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**CENTRAL BOARD OF IRRIGATION
INDIA**



सत्यमेव जयते

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1948

PART I

EDITED BY

N. D. GULHATI, I. S. E., M. I. E. (INDIA)

SECRETARY



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THE CENTRAL BOARD OF IRRIGATION 1948.



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FOREWORD

This Annual Report contains an account of research and other technical investigations on subjects connected with irrigation and hydro-electric, carried out in India, Burma and Ceylon during the year 1947. It is published both for the information of irrigation and hydel engineers in India, Burma and Ceylon and to make known in other countries the problems of Irrigation and hydro-electric developments in this part of the world and how they are being overcome.

Summary reports of the work carried out during the year 1947 at the nine research stations, and papers on specific subjects selected by the Board, together with the discussions thereon, appear under the respective subject head. The discussions constitute the technical proceedings of :—

(i) The Eighteenth Annual Meeting of the Research Committee, August 1948,

(ii) The Nineteenth Annual Meeting of the Central Board of Irrigation December, 1948,

in addition to which an informal meeting of the Research Committee was held in April 1948.

The Preliminary Notes were written by the Secretary for the information of those attending the Research Committee and Board Meetings.

It is regretted that due to lack of space, it has not been possible to include in full all articles contributed to the Research Committee Meeting. Abstracts or abridgements of articles not included in full are, however, provided. In other cases where abstracts or explanatory introductions were not supplied by authors, the Secretary has provided introductory abstracts.

The undersigned would repeat the request, contained in previous reports, for the supply of information relating to any of the problems mentioned in the publication. He will gladly furnish further details of any of the experiments, investigations, or other information relating thereto.

SIMLA.

Dated, January, 1949.

N. D. GULHATI,

Secretary,

Central Board of Irrigation.

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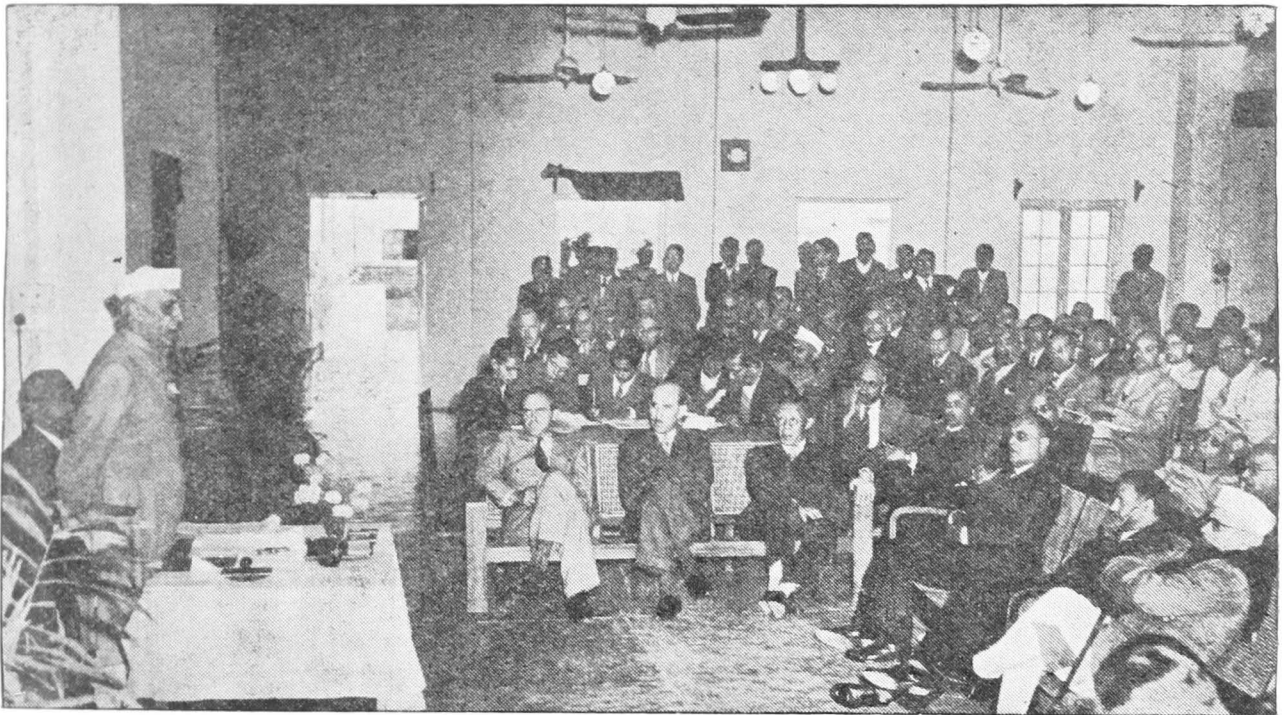
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Hon'ble Pandit Jawahar Lal Nehru, Prime Minister of India delivering his address at the Nineteenth Annual Meeting of the Central Board of Irrigation.

HARD LABOUR TO SOLVE ACCUMULATED PROBLEMS ENGINEERS EFFECTIVE AND IMPORTANT ROLE

[Address by the Honb'le Pandit Jawahar Lal Nehru to the Nineteenth Annual Meeting of the Central Board of Irrigation held in Constitution Club, New Delhi on December 5, 1948]

Mr. Khosla, Members of the Central Board of Irrigation, Your Excellencies and Gentlemen,

I am happy to associate myself with this meeting of yours and I am thankful to you for having invited me on this occasion. I have been interested in many types of activities during the past few years and in the position I occupy now, I have to cultivate a many sided-interest in many things. Life itself is rather an intricate and complicated affair for the individual and for the Nation and it is some times difficult to say which of any two things is more important, for each depends upon the other. Nevertheless it is true, as I have said many times before and as you, Sir, have said in the course of your address, that the development of river valleys in India is of the most basic and fundamental importance. For a number of years past, I have been very greatly interested in this matter not as an engineer, because I am not an engineer but in its wider public aspect of being, in a sense, the foundation of very large scale planning in India. I have been interested in planning because it seems such an extraordinary and such an unfortunate fact that with the potential resources available in India, and in a way it applies to the whole world, that all these enormous resources have not been utilised to raise the standard of living of our people and our Nation.

There was a time in the past—in the long past—when it might have been said with some correctness that the world's resources were not really enough to raise standard of living of the population of the world to the extent desired. Now I suppose it must be clear to the meanest intelligence that with the proper utilisation of the present resources of the world, leaving out further development, or leave out the world, of India if you like, we can raise the standard very greatly. That can be shown with a pencil and paper. Nevertheless the fact remains not only that we did not utilise them to the best advantage but we wasted these resources in destructive activities. That is the tragedy of the present generation, even more so than it has been of past generations.

Always found in history, we find to an acute degree today this conflict between the forces of constructive effort and of destruction. We find this conflict in the attitude of nations to one another, of groups and ultimately perhaps in the spirit of man himself. Now no man can be prophet enough to say what is going to happen. Nevertheless any man can work effectively, with the faith in him, that the forces of constructive and creative effort shall win. I have no doubt that they will win but I do not know what damage the other forces might bring about by delaying the process of planning and raising the standard of humanity.

Well, we have to convert this vast potential into actuality. Look at the map of Asia and of India. It stares me in my room and in my office and whenever I look at it, all kinds of pictures come into my mind ; pictures of the long past of our history, of the gradual development of men from the earliest stages, of great caravan routes, of the early beginning of culture, civilization and agriculture, and of the early days when perhaps the first canals and irrigation works were made and all that flows from them. Then I think of the future. My attention is concentrated on that huge block of massive mountains called the Himalayas which guard our north-eastern frontier. Look at them. Think of them. Can you think of any other part of the world similar to it in extent, which is as great a reservoir of power, of potential strength and power ; I know no other place in the world which has as much tremendous power locked up as in the Himalayas and the water which comes to the rivers from them. How are we to utilise it ? There are many ways. Essentially it is the job of the engineers to tap this tremendous reserve of power for the benefit of the people. It falls to the lot of you engineers to play a very affective and vitally important role in this work. Looked at from that point of view the profession and work of an engineer in India is of the highest importance and significance.

You can judge the growth of a Nation by finding out which class of that Nation, in a particular period of history, is held in honour and repute more than the others. At one time you may find that landholder, the proprietor of the land, is a noble man and he is held in greatest esteem. From that you can judge the nature of the society of that period. So you will find various occupations occupying the forefront at different periods and you can come to some conclusion as to the nature of social background of the society of the time ; whether it is static, whether it is creative or whether its growth is dynamically constructive.

