.53	0.49	1.02
<i>10 Cusec Pumping Sets</i>														
1	10	30	3	33	50	54	65	27	1.81	0.18	0.02	0.20	0.22	0.42
2	10	40	4	44	67	72	86	36	2.41	0.24	0.02	0.26	0.26	0.52
3	10	50	5	55	83	89	107	44.5	3.00	0.30	0.03	0.33	0.26	0.59
4	10	60	6	66	100	108	130	54	3.62	0.36	0.04	0.40	0.31	0.71
5	10	70	7	77	116	125	150	62.5	4.18	0.42	0.04	0.46	0.35	0.81
6	10	80	8	88	133	143	171	71.5	4.78	0.48	0.05	0.53	0.36	0.89

RIVER PUMPING SCHEMES FOR IRRIGATION

Statement showing the approximate capital cost of plant, "fixed" annual charges, and "fixed" charges per acre-inch (at canal head) with oil engine driven pumps

Serial No.	Discharge in Cusecs	Site H. P. of oil-engine.	Capital cost							Interest on capital at 4% of Col. (10)	Depreciation.			Establishment charges per year.†	Total "fixed" charges per year	Total acre-inches pumped for the whole year assuming 18 hours pumping per day for 200 days in a year = 3570 × Q (Col. 2).	"Fixed" charges per acre inch Col. (16) (17)
			Oil engine + 10% for cost of spares and carriage	Pump + 10% for spares and carriage.	Cooling tanks and belt drive or rope drive	Bends and valves & C. I. suction pipe	R. C. Hume pipe rising-main including carriage	Foundation and shed & cost of installation	Total		At 8% of Cols. (4), (5) & (6).	At 5% of Cols. (7), (8) & (9).	Repairs at 3% of Col. (10)				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
			Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
						(12" C. I. pipes on suction side for 5 cusec pumps)	(15" Hume pipes for 5 cusec pumps. Cost varying with head)	5 Cusec	pumping sets								
1	5	32	8,500	3,300	2,500	2,000	1,000	2,000	10,300	772	1,144	250	570	2,400	5,145	17,850	0.29
2	5	43	11,000	3,300	3,000	2,200	1,200	2,250	22,050	918	1,884	282	688	2,400	5,072	17,850	0.28
3	5	54	10,000	3,300	3,500	2,400	1,400	2,500	25,100	1,164	1,824	315	873	2,400	6,576	17,850	0.37
4	5	65	20,000	3,300	1,800*	2,000	1,600	2,750	32,050	1,232	2,008	347	961	2,700	7,298	17,850	0.41
5	5	74	20,000	3,300	2,000*	2,800	1,800	3,000	32,900	1,316	2,024	380	987	2,700	7,407	17,850	0.42
6	5	86	28,000	3,300	2,300*	3,000	2,000	3,500	42,100	1,684	2,688	425	1,263	2,700	8,760	17,850	0.49
						(15" C. I. pipes on suction side for 10 cusec pumps)	(18" Hume pipes for 10 cusec pumps. Cost varying with head)	10 Cusec	pumping sets								
1	10	65	20,000	4,500	1,800*	4,500	1,500	3,000	35,300	1,412	2,104	450	1,059	2,700	7,725	35,700	0.22
2	10	88	28,000	4,500	2,300*	4,000	1,800	3,500	45,000	1,800	2,784	510	1,350	2,700	9,144	35,700	0.26
3	10	107	28,000	4,500	2,500*	5,300	2,100	4,000	46,400	1,856	2,800	570	1,392	2,700	9,318	35,700	0.26
4	10	130	30,000	4,500	3,000*	5,700	2,400	4,500	50,100	2,244	3,480	630	1,683	3,000	11,037	35,700	0.31
5	10	150	44,000	4,500	3,500*	6,100	2,700	5,000	65,800	2,632	4,160	690	1,974	3,000	12,456	35,700	0.35
6	10	171	44,000	4,500	3,500*	6,500	3,000	6,000	67,500	2,700	4,160	775	2,025	3,000	12,660	35,700	0.36

* Cost of water pump, for circulating water is included in the cost of oil-engine given in col. (4).