A short while ago, not to go back to the long past of history, it is very interesting to consider that a short while ago, in the last generation or two in India, there were two avenues to which Indians looked forward to. One was Government service, more especially administrative Government service. Of course, a state should have good administration. It is important. But the administrative service in India was rather of an unusual variety. It was good in so far as it went, in so far as it served the purpose for which it was meant. It was not meant for other purposes. It was not really meant to cultivate a social outlook in the Government or the people but in so far as it went it did its work well. Perhaps it may have been said so 30, 40 or 50 years ago, that the ambition of an Indian was to belong to that administrative service in India because that brought respect and a certain measure of power, considerable emoluments in office and prestige. About the same time was another branch. To those people who did not take up Governmental service, the law provided the greatest opportunities of distinction, of money making and the like. So we find that in the past two or three generations in India there were two peaks of ambition of Indian young men to rise in the superior administrative service or to rise in the profession of law. That of course, has happened in other countries too. Now both these, the profession of law and administrative service, useful I suppose they are in their own way (though I have rather some doubts

about the profession of the law), but both of them represented what might be called a static view of society, not essentially changing nor dynamic. The lawyer always talk about precedents. The administrator carries on with the aid of conventional practice. Of course, there may have been a dynamic administrator and a dynamic lawyer but they represented a static unchanging view of the society. No country can, however, be completely unchanging. You find that the same lawyer played a very important part in the national movements. That again might be the same in other countries too. At a certain stage in national movements the lawyer has played a great part in other countries also. To-day you will find that the lawyer has progressively not played that part in the national movement or other varieties of national endeavour. He is still important in his own particular field of activity but that importance, looking at from a wider viewpoint, is infinitely less than it used to be. The civil administrator in India is still important as an administrator always is. But his importance is much less than it used to be.

What is a young man's ambition today? There may be varieties of ambitions but I rather doubt if there are quite so many people who think in terms of law or administrative service. They think in other terms. They think of the politician's life or going to these assemblies and then becoming Ministers, Secretaries, *etc.* Not a very happy training for anybody but still people do look that way. They think of joining our Defence Services, the Army, the Airforce and the Navy. They think of becoming economists because an economist plays a big part in modern world. They think of becoming engineers, because engineers are playing and will play an important part. You see the static nature of our society gradually changing into something dynamic and that will reflect in the peoples' and individuals urge as to what profession he should take up.

The world as it is constituted today is tremendously dynamic. That is tight of course and that is inevitable even if somehow we have been failing in that because the world as it is constituted today is in a stage of revolutionary change of the time that you just cannot help except to try to change yourself; otherwise, you get into trouble. Apart from that, coming back to India, we passed through a period, a fairly long one though it was very short in term of India's long history, a period which though changing undoubtedly it was, nevertheless in another sense unchanging—this British period in our history. Changes worked consciously and unconsciously but when the superior outside power dominates a certain situation, the various forces that are working inside the country are curbed by that power and they cannot easily find balance and adjustment between themselves. That finding of balance is achieved by the evolutionary process or by a revolutionary process or by peaceful or violent means. Always in any human society there is an attempt to find balance and so long as it does not succeed there is trouble. Now when some outside agency prevents that balance the result, for the moment may be even good if you like, but the result is that problems accumulate—problems which history solves in its own way, sometime peacefully sometime in a bloody way. If you do not solve it, you solve the problem by killing it. So also nations, and communities but when this extraordinary agency prevents that solution, problems

accumulate. So in India problems accumulated. The problem of the Indian States have no doubt been solved. Our agrarian problems which ought to have been solved long ago dragged on and on till we have to face them and to solve them in a hurry, when this should have been solved gradually and in a much better way. Now because problems have accumulated we have today to face not one problem but a multitude of problems and it is very difficult to say that you set aside all those problems or take up one or two first. We just cannot, because if we slacken our attempt to solve some problems and merely concentrate on one or another, the other problems tend to overwhelm us. Let us take the problem of refugees, millions of them. It is not a fundamental problem as problems go. It is a temporary problem but it is of exceeding importance. It is important because a large number of human beings and their lives are involved and where human lives in large numbers are involved it is of vital significance to the Nation. We cannot allow that human material to deteriorate and to simply go to pieces but apart from that, apart from the human aspect of it, if we try to ignore it, the problem becomes worse and comes in the way of other problems.

These accumulated problems have to be faced to some extent together. One has to proceed on various fronts and one has to see that the progress is more or less co-ordinated on each front or else you go ahead in one front and there is a bottleneck and you have to stop. That is where planning comes in, planning becomes essential.

We have talked about planning for a considerable time in India. I myself have been associated with the planning scheme and the like. I must confess a feeling of exceeding disappointment that all our effort has not yielded better results as I expected and as results should have been. When you know what has happened in the past and our difficulties and our failings in the matter, it is well, if I may say so, for each one of us whether he happens to occupy a very responsible position as a Prime Minister or other Minister or any other important officer of the State, it is well always to think in terms of any problem that we are entrusted with, not as if failure was somebody else's responsibility or somebody else's fault but that we are ourselves responsible for any failure that may occur. There is too much of a tendency for each one of us and again I say—I include the Prime Minister and other Ministers in this category, always to think in terms of somebody else having failed. If each person thought of his own job and that he has failed in it we will get on better with the problem. The fact is that each major job requires the co-operation and the good work of a large number of persons from the top to the bottom and if that co-operation is lacking, this spirit of working together is lacking—then that job is not done properly or is delayed and then it does not serve much useful purpose for us to go on finding fault with each other though some times that may be necessary. We have various jobs to do in this country in every field. Somebody said once that we have been born in a period of world history which is both changing and revolutionary and very inconceivable things happening. Now it is no good complaining of those inconceivable happenings. Since we

are born we have to face them. We cannot escape. Not being able to escape we have to face them like men and conquer these difficulties. I am afraid in our generation (I do not know about succeeding generations) there is going to be little rest or real peace. There are going to be no dividends of leisure and repose brought about for our generation. The prospect before us is work, hard labour. This generation is sentenced to hard labour. That hard labour can be of the type of constructive activity which however hard is something that raise the community and the Nation, or it may be in fruitless ways, or even in evil ways, but hard labour you cannot escape. Therefore let us divert that hard labour into constructive and creative channels so that at least it may be said of this generation that we helped to build up our country to the extent possible so that the next generation and succeeding generations may have leisure—greater leisure, though I am not myself keen on too much leisure for any individual but some leisure there ought to be. Perhaps it is not leisure that is so much required. It is the type of work that itself is better than the leisure. However, I am afraid I am just meandering in my thoughts and ideas.

I listened to Mr. Khosla's address with interest. I might say that I agree with almost everything that he has said in his address. I like the approach and I hope it is going to be the approach of this Board and of engineers as a whole in India and of the Government. I do wish you to realise the engineers who are present here, that the burden on the engineers today and the responsibility for constructive effort is tremendous and a great deal depends on how they discharge, and in what spirit they discharge it. We want you to be first rate and competent in your jobs, because second-rate-ness is never good. It is bad for the Nation. But in addition to that, we also want you to infuse your work with something, some higher spirit on doing a fine creative job with some fulfilment of certain objectives and ideals, that immediately infuses into your work something which is bigger than you. To go back to the middle ages or to even older times you see still the remains of ancient buildings, ancient structures, temples, cathedrals, mosques and the like. No one knows who built them but any man who sees them knows that the people who built them were not only fine builders, fine engineers, but they were men of faith in their work. No man can build or construct anything just beautiful unless he has full faith in him. See the magnificent cathedrals of Europe. People seldom know who were their builders but we do know, because the evidence is there for our eyes to see, that the embodiment of the faith of the builder is the engineer. So also our great temples and mosques and other buildings. Now we live in a different age. We do not spend much time and energies so much on mosques, cathedrals and temples but in other types of public works. But those public works should also be fine and beautiful because there is that faith. So I would like you to work in that faith and you will and that if you work with that faith, and that spirit, that will itself be joy to you.

On a smaller matter Mr. Khosla mentioned something about the dictionary in Hindi of technical terms. I am glad to hear that. But may I warn you that in evolving terms, technical terms you do not evolve something which the common man does not understand. There is too much of a tendency

today for that. For my part I think that words from foreign languages which have become current coins in this country should be retained, retained partly because they are current coins, partly because the more common words you have with the rest of the world the better in scientific and technical subjects. Science and technology know no frontiers. No body talks or ought to talk about English Science, French Science, American Science, Chinese Science. Science is something bigger than the countries. There ought to be no such thing as Indian Science. So also technology. This great business of looking at these questions in a narrow nationalist way will ultimately lead to the narrowing of your science and the narrowing of your technology and your work itself. This business of evolving special terms which are neither known by the general public nor by anybody else in the wide world really means that you are isolating yourself from the general drift of knowledge and at the same time dissociating yourself from your own people who do not understand your technical terms and you convert yourself into something which no body understands and no body cares for.

Gentlemen, I have great pleasure in declaring open the annual meeting of the Central Board of Irrigation.



Shri A. N. Khosla

THE PRESIDENTIAL ADDRESS

Delivered by Shri A. N. Khosla, I.S.E., President, Central Board of Irrigation at the 19th Annual meeting of the Central Board of Irrigation held at New Delhi on December 6, 1948.

Honourable Prime Minister, Ladies and Gentlemen,

On behalf of myself and the members of the Central Board of Irrigation, it is my proud privilege to welcome you Sir, our beloved Leader to this, the Nineteenth Annual Meeting of the Board.

The dawn of freedom has brought with it a new outlook, new sense of values and a new purpose in life—an all-round urge for creative effort and an over-mastering desire to get things done. We welcome you, Sir, as the embodiment of this progressive spirit of the times.

I also extend a hearty welcome to other distinguished guests.

I feel deeply grateful to the members of the Central Board of Irrigation for having done me the honour of electing me President of the Board for the third time in succession. It has, no doubt, meant a substantial addition to my already heavy burden of responsibilities in the Government of India, but I feel happy to note that during this period of three years, there has been a definite move forward and some concrete achievement.

THE BOARD

The Central Board of Irrigation was constituted in its present form in 1930. It originally comprised all the Irrigation Chief Engineers from Provinces. In 1940 the membership was thrown open to the Chief Engineers of some selected States and in 1945 to the Chief Engineers Electricity in the Provinces and senior officers of the newly formed Central Waterpower, Irrigation and Navigation Commission and later to the Central Technical Power Board. The Chief Engineers of Burma and Ceylon are also members of the Board. The Railway Board, individual Railways, Port Trusts and smaller States in India and the Sudan in Africa subscribe to the Board.

With the setting up of the Central Waterpower, Irrigation and Navigation Commission, the functions of the Board have been readjusted. The Library has been taken over by the Central Waterpower, Irrigation and Navigation Commission and the Board's principal responsibility now is to hold the annual meetings and six-monthly research meetings for the co-ordination of allied research activities.

The Board is the National Committee for India for the International Commission on Large Dams and the proposed International Commission on Irrigation and Canals. It has organised a National Committee in India for the International Society on Soil Mechanics and Foundation Engineering. It provides liaison with the International Association of Hydraulic Structures Research and other International Scientific Organisations. The Board is represented on several technical committees such as the Indian Standards Insti-

tution, the Indian Roads Congress, the Council of Technical Education, the Crops and Soils Wing of the Indian Council of Agricultural Research and the Geophysics planning Committee. It has set up a number of *ad-hoc* and permanent committees to deal with specific technical subjects.

The Board publishes a quarterly journal dealing generally with Irrigation and hydro-electric problems and has put out some popular leaflets. These have been well received in India and abroad. The Board is endeavouring to bring out a dictionary of technical terms in Hindi and to translate the popular pamphlets in Indian languages. It has built up a unique and efficient information service for the engineering profession, particularly, the Irrigation and Hydro-electric branches.

The Board has put forward several constructive suggestions affecting all-India problems. Some of these have been wholly or in part accepted by the Central and Provincial Governments; the two outstanding examples being the setting up of the Central Waterpower, Irrigation and Navigation Commission and the proposed legislation regarding Inter-state rivers and waterways for purposes of development, which is understood to be under active consideration of the Government of India.

For the great progress made during the last three years, the bulk of the credit goes to our most energetic Secretary, Shri N. D. Gulhati, I.S.E. This is the last meeting of the Board which he will attend as its Secretary. I have no doubt that the members of the Board would wish me to place on record the Board's appreciation of the outstanding service rendered by him and the other officers associated with him in his work. I have also to thank Shri S.A. Gadkary for his inspection of the office of the Board.

I like to take this opportunity of making an announcement on behalf of the Board.

The Executive Committee has decided yesterday to institute a medal to be called the "Central Board of Irrigation Medal" to be awarded every year to the best published research or other original contribution to the development of the water resources of the country.

THE TWO FUNDAMENTAL NEEDS

Our two fundamental needs today are food and cheap hydro-electric power with which to maintain national health, well-being integrity during peace and war. Water is the key to the fulfilment of these fundamental needs. The progressive conservation and optimum utilisation of our immense water resources should, therefore, be our first task and given the highest priority. As I have said many a times before, we are utilising not more than 6 per cent. of the total water wealth of the country, the balance 94 per cent. being allowed to run to waste and do untold damage to life and property in its passage to the sea.

There are vast areas of good culturable but arid lands spread over the length and breadth of this vast country, which are lying unproductive for want of irrigation facilities. These facilities are in most cases both technically and economically feasible and if made available, even in part, would not only make the country self-sufficient but a surplus area for food production. Our development of these facilities has, however, for various reasons, lagged far behind the needs of our growing population, with the result that today we are im-

porting food-stuffs to the value of 100 *crores* of rupees each year, the equivalent of the total cost of any one of the mammoth schemes, such as the Kosi the Bhakra or the Ramapadasagar.

Our industrial development has progressed at a snails' pace, one important reason being the lack of cheap power. The result is that we have to depend almost exclusively on foreign machinery and foreign manufactures for most of our development plans. The total installed capacity of hydro-electric power in India with a population of over 300 millions is barely half a million kW. which in terms of population represents a negligible fraction of that installed in the more developed regions of the world. Power from water is a perpetual asset and does not involve the use of coal which is a diminishing asset and the high grade quality of which is badly needed for metallurgical and other purposes. The extent of water-power development in India will be a measure of the prosperity of her people and their importance in world affairs.

RIVER VALLEY DEVELOPMENT PROJECTS

The necessity for the conservation and utilisation of the water resources of the country for purposes of flood control, irrigation, power generation, navigation and allied facilities, on a regional basis, has now been definitely accepted. The completion of any one of our major river valley schemes will provide enough additional food to almost wipe out the country's entire deficit and enough power to start several heavy industries of economic and strategic importance. Some large river valley development schemes such as the Tungabhadra in Madras, the Bhakra dam in East Punjab, the Damodar Valley Project in Bihar and Bengal, the Hirakud Dam in Orissa are under actual construction. Some other projects are ready for sanction and execution. Others still are in various stages of investigation and preparation. There are several areas of potential development particularly, in the acceding States, to which, it has not been possible so far to give even preliminary consideration.

Some of these mammoth schemes, like the Bhakra, Kosi and Ramapadasagar are likely to cost over one hundred *crores* each. In view of colossal expenditure involved, the immensity of the field to be covered by these schemes and their intimate bearing on the agricultural and industrial development of the country and on the everyday life of the people, it is possible that in the not distant future there may be need for a separate portfolio in the Government of India to deal exclusively with river Valley Developments.

In the past progress in river valley developments has been held up, in some cases for as long as 40 to 50 years because of interminable water disputes between the Provinces and States concerned with a river. While the powers that be continued to disagree, no constructive work could be done, the region concerned remained undeveloped and the common man continued to groan in poverty and semi-starvation. The proposal in the New Constitution of India to bring the subjects of "Development of Inter-state rivers and waterways for flood control, irrigation, power, navigation and other purposes" in list I of Schedule VII will be the biggest step forward in the integrated development of river valleys, which will also be considerably facilitated by the integration and merger of Indian States which has been so ably and thoroughly brought about by your esteemed colleague the Hon'ble Sardar Patel.

DIFFICULTIES AND BOTTLENECKS

But there are serious difficulties in the way of rapid realisation of our plans. These are inflation, the ascending spiral of high prices, shortage of steel, cement and other essential materials of construction, bottlenecks of transport and inadequacy of technical manpower of the requisite qualifications. Added to these there is, a fair amount of red tape and in certain quarters a lack of sense of responsibility and an absence of pioneer zeal.

PRIORITIES AND PHASING OF PROJECTS

For balanced and sustained development, we have to take stock of our resources in men, money and materials and phase our activities in such a way that the overall advance towards the objective is uninterrupted and progressive and at no stage out of joint with the other phases of national activity. But despite inflation we cannot afford to be static, and permit our resources to remain in disuse. The antidote to inflation does not lie in a stoppage of productive effort, nor in permitting human material to stagnate through lack of opportunity and incentive. It lies in the freezing of surplus purchasing power and canalising it into means of production.

If we take up first things first and adjust priorities in that spirit, the question of inflation will not enter into the picture. We want more food. We want cheap power for industry and agriculture. We want to be, as far as possible, self-sufficient in our basic tools of production, such as heavy machinery for essential industries; and in the production of essential materials, like steel, cement, oils *etc.* Then we want adequate means of transport for raw materials as well as finished products.