† Establishment charges are based on—

(a) Two oil engine drivers at Rs. 60 p. m.

(b) Two cleaners at Rs. 20 p. m.

Supervision charges at 25 per cent

(Say from Rs. 200 per month to Rs. 250 per month).

‡ Total pumping days 100 for Rabi and 100 for Kharif

Let Q be the pump discharge in cusecs.

Assuming 18 hours pumping per day for 200 days total quantity pumped = 200 × 18 × 60 × 60 × Q. C. R.

Therefore equivalent acre-inches pumped =

$$200 \times 18 \times 60 \times 60 \times Q \times 12$$

$$= 3570 \times Q.$$

43560

APPENDIX E

Schedule of approximate cost for drainage of flooded areas

Assume that during the early growth of paddy it is necessary to lower the water depth in a locality by pumping to 1' within 7 days with an average daily rainfall of, say, 1".

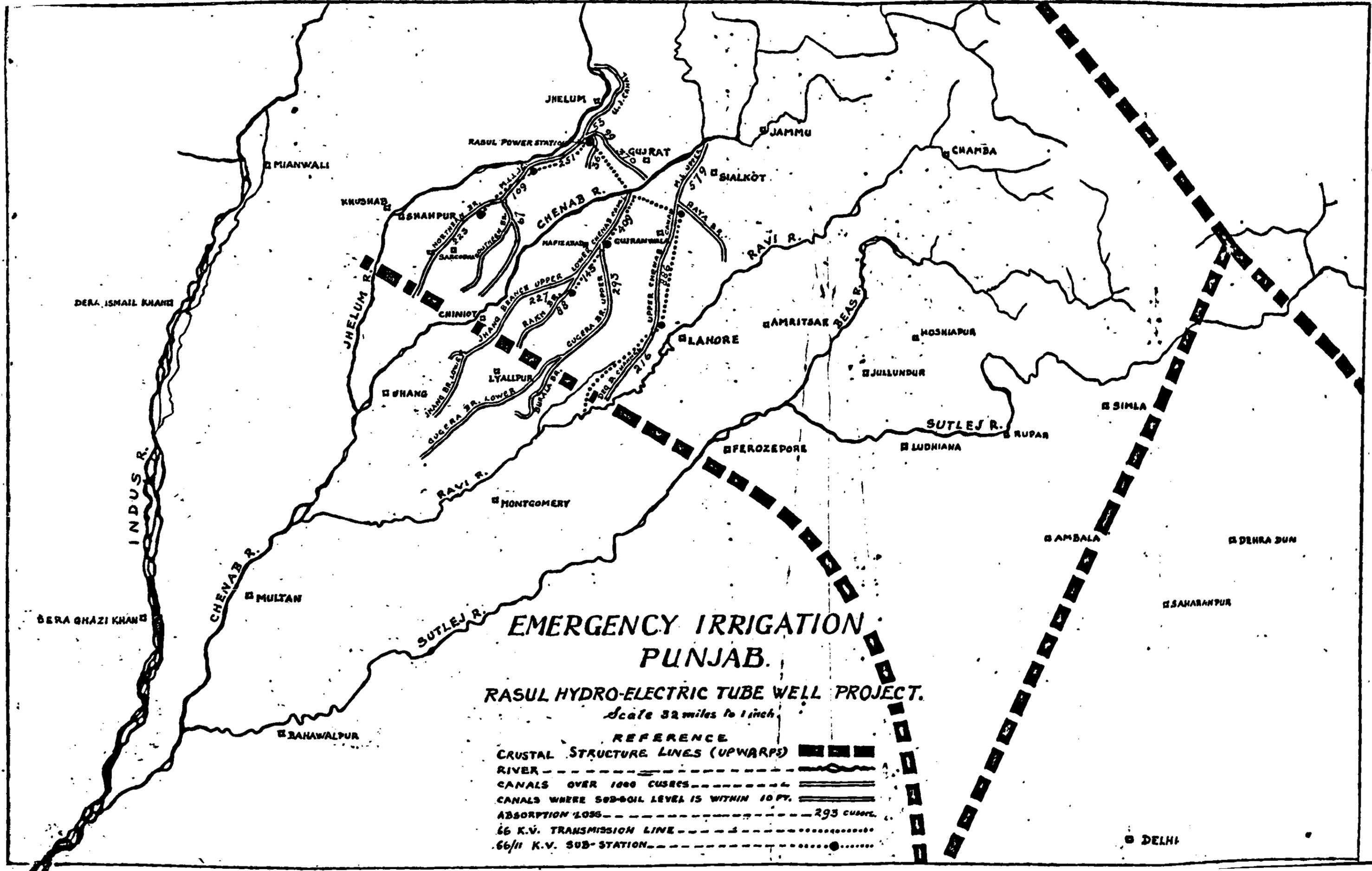
The total volume to be pumped per 5 acre plot is $5 \times 43560 \times 2.6$ plus, say 20% for leakage through the marginal bunds or 6,80,000 cft. Assuming (i) the lift on to adjacent high ground as 5 feet plus loss in friction and channels or, say 7 ft. and (ii) the overall efficiency of the motor pump at 60%, the number of units required is