The first place, in order of priority, would naturally go to the conservation and utilisation of water resources, through river valley development, thus providing the basic tools for national advance and self-sufficiency; that is flood control to release more lands for productive cultivation, irrigation facilities to grow more food, large scale generation of hydro-electric power to turn the wheels of industry and navigation facilities for the transport of the products of agriculture and industry. The next in order of priority, should come the manufacture of hydro-electric machinery, setting up of iron and steel factories, cement mills, and the manufacture of synthetic petrol, fuel-oils, fertilisers and other essential commodities. At par with the above will be the land transport facilities, particularly the extension of railways to sources of raw materials and manufacturing centres.

Priorities and phasing must be taken up together so that the overall demand in men, money and materials in a region or the country as a whole, does not materially exceed the available or potentially available resources of the area concerned. Further, development must be integrated so that all related phases may advance in step. For instance it will not do to generate a million kW. of power without at the same time setting up the necessary industries and other rural and urban undertakings to utilise that power. In order to make the best use of our human and material resources, the ideal arrangement will be to have the various projects staggered in point of execution so that while peak construction activity is proceeding on one or two projects, there will be

only preparatory work and lesser construction activity on the others. Similarly as the peak activity starts tailing off on the former, the work on the latter should get into peak stride. But this process must be continuous so that the ever increasing knowledge and experience gained on successive jobs may be passed on from project to project thus ensuring that each succeeding job shall be done better and cheaper, than the one done before. For this purpose, it is necessary that while one project is under construction, there should be at least three or four projects under surveys and investigation. The staff, money and material requirements for surveys and investigations will be relatively small. Normally two to three years will be required for such investigations in the case of large projects and it will be fatal to proceed to construction without carrying out full investigations and preparatory project studies. In this way, as soon as the construction activities on any project or set of projects get on to the concluding stages, it will be possible, as a result of detailed investigations carried out in the meanwhile on several other projects, to decide as to which project or projects should be taken up next in order of priority and which kept back or altogether rejected from consideration of engineering and economic feasibility, direct and indirect benefits and special needs of the region or the nation.

The decisions about relative priorities will obviously be taken by the Priorities Committee of the Cabinet. The phasing of projects and the allocation of essential materials between such projects should be similarly controlled, with a view to obtain the best overall results.

PLANNING

Planning should be regional and total so as to cover all related purposes in any particular region. Planning should not be confined merely to one or two five-year periods. It must extend much farther ahead. The work of development of river valleys in India will be a continuous process. It will not end in 20, 30 or even 40 years. Ours is a vast country and there are numerous virgin regions to be served. Our first aim should be to provide each region as quickly as possible with one completed project or part of a project adequate to its immediate need, and then build up in course of time to total development. Total planning does not preclude partial or stage development. It will be desirable to undertake construction of a part of the total plan to achieve quick results and at small expense of available resources but with the clear understanding that such partial development will be an integral part of the total development and in no way and at no stage in conflict with it. In this way it will be possible to serve several areas simultaneously, expeditiously and without straining, beyond limit, our available resources in men, money and materials.

NEED FOR QUICK ACTION

Any attempt to unduly delay development schemes for any reason whatsoever, will seriously affect the morale of the people. The common man has been given hopes. He has been looking forward to the fulfilment of these hopes. If he now finds himself faced with mere long range promises without any immediate tangible steps towards achievement, he will start losing faith in his own future and relapse into the despondency of pre-freedom days.

You, Sir, by your unerring judgment have led the country through many crises and by your great leadership enhanced the prestige of India. Your contempt for the in-efficient, your impatience with red tape and your overriding desire to get things done, are a sure guarantee of ever-increasing progress on all fronts of our national activity.

The economic future of the country lies in the rapid and sustained development of our river valleys and their great water resources. With your guidance and support, Sir, we trust that this development will soon take place on sound and sure lines, and the common man will see the fulfilment of his hopes and desires and look forward with confidence to an era of full employment and ever-increasing prosperity.

To you, my fellow engineers, I would like to make an earnest appeal to put your heart and soul in the service of the Nation. You may not rise to positions of power and prestige, but something greater than these will be yours—the satisfaction that you have contributed your mite to the building up of a glorious new chapter in the history of our motherland.

JAI HIND.

I—Meetings of the Board and Committees

1—Meetings of the Board and Committees

ELEVENTH INFORMAL WINTER MEETING OF THE RESEARCH COMMITTEE

The informal winter meeting of the Research Committee was held at the Thomason College, Roorkee on April 12 to 14, 1948.

On the afternoon of April 13, the Research Committee held an informal discussion in which the following officers took part :—

Rai Bahadur S. K. Guha, I.S.E., Chief Engineer, Bengal ; Kanwar Balbir Singh, I.S.E., Chief Engineer for Irrigation, United Provinces ; Dr. N. K. Bose, M. Sc., Ph. D., Director, River Research Institute, Bengal ; Shri S. L. Malhotra, I.S.E., Director, Irrigation Research, East Punjab ; Shri B.N. Khatri, I.S.E., Superintending Engineer, Irrigation Department, United Provinces ; Shri D. N. Khurana, I.S.E., Superintending Engineer, Central Provinces, Berar ; Shri R. S. Chaturvedi, Executive Engineer, United Provinces Irrigation Research Division ; Shri Naegamvala, Executive Engineer, Irrigation and Research Division, Poona (Bombay) ; Shri N. D. Gulhati, I.S.E. M.I.E., (India), Secretary, Central Board of Irrigation ; Shri P. R. Ahuja, P.S.E.,—I, Deputy Secretary, Central Board of Irrigation ; and Dr. N. N. Bhandari, B.A., D.I.C., Ph.D., Assistant Secretary, Central Board of Irrigation.

Rai S. K. Guha Bahadur, took the chair.

Dr. Bose opened the discussion and said that he had felt considerable difficulty in the selection of bed material for models in connection with experiments on silt exclusion. He explained that Hooghly sand was very fine and the micaceous part floated on the top. He understood that Shri K. K. Framji had asked for a supply of 1,000 tons of Hooghly sand from the Port Commissioners for use in the Hooghly model at Poona. This would cost about Rs. 40,000 as freight.

Mr. Chaturvedi said that he had never been faced by this difficulty. During rains he might encounter it.

Dr. Bose said that after considerable investigation he had found mustard seed as a suitable bed material.

Dr. Bhandari enquired whether the seeds did not float up.

Dr. Bose answered that they did not float but settled down and rolled along the bed.

Mr. Malhotra referred to the use of plastic for preparing models, and enquired if a suitable material could be had in India. It was decided that the Secretary should obtain the necessary information.

Mr. Chaturvedi pointed out the difficulties being experienced for want of dollars for the purchase of essential equipment for Research Stations.

It was agreed that the Central Board of Irrigation should request the Government of India, that high priority be given to such requirements.

The party was taken round for inspection of the Mohammadpur Power House (under construction) on the morning of April 13, and the Dhanauri Drilling School, Bahadarabad Irrigation Research Station and the Bhimgoda Weir on April 14, by Kanwar Balbir Singh, Chief Engineer for Irrigation, United Provinces and his staff.

THE EIGHTEENTH ANNUAL MEETING OF THE RESEARCH COMMITTEE

The Eighteenth Annual Meeting of the Research Committee of the Central Board of Irrigation was held at the Grand Hotel, Simla, from the 2nd to the 7th August, 1948. It was inaugurated by Rai Bahadur A. N. Khosla, I. S. E., President of the Central Board of Irrigation. The following other Members of the Board were present :—

- Mr. A. R. Venkatachari, I.S.E., (Vice President), Chief Engineer Irrigation, Madras.
- Mr. S. A. Gadkary, B.E., M.I.E.E. (London), A.A.I.E., C.P.E., Tech., M.I.E. (Ind.), Member, Central Waterpower, Irrigation and Navigation Commission, New Delhi (Member of the Executive Committee).
- Lala Gita Ram Garg, I.S.E., Chief Engineer and Secretary, East Punjab.
- Sardar Sarup Singh, I.S.E., Chief Engineer and Secretary, East Punjab.
- Mr. G. B. Mondal, I.S.E., Chief Engineer, Irrigation, P.W.D., West Bengal, Calcutta.
- Mr. R. Chandra, I.S.E., Chief Engineer and Secretary, P.W.D., Assam.
- Mr. S. D. Khangar, I.S.E., Chief Engineer and Secretary Bihar, Patna.
- Sardar Man Singh, I.S.E., Member, Central Waterpower, Irrigation and Navigation Commission, New Delhi.
- Mr. Kanwar Sain, I.S.E., Chief Engineer, Bikaner State.
- Mr. R. R. Handa, I.S.E., Chief Engineer and Secretary, P.W.D., Orissa, Cuttack.
- Mr. M. L. Bahl, I.S.E., Chief Engineer and Secretary, Bihar, Patna.
- Sardar Raghubir Singh, Chief Engineer, Patiala.

The permanent members of the Research Committee present were :—

- Dr. N. K. Bose, M.Sc., Ph.D., Director, River Research Institute, West Bengal, Calcutta.
- Mr. S. L. Malhotra, I.S.E., Director, Irrigation Research Institute, East Punjab, Amritsar.
- Mr. D. V. Joglekar, Director, Central Waterpower, Irrigation and Navigation Research Station, Poona.

T.P. Kuttiammu, Esquire B.E., A.M.I.E., Executive Engineer, P.W.D. Madras.

Mr. J. P. Naegamvala, B.S.E.(I), Executive Engineer, Poona Irrigation Research Division, Poona.

Mr. N. S. Govinda Rao, Assistant Director, Mysore, and

Mr. S. N. Gupta, Assistant Engineer, United Provinces.

They were assisted by their Research Officers, Mr. T.N. Seshadri, (Madras), Mr. S. K. Banerji, Mr. G. Sinha and Mr. P. B. Ray, (West Bengal) ; Dr. V. K. Gokhale and Dr. D. G. Kulkarni, (Bombay) ; Dr. H.L. Uppal, Dr. Jai Krishan Malhotra and Dr. C. L. Dhawan, (East Punjab) ; Mr. A. P. Bhattacharya and Mr. L. K. Mital, (United Provinces) ; Mr. V. N. Nagaraja, (Mysore) ; and Mr. S.T. Ghotankar and Mr. G. V. Gole of the Central Waterpower, Irrigation and Navigation Research Station, Poona.

The other officers present included Mr. H. L. Vadera, I.S.E., Mr. M.L. Sood, I.S.E., Mr. M. L. Aggarwal, I.S.E., Dr. R. C. Hoon and Mr. G. M. Panchang, (C.W.I.N.C.) ; Mr. H. G. Cocksedge, (Assam) ; Mr. D. Mehta, I.S.E., (Bihar) ; Mr. C. L. Handa, I.S.E., (East Punjab) ; Shri T. S. Venkatarama Iyer and Dr. K. L. Rao, (Madras) ; Sardar Bahadur Sardar H. S. Kahai, (Orissa) ; Mr. B. P. Saxena, I.S.E., Mr. B. N. Khattri, I.S.E., Mr. J. N. Mitra, Mr. Radhey Shyam, and Mr. K. P. Shukla, (United Provinces).

Officers of other Departments present included Mr. Brij Narayan, Additional Consulting Engineer (Roads), Mr. K. S. Raghavachary, Assistant Standardization Casting Officer, Mr. S. L. Bazaz, Bridge Specialist Officer, and Mr. H. Sunder Rao, Secretary, Indian Roads Congress ; Mr. R. L. Sethi, Agricultural Commissioner, Indian Council of Agricultural Research ; Mr. M. C. Bijawat, Chairman, Central Ground Water Organization and Dr. V. I. Vaidhianathan, Deputy Director ; Dr. L. A. Ramdas, Director, Agricultural Meteorology of the Meteorological Department ; Mr. K. F. Antia and Mr. H. H. Banerjee of the Central Standards Office, (Railway Board) ; Brigadier R. E. Aserappa of the Engineer-in-Chief's Branch ; Mr. M. P. Mathrani, I.S.E., and Mr. H.J. Ajwani, (Damodar Valley Corporation) ; Mr. J. N. Mookerjee, Director, Indian Agricultural Research Institute ; Mr. J. P. Mehrotra, Deputy Director, Engineering, Indian Standards Institution ; Mr. G. C. Mitter, Chief Technical Adviser (Mints), Bombay, on behalf of the Council for Scientific and Industrial Research ; and Dr. I. M. Puri, Deputy Director, Malaria Institute of India. Mr. H. S. Kulkarni and many other officers of the Central Electrical Commission and East Punjab Government attended part of the meeting.

The following officers of the Central Board of Irrigation were present :—

Shri N. D. Gulhati, I.S.E., M.I.E. (India), Secretary and Capt. P. R. Ahuja, Deputy Secretary ; Dr. N. N. Bhandari, Shri R. C. Shenoy, Shri D. D. Soni and Shri M. S. Khanna, Assistant Secretaries.

Opening the proceedings Shri A. N. Khos'a said :—

Gentlemen,

It is my pleasant duty to welcome you all to the 18th Annual Meeting of the Research Committee of the Central Board of Irrigation. I feel greatly honoured in being called upon to preside over its deliberations for the third time in succession.

It is a unique gathering this year. We have representatives from all over the country and from all departments and organisations whose activities are allied with ours. This year we have an attendance of about 75 while last year and in the years before the attendance was below 30. This large increase indicates a welcome recognition by all the governments of the valuable work done by this Board and of the great importance of research in relation to the multiple-purpose development of river valleys.

I welcome the new members of the Research Committee, Messrs. S. L. Malhotra and J. P. Naegamvala. I congratulate Mr. D. V. Joglekar on his promotion as Director of the Central Waterpower, Irrigation and Navigation Research Station.

In particular, I would like to extend, on behalf of the Central Board of Irrigation, a hearty welcome to officers of the Indian Army, the Ministries of Agriculture and Transport, the Indian Roads Congress, the Council of Scientific and Industrial Research, the India Meteorological Department and the Indian Standards Institution, who are with us today. I and the Board are indeed grateful to all of them for their response and co-operation in planning for the conservation and optimum utilisation of the vast water resources of this country.

I take this opportunity to express regret that our colleagues from Pakistan have not found it possible to attend. It is my sincere hope that in the very near future we shall again sit together and co-operate in solving the problems of common interest.

Gentlemen, since we met here in July last year there have been momentous changes in the country. We are now a free people. Mahatma Gandhi, the Father of the Nation and our Saviour, with his band of devoted workers, won us this freedom. This was followed by an unfortunate upheaval in the country. Soon after, the cruel hand of an assassin removed from our midst that greatest man of all times.

I had the honour and privilege of sitting at the feet of Mahatma Ji on more than one occasion and vividly recollect the keen and realistic interest he had in our schemes of development. He had recognised that in the conservation and utilisation of our water resources lay the key to the future greatness of India and the welfare of our people.

The extent of development of the material resources of a country is a measure of its strength and greatness and of the standard and status of its people. India has vast resources in water, land and minerals. But only a

negligible fraction of these resources have so far been harnessed for beneficial use. That accounts for the low standard of living of her 300 million people and their backwardness in education and opportunities. For a contrast, look at the many nations of Europe, Sweden, Norway, Switzerland and Czechoslovakia with populations of $6\frac{1}{2}$, $3\frac{1}{2}$, 4 and 11 millions respectively, have attained a high degree of industrialisation as a result of their resource development. The case of Switzerland is of particular interest. She has no mineral wealth worth the name and relatively small area of cultivable land. Her greatness as a nation, her prosperity and the high standard of living of her people have been secured by the brains, initiative, industry and perseverance of her manpower. They export the products of her technological skill and labour. This leaves them rich dividends and gives this nation of four million people an importance and status far above that of countries with many times that population. Why cannot India, with her vast manpower and almost unlimited natural resources, rise to unparalleled heights of greatness and material prosperity Undoubtedly she can, but that will need, on the part of all her people, unprecedented and sustained effort, a living faith in her great destiny and an unshakeable determination to reach goal.

The future of the country lies in the hands of engineers, scientists and technologists. They have to plan and construct. They have to create the works from which will flow wealth and prosperity. They have to conserve the natural resources of the country and utilise them for the service of the nation. The water wealth of the country which at present is running waste to the sea, mostly in the form of devastating floods, can be conserved for purposes of irrigation to provide other amenities and for improving, by regulated flow, the wide network of our navigable waterways to help in the better distribution of the products of agriculture and industry.

We must, however, recognise that the task ahead of us is stupendous—something enormously big in relation to our present capacity and creative genius. We, of the technical services, must put our shoulders to the wheel and work with faith, courage and determination in a spirit of humility, sacrifice and service so that through supreme and steady joint effort and in the course of the next decade or so, we may create wealth and lasting prosperity for the nation. The fulfilment of our task will be our reward.