$$\frac{680000 \times 62.5 \times 7 \times 0.746 \times 100}{33000 \times 60 \times 60} = 187 \text{ K.W.H.}$$

Assuming that hydel energy is available locally at 0.75 anna per unit the cost in current alone of dewatering 5 acres is Rs. 8.8 or roughly 2 per acre.

The size of motor required for a 5 acre plot is $\frac{187}{0.746 \times 7 \times 24} = 1.5 \text{ H.P.}$, which is too small for practical purposes. If four such 5 acre plots are dewatered as a unit by one pump, a 7.5 H.P. set would be employed. The cost of a portable 7.5 H.P. motor-pump with flexible pipe and fittings may be taken as Rs. 1,500 or Rs. 375 per 5 acre plot.

The cost of 2520 feet of the earthen perimeter bund (of, say 20 sq. feet average section) required to enclose four 5 acre plots is Rs. 400 or Rs. 100 per plot. The total capital cost for motor-pumps and earthen bunds for each 5 acre plot is therefore Rs. 475 or, say, Rs. 100 per acre plot. Allowing nominal interest (3%) and depreciation charges (7%) the annual fixed cost of dewatering 5 acres may be of the order of Rs. 48 or Rs. 10 per acre; or adding 2 for energy 12 per acre. The same water will irrigate 15 acres of paddy to a depth of 1 foot.