Gentlemen, in making this appeal to you, I am painfully conscious of the many obstacles and limitations which stand in the way of the full exercise of your initiative, organising capacity and technical skill. Wherever I have gone in the Provinces or the States, I have noticed the utmost keenness and a burning desire among engineers and technicians to do something constructive and to achieve results without delay. But I have also noticed among them a painful sense of frustration, which has manifested itself before the opportunity for achievement has materialised. They want to advance, but they cannot, because of an unfortunate system in which red tape has priority over achievement and which threatens to strangle all creative effort. While, therefore, I make an earnest appeal to you, technical officers, to put in your very best and to make every possible sacrifice in the service of our people, for

the maintenance of our freedom and to raise our great country to its rightful high position among the nations of the world. I would also appeal to the powers that be to trust their technical services and spare them the unnecessary handicaps, harassments and delays of red tape. They are to be the creators of wealth and prosperity and must be given the necessary atmosphere and the opportunities to make it possible for them to achieve the best results in the shortest space of time unfettered by the bonds of a system which is an fortunate legacy of the past.

Gentlemen—before I start referring to the achievements of the various research stations in the country, their future programme and objectives, I would like to mention some of the important things that struck me during my visit in Europe in the last two months. A number of us went to Sweden to attend the sessions of the World Power Conference, the International Commission on Large Dams and the International Association of Hydraulic Structures Research. For the first time we appeared in the international picture. The many nations of the world that attended these conferences were deeply interested in the vast potentialities of this country and its present achievements. We have invited these Commissions to hold their next sessions in India early in 1951. Our representatives also attended the International Conference on Soil Mechanics and Foundation Engineering. In Sweden, Norway, Switzerland, France, Czechoslovakia, Scotland and England we took note of the enormous development they have made in manufactures of every description. We saw the great work they are doing in the research laboratories attached to the major institutions and industry. Research is paying them large dividends in the shape of improved outturn and quality and lower costs of production. During these visits I was, in particular, anxious to find the best way of making quick advance in the manufacture of all hydraulic and electrical plants required for the many river valley development projects in our own country. Also I wanted to ascertain the position regarding specialised foreign technical personnel and the training of Indian technical personnel. You will recall that this Board recently passed a resolution to the effect that we should take the earliest possible steps to start manufacture in our own country of all heavy machinery required for hydroelectric projects, that we should start intensive research and model studies with a view to keep our achievements in the construction and manufacturing fields, abreast of other nations. As a result of my exploratory investigations, I have come to the conclusion that in co-operation with some of the foreign manufacturing concerns, we can start manufactures in many fields in India. We should take immediate steps in this respect. In this way we will be progressively working towards self-sufficiency and succeed in preparing our engineers, scientists and technicians for present and future needs by giving them actual training and responsibilities of the job. The type of superficial training that our men are receiving at present in foreign countries will not fit them for the task of undertaking manufactures in our own. It is only through intimate touch with actual work and necessary responsibility that our men will get the inside knowledge, so necessary for independent manufactures. Otherwise, they will continue to play the roll of observers, the actual work of manufactures being left to others.

Mr. Gulhati, the Secretary of the Board, who was also the Secretary of the Delegation that went abroad will soon give you a brief account of the meetings we attended and the impressions we gathered there.

With the extensive field laboratories at Malikipore in East Punjab and a newly established research station at Amritsar, the East Punjab has organised a new research institute and I am glad to see that inspite of numerous difficulties, they have been able to send to us their annual report for the work done during the year ending December 1947. I also understand that Assam is contemplating the establishment of an Irrigation and Soil Mechanics Laboratory and I have no doubt that they can depend on the existing research laboratories in India to assist them in this task.

Gentlemen, I do not propose to dwell on any particular subject during my address to you this morning. We have before us a very heavy task for the week as you can see from the annual reports of the Research Stations. I thank those who have been able to give us printed reports inspite of the many difficulties that now prevail. Those, who have not been fortunate in getting their report printed this time, will, I hope, be able to do so next year. I am also glad to note that the recommendations of the Central Board of Irrigation regarding the form and arrangement of the report have been followed by most of the Research Stations and I hope that others will also bring their reports to these lines by next year. On account of my absence from India, I have not been able to study these reports, but I find that continued progress has been made in many of the spheres of your activities. Considerable work has been done on the development of the design of the volute spillway siphon, both on experimental lines and in mathematical studies. Many local problems of river control and in connection with the design of individual works, have been tackled by you all, some new studies have been initiated on the conditions of sub-soil water table in certain areas and an increasing use of soil mechanics and soil stabilization is in evidence. I have great pleasure in congratulating the Directors of Research Stations and their staff for the work they have put in during the last year and I hope the discussions that we shall have during this week will be of mutual benefit to all of us.

Before I conclude, I like to say a few words regarding the procedure at this meeting. We have a very heavy agenda. The list of subjects, the progress on which we review at this meeting, has increased considerably of late. You have been supplied with a classified list of items under different subjects that are contained in the Annual Reports of the Research Stations or in individual contributions. May I request the Research Officers taking part in the discussions to be brief and to the point. In proceeding with the discussions on various subject I shall ask the authors of the papers or the Directors of Stations to introduce these items. The Directors may, if they so desire, ask the Research Officers concerned to introduce any item. The latter should be brief in their remarks and if there is nothing fresh to mention or no important point to bring out, they may merely say that there is nothing to add as introduction.

In accordance with the Constitution, the Executive Committee is to decide who should be co-opted as members of the Research Committee. Some

resolutions may have to put to vote. In order to make it clear as to who is entitled to vote, the names of the permanent members of the research committee and those co-opted as members for the current meetings are as follows:—

Permanent members

- The President
- Mr. A. R. Venkatachari
- Mr. S. A. Gadkary
- Dr. N. K. Bose
- Mr. S. L. Malhotra
- Mr. D. V. Joglekar
- Mr. T. P. Kuttiammu
- Mr. Govinda Rao
- Mr. J. P. Naegamvala, and
- Mr. S. N. Gupta.

Co-opted for this meeting

- Mr. B. N. Khatri
- Mr. Kanwar Sain
- Dr. R. C. Hoon
- Dr. J. K. Malhotra

I have also to request that any one desiring to speak will kindly stand up. This will lead to a better appreciation of the speaker's remarks. The Secretary will welcome written notes from speakers of what they have said. This will assist him in the preparation of the minutes. Stenographers can be provided during this meeting to those who may need their services.

Gentlemen, I declare open the 18th Research Committee Meeting of the Central Board of Irrigation.

Shri N. D. Gulhati, Secretary, Central Board of Irrigation gave a brief account of the meetings of the International Association of Hydraulic Structures, Research, and of the International Conference on Large Dams that he and other Indian delegates attended in June 1948 in Sweden.

Shri A. N. Khosla then gave further impression of his recent visit to Europe and urged on all to contribute some very good papers for the meetings of the International Conference on Large Dams and the International Association of Hydraulic Structures Research to be held in India in 1951.

**FORMAL CONFIRMATION OF THE MINUTES OF THE PROCEEDINGS OF
THE SEVENTEENTH RESEARCH COMMITTEE MEETINGS**

The minutes which had been circulated at the previous meeting of the Board were confirmed.

NINETEENTH ANNUAL MEETING OF THE BOARD

The Nineteenth (1948) Annual Meeting of the Board was held from December 6 to 11, 1948 at the Constitution Club, New Delhi, under the Chairmanship of M. A. N. Khosla, I.S.E., President of the Board.

The distinguished visitors present at the opening session included the Hon'ble Shri N. V. Gadgil, Minister for Works, Mines and Power, Government of India, representatives of Embassies in New Delhi, members of the Constituent Assembly, officers of the Government of India Secretariat and heads of several departments. The following members were present :—

Mr. A. N. Khosla, Mr. N. N. Iyengar, Sardar Man Singh and S. A. Gadkary, Esqr. (Government of India); Mr. R. Chandra (Assam); Mr. D. Mehta (Bihar); Mr. Kanwar Sain (Bikaner); Mr. N. P. Gurjar and Mr. P. B. Advani (Bombay); L. Gita Ram Garg and Mr. S. S. Kumar (East Punjab); Major N. K. Bhonsle (Gwalior); Mr. A. R. Venkatachari, Mr. N. Govindaraja Ayyangar and Mr. G. Sundram (Madras); Mr. R. R. Handa and Mr. R. L. Narayanan (Orissa); Sardar Raghbir Singh (Patiala); Mr. Balbir Singh (United Provinces); and Mr. S. K. Guha (West Bengal).

Mr. A. N. Khosla, I.S.E., President of the Board welcomed the Hon'ble Pandit Jawahar Lal Nehru, the Prime Minister of India, other distinguished guests and the members of the Board. The Hon'ble Pandit Jawahar Lal Nehru, then addressed the gathering and declared the meeting open*

In the technical discussions, the members of the Board were assisted by: Dr. R. C. Hoon, Mr. D. V. Joglekar, Mr. S. T. Ghotankar, Mr. J. P. Naegamvala, B.S.E.(I), Mr. T. J. Mirchandani, Mr. S. N. Gupta, Mr. A. P. Bhattacharya, Mr. J. N. Mitra, Mr. K. N. Kathpalia, Mr. S. R. Aggarwal, Mr. A. C. Mitra, Mr. B. N. Khatri, Mr. D. P. Rohtagi, Mr. Moti Ram, Mr. C. L. Handa, I.S.E., Mr. B. S. Talwani, Mr. H. R. Bhatia, Dr. H. L. Uppal, Dr. J. K. Malhotra, Dr. C. L. Dhawan, Dr. N. K. Bose, Mr. N. Padmanabha Iyer, Mr. Narasimham, Mr. T. Mylvaganam, Mr. E. V. S. Iyer, Mr. P. C. Das and Mr. K. G. Mazumdar.

Messrs. M. D. Mithal, T. M. Oag, R. D. Dhir, M. L. Sood, H. L. Vadhera, K. L. Vij, B. S. Nag and A. R. Khanna of the Central Waterpower, Irrigation and Navigation Commission, Mr. Brij Narain and Mr. S. L. Bazaz of the Ministry of Transport, Mr. K. P. P. Menon and Mr. H. S. Kulkarni of the Central Electricity Commission attended part of the proceedings.

Dr. S. K. Banerji, Director-General of the India Meteorological Department participated in the discussion on the subjects connected with Hydrology. Col. Jaswant Singh of the Malaria Institute addressed the Board on the "Anti-malarial aspects of water-utilisation projects".

* Printed elsewhere in this Report.

Various items on the administrative and technical agenda were discussed from Monday to Saturday. In addition, meetings of Executive Committee of the Board, of the Advisory Committee of the International Congress on Large Dams, Executive Committee of the National Society of Soil Mechanics and Foundation Engineering and the sub-committee to examine the draft of the revised edition of Central Board of Irrigation Publication No. 7 'Hydraulic Jump or Standing Wave' were also held. Cine films of engineering interest were also shown to the officers attending the Board meeting in the Intelligence Administrative Room, Queensway, New Delhi. The Board visited the soil mechanics Laboratory of the East Punjab, Public Works Department, Buildings and Roads Branch, at Karnal, some of the houses built of stabilised soil by the same department and some works on the Western Yamuna Canal on December 12.

His Excellency Shri Chakarvarty Rajagopalacharya, Governor-General of India was at home to the members of the Board and other officers attending the meeting and their wives on December 6.

The Annual Board Dinner was held on December 7, at the Constitution House, New Delhi.

RAO BAHADUR SHRI A. R. VENKATACHARI, I.S.E., ELECTED PRESIDENT

Rao Bahadur Shri A. R. Venkatachari, I.S.E., Chief Engineer for Irrigation, Madras was elected President of the Board for 1949.

OTHER MEMBERS OF THE EXECUTIVE COMMITTEE

Kanwar Balbir Singh, I.S.E., Chief Engineer, United Provinces, Public Works Department, Irrigation Branch, was elected Vice-President. Shri A. N. Khosla, I. S. E., Consulting Engineer to the Government of India, Ministry of Works, Mines and Power and Shri P. B. Advani, Electrical Commissioner to the Government of Bombay were elected as members of the Executive Committee.

The meeting closed with a hearty vote of thanks to the outgoing President of the Board Shri A. N. Khosla, I.S.E.

FOURTH MEETING OF THE SUB-COMMITTEE ON WATER BALANCE INVESTIGATIONS OF THE DAMODAR VALLEY

The fourth meeting of the sub-committee was held on 15th April 1948 in room No. 158C North Block, Central Secretariat, New Delhi.

The following were present :—

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|-----------------------|------------------------------|
| (1) Dr. S.K. Banerji | (Meteorological Department). |
| (2) Dr. N. K. Bose | (West Bengal). |
| (3) Mr. H. J. Ajwani | (C. T. P. B. for D. V. C.) |
| (4) Mr. N. D. Gulhati | (C. B. I.) |

Mr. S. K. Guha, Chief Engineer, West Bengal, Mr. R. K. Misra of the Meteorological Department and Mr. P. R. Ahuja, Deputy Secretary, Central Board of Irrigation were present by invitation.

Dr. Bannerji was voted to the chair.

Referring to the minutes of the 3rd meeting, Dr. Bannerji reported that the officer deputed for the purpose, Mr. R. K. Misra had submitted his report on a general reconnaissance of the transpiration and evaporation losses in the Damodar Catchment. Mr. Misra, who was present, was requested to describe briefly the result of his investigation.

Mr. Misra said that his report * was the outcome of a very rapid four weeks survey of the Damodar Catchment, undertaken during last March. The idea, underlying this undertaking, was to assess the problems connected with the study of water losses by transpiration from the vegetative cover and evaporation from the bare soil over the Damodar Catchment area. He said that in the past transpiration had mostly been studied with reference to isolated plants under unnatural conditions. Little was known of transpiration from a community of plants when considered on a large scale. Hohnel in Austria had experimented between 1878 and 1880 with 5 to 6 years old seedling of forest plants transplanted in potometers. Horton (America, 1923) tried to make use of Hohnel's data by collecting some more information. His (Horton's) main object was to establish some kind of relationship between the height and diameter of trees on the one hand and the amount of water transpired through those on the other. On the basis of his conclusions Horton worked out an empirical formula whereby the transpiration from any forest could be calculated, if the height, diameter and number of trees over an area and its evaporation were known.

Transpiration loss from crop-plants (in particular) had invariably been expressed in terms of the amount of water lost per unit of dry weight of plants excluding the roots and had been variously termed coefficient of transpiration, transpiration ratio and water requirement of plants *etc.* Of course, the work was restricted to potted plants only.

Mr. Misra further said that the methods of estimation of transpiration from forests or crops was most unsatisfactory. However, in order to form a rough idea of the magnitude of the loss involved in case of the Damodar Catchment area an attempt was made by him to calculate the transpiration loss with the help of the existing knowledge. The tour of the Damodar Catchment was accordingly utilized by him to collect certain information which would help him to evaluate this loss. The information collected was :

- (i) the distribution of the area under various categories, like forests crops, fallow, not available for cultivation and waste.
- (ii) the various crops of the catchment and area under each.
- (iii) the total number of trees in the whole catchment and their average size. This was done by sampling of the vegetation at many points within the catchment, and on the basis of such information the total transpiration loss was worked out by him to be of the order of 12 inches if spread over the whole catchment of 7,200 square miles.

* An extract printed as Appendix I.

EVAPORATION FROM THE BARE SOIL

Regarding Evaporation from the bare soil Mr. Misra said " the problem of evaporation from soil surface has been engaging attention of the Agricultural Meteorological Section at Poona for a number of years. Besides many publications on the subject, Dr. Ramdas has recently tried to summarise the main results in a report on " Soil Moisture and Evaporation Investigation " presented to the Central Board of Irrigation in July 1947. He has worked out a formula whereby evaporation from any soil can be calculated provided certain factors are known.

Samples of soil from three different stations of the Damodar Catchment were collected and sent to Poona for analysis during the tour under review. The mechanical and chemical analyses of these samples are being done at the Laboratories of the Agricultural Chemist to the Government of Bombay. The Central Agricultural Meteorological Observatory at Poona is undertaking to determine certain factors which are necessary to determine evaporation. However, on the basis of some assumptions, the evaporation has been worked out, for the time being, to be of the order of 10 inches if spread over the whole catchment."

Mr. Misra concluded by saying that the total loss of water from the catchment on account of transpiration and evaporation worked out to be of the order of 22 inches or 40 per cent. of the annual precipitation of 55 inches. He emphasized once again that above derivation should be regarded as a mere guess as precise information can only be given after investigations are carried out on scientific lines. Mr. Misra's report forms an appendix to the proceedings.

Dr. Bannerji then explained various figures and tables incorporated in Mr. Misra's report. A short discussion followed and the following resolution was then adopted :

"Resolved that the sub-committee thanks Mr. Misra for the excellent study he has made in such a short time and further requested Dr. Banerji to prepare a plan of work, together with an estimate of the cost spread over a number of years, required to carry out the investigations in details.

That the estimate when ready should be forwarded to the Damodar valley corporation with a request to meet the cost of the investigations.

Resolved further that the sub-committee is of the considered opinion that the results obtained from such investigations, apart from their academic value would be of immediate use to the Damodar valley corporation for :

- (a) Determining the availability of the water supplies in the Damodar valley catchment area,
- (b) For determining water requirements of crops taking into consideration loss due to transpiration,
- (c) For determining the optimum utilization of stored waters, and
- (d) For knowing the effect of afforestation of the water balance,

Dr. Bose then reported that the Sub-Committee had previously recommended installation of 8 gauge and 4 discharge sites in the Damodar Catchment area but that Mr. Mattson, Special Officer, Damodar Valley Corporation had now asked him (Dr. Bose) to install 41 gauge and 12 discharge sites and that these proposals had been submitted to the Chief Engineer, Irrigation Bengal by him. This was noted.