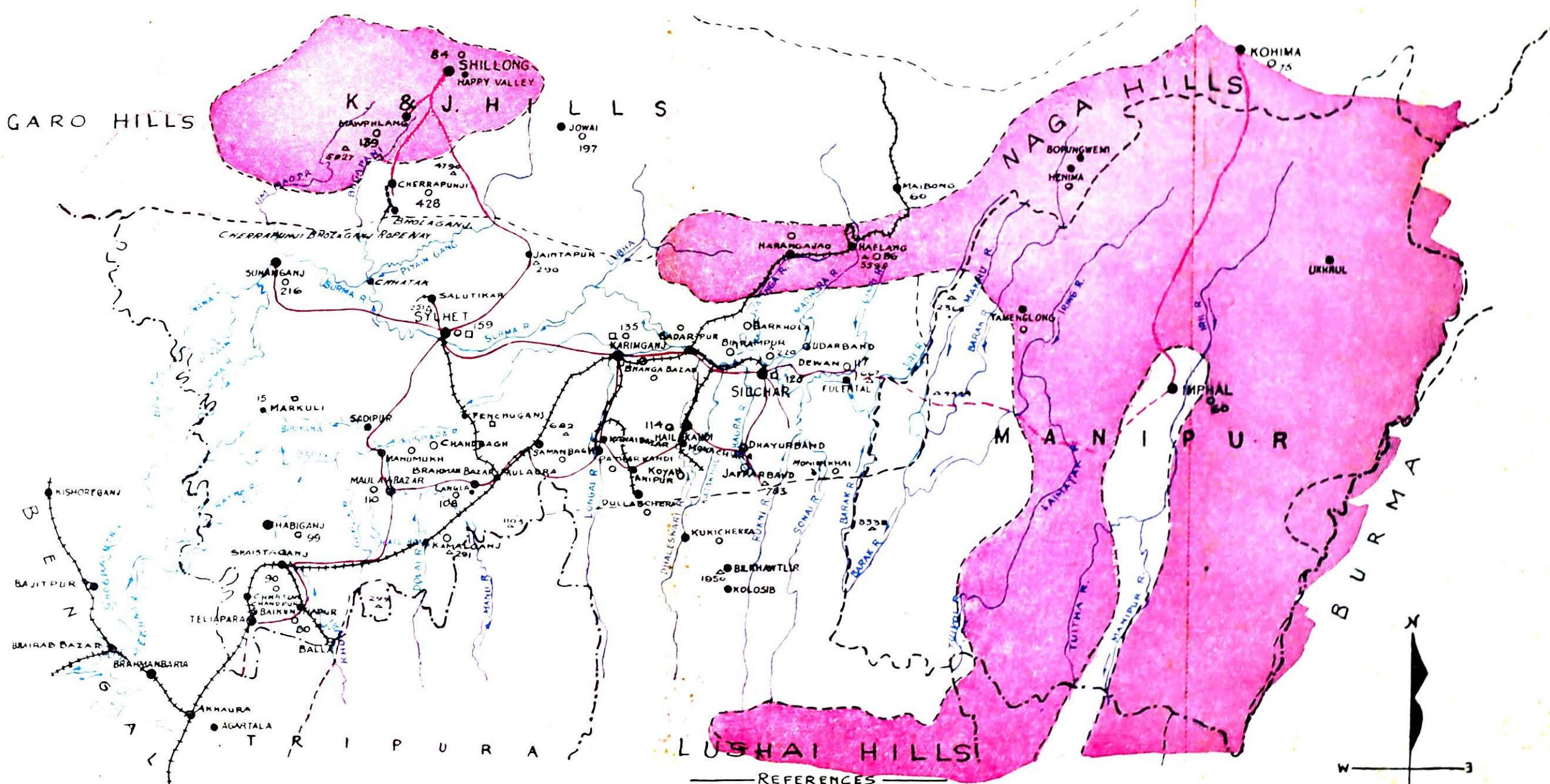


EMERGENCY IRRIGATION PUNJAB.

RASUL HYDRO-ELECTRIC TUBE WELL PROJECT.
Scale 32 miles to 1 inch

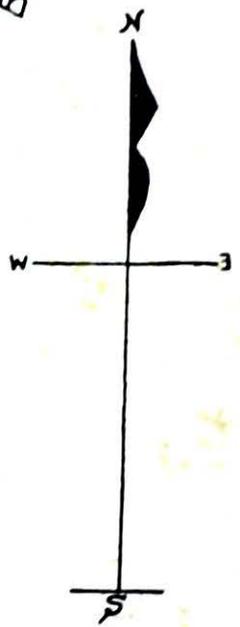
- REFERENCE
- CRUSTAL STRUCTURE LINES (UPWARPS)
 - RIVER
 - CANALS OVER 1000 CUSECS
 - CANALS WHERE SUB-SOIL LEVEL IS WITHIN 10 FT.
 - ABSORPTION LOSS 293 CUSECS.
 - 66 K.V. TRANSMISSION LINE
 - 66/11 K.V. SUB-STATION

INDEX MAP
OF
SURMA VALLEY
SCALE - 1.014 INCHES = 16 MILES



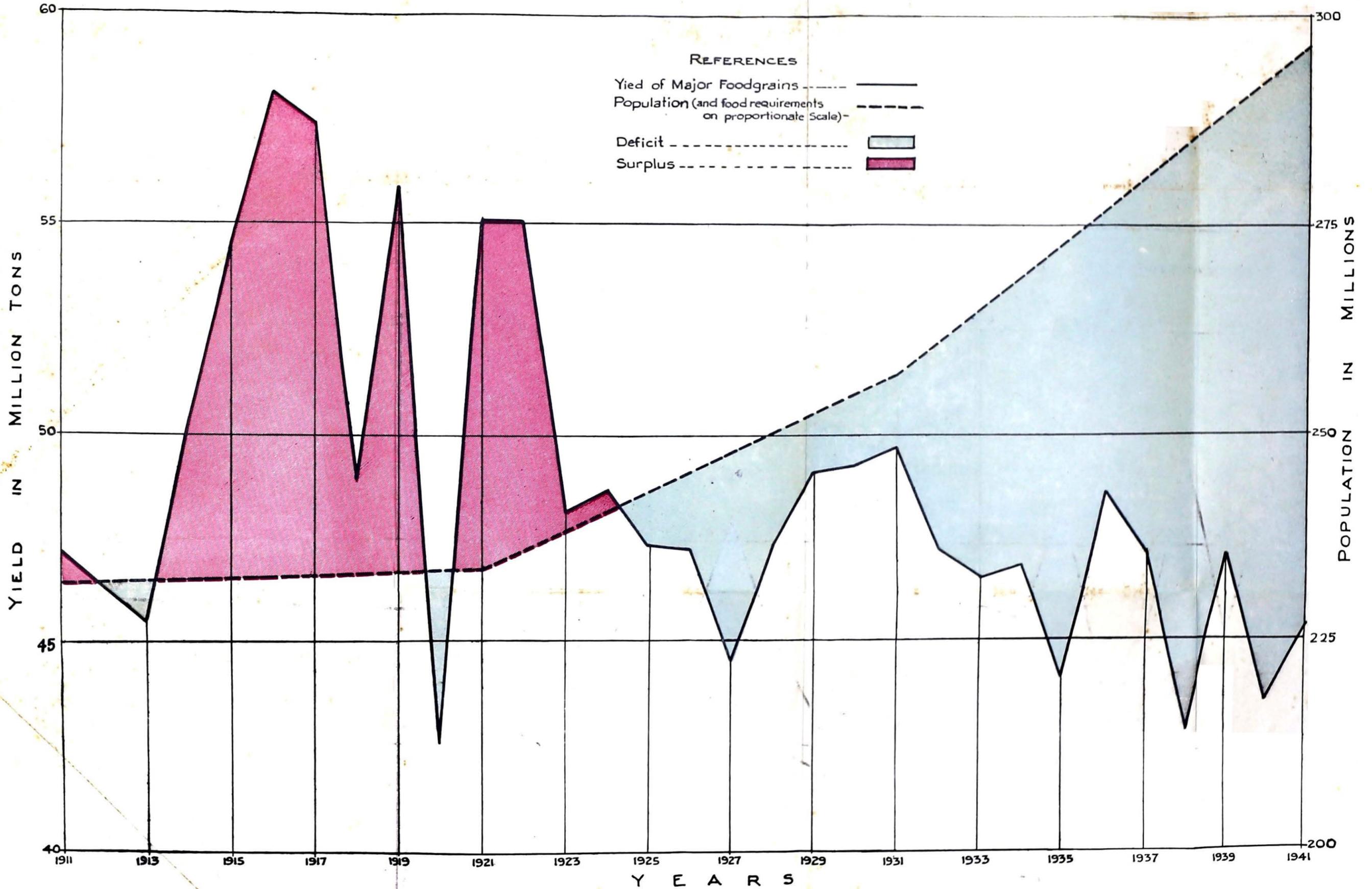
REFERENCES

PROVINCIAL BOUNDARY SHOWN	THUS	
METALLED OR GRAVELLED	"	
BRIDGE ROAD MADE MOTORABLE ROAD	"	
RAILWAYS	"	
RIVERS	"	
RAINGAUGE STATIONS	"	
RIVERGAUGE	"	
HILL AREA ABOVE 5000 FEET	"	
HILL AREA BELOW 5000 "	"	



"PLANNING FOR PLENTY"

GRAPH SHOWING INDIAN POPULATION & YIELD OF MAJOR FOODGRAINS
(RICE, BARLEY, JOWAR, BAJRI, MAIZE & GRAM)
AND
*REQUIREMENTS OF FOOD IN BRITISH INDIA.



Copied.
S.C. Singhal
Draftsman.

* The scale has been so adjusted that the population curve represents the food requirements also.

(GRAPH KINDLY SUPPLIED BY E.H.&L. DEPT.)
W.L. STAMPE.