The Sub-Committee was further informed by Dr. Bose that the estimate for sub-soil flow observations had not been sanctioned yet. It was decided to request Chief Engineer West Bengal to expedite the sanction of the estimate so that the work could be carried out before the Monsoons. Also that the Secretary should ask the Administrator Damodar Valley Corporation to intimate to the Chief Engineer Irrigation Bengal, as early as possible, his (administrator Damodar Valley's) willingness to accept the liabilities involved, about Rs. 24,000 (Cost of installation of pipes about Rs. 18,000 and of establishment for one year Rs. 6,000).

FIFTH MEETING OF THE SUB-COMMITTEE ON WATER BALANCE INVESTIGATIONS OF THE DAMODAR VALLEY

The fifth meeting of the sub-committee was held on August 1, 1948 at 2-30 P.M. in Kennedy House, Simla.

The following were present :

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|-------------------|------------------------------|
| Mr. A. N. Khosla | President, C. B. I. |
| Dr. N. K. Bose | (West Bengal). |
| Dr. L. A. Ramdas | (Meteorological Department). |
| Mr. H. J. Ajwani | (D. V. C.) |
| Mr. N. D. Gulhati | Secretary, C. B. I. |

Dr. Bose reported the progress made on different aspects of the investigations. He intimated that the Meteorological Department had established the observatories and rain-gauge stations. Observations at some of these observatories and rain-gauge stations were being carried out by the staff of Dr. Bose, but so far no definite arrangements had been made by the Damodar Valley Corporation with the West Bengal Government in this connection. He also said that some instruments had been stolen or damaged and that proper supervision and watch was called for. Some arrangements in this connection between the Meteorological Department and the Damodar Valley Corporation or the West Bengal Government were necessary.

Dr. Bose also intimated that the river discharge data was being collected by him at a number of sites. He pointed out that the rainfall run off and soil erosion experiments that were being carried out in the Damodar Valley before the D. V. C. came into being should be continued. He suggested that this would be of great interest to the D. V. C. He said that he had submitted an estimate for the work to the West Bengal Government for transmission to D. V. C. for allotment of funds.

With regard to the studies of the sub-soil flow in the Damodar Valley, Dr. Bose said that he had forwarded an estimate to the West Bengal Government which had presumably been forwarded to D. V. C. for meeting the cost of the work.

Mr. Gulhati said that the scheme of field laboratory in the Damodar Valley to investigate the factor of water losses by transpiration and evaporation had been received from the Meteorological Department and forwarded to D.V.C. for according sanction to the expenditure. Some correspondence on the subject had passed between the D. V. C. and the Meteorological Department. Final decision had not yet been taken. The main reasons appeared to be that the D. V. C. had just come into being. Dr. Ramdas gave some further details of the work that was being organised by the Meteorological Department in this connection. Mr. Khosla referred to the investigations he had been carrying on for some time past which revealed that temperature was an all inclusive factor in determining the losses on account of evaporation, and transpiration *etc.* It was decided that this fact be borne in mind when analysing the results.

The progress made with regard to these investigations was noted by the Committee and Mr. Ajwani was requested to see to early decisions being taken by the D. V. C. in connection with these investigations. The Secretary was also instructed to write to the Chairman, D. V. C., explaining the progress on the investigations and the difficulties that were being experienced and request for early sanction to the expenditure required for these investigations.

II—Summarized Annual Reports of Research
Stations

Central Waterways, Irrigation and Navigation Research Station, Poona

SECTION A—HYDROLOGY

(i) Total Volume of Runoff including the Standardisation of Hydrographs and their Analysis

(a) Some features of precipitational variations in the Upper Indus Catchment—a probability method of approach.

An attempt has been made to study the recorded data of 75 years (1865-1940) of all the standard raingauge stations in the Upper Indus Catchment to be able to answer some important questions for example : whether rainfall phenomena are subject to any long term or short term cyclic law and, if so, what is the most probable period of the cycle ; if not, what is the least number of years (35 years) for which the mean value is sensibly the same as of longer average ; what are the limits within which year to year variations lie ; and what is the probability of the worst year, the worst 3 and the worst 4 in a 10-year period.

The findings in brief are :

(i) The data were insufficient to establish any plausible periodogram.

(ii) The relative dispersion measures about the mean rainfalls were appreciably large and did not admit of the long term average annual rainfall being accepted as the reliable measure of precipitation to be expected in any random year.

(iii) The rainfall in a flood year could be several time the mean annual rainfall which that in a dry year could at the worst be in deficit by over the mean rainfall.

(iv) Flood years (including among them all years with rainfall exceeding the mean fall) were relatively of rare occurrence than years with rainfall in deficit from the mean.

(v) Divergence from normal rainfall were greater for stations in relatively dry zone than in zones susceptible to high intensity of rainfall.

The method of estimating the probability of the rainfall in a sequence of years fall short every time of any specified low rainfall has also been discussed.

(ii) Maximum Runoff Discharge**(a) Maximum runoff formulae and their application.**

See page 112 of this report.

3A. MEASUREMENT OF FLOWING WATER*Coefficient of discharge in Notch-type and Weir-type falls on the Mahanadi Main Canal, Central Provinces.*

Advice of station was solicited regarding the correctness of the coefficient of discharge in falls on the Mahanadi Canal data of which were analysed using the Notch (Punjab type) fall formula. It was recommended that it was better either to estimate 'C' by current meter observation or by model tests instead of estimating the discharges from the Punjab Notch formula. (for details see page 138).

4A. THE SAMPLING OF BED AND SUSPENDED LOADS*Comparative analysis of sand by Puri Sand-meter and Air Sand-meter.*

Experiments were carried out to see if a similar distribution was obtained when the same sample was analysed by the two sand-meters. It has been found that in the Air Sand-meter there is little chance of any personal error and any variations in the distribution are due to air eddies which can be minimised, if not altogether eliminated. Analysis by Puri Sand-meter is subject to three sources of error *viz.* (1) the whole sample taken for analysis is dropped altogether from the top with the result that there may be collision of particles and some coarse particles may drag along with them some fine particles lessening their velocity, (2) the time of interval of collection of particles in the troughs down to 0.24 mm. diameter is very small so that some error is inevitable in bringing the collecting trough below the vertical brass tube within such short intervals and (3) the distribution percentage of the particles at a diameter interval of $(2)\frac{1}{4}$ is obtained after drawing the mean summation curve, which may itself involve some personal error (for details see page 159).

SECTION C.—HYDRAULIC WORKS**1C—LIMITATION OF MODEL EXPERIMENTS AND COMPARISON OF MODELS AND PROTOTYPES****(a) Protecting the right bank of the Luni river at Balotra by means of a repelling spur.**

In consequence of the abnormal rainfall in the Aravali Ranges, the main line of the Jodhpur Railway between Parlu and Gole was severely damaged. The river spilled over the banks between Balotra and Tilwara causing extensive breaches. In addition to other recommendations for the protection of the railway embankment to prevent attack at Balotra a *repelling* spur was recommended in 1944. Since then, the floods in the river were very low and the spur has not been tested under high flood conditions; but even under continued low floods the spur, in the opinion of the local officers, has served its purpose satisfactorily. The main channel of the river which, even when the rainfall was normal, used to run along the side of the spur, has been repelled by the spur and now flows at a distance of 300 feet from it.

(b) Scour below the Central Sluices of the Mahanadi Anicut at Cuttack—Orissa.

Comparison of the scour patterns below the Central Sluices of the Mahanadi Anicut, respectively before and after the modifications suggested by the Station were carried out at site reveals that, while under the old conditions, the deep scour-hole (down to R. L. 25) was almost abutting the pavement, after the modifications there has been silting at this point to the extent of 20 feet.

The deepest bed contour, 260 feet away from the dwarf wall No. 4, was previously R. L. 15 : while after the modification it has accreted to 20 feet or more.

Further, at the left corner between walls 3 and 4 the apron had collapsed leaving deep scour-hole, but after the modifications at this point the bed has silted by more than five feet.

It is clear that the conditions have markedly improved since the construction of the energy dissipating device.

2C—RIVER CONTROL

(i) Flood protection works

(a) Re-distribution of sand load between the Mahanadi and Katjuri systems at Cuttack, Orissa.

Experiments were done during the year in continuation of last year's experiments to improve the distribution of sand load between the Mahanadi and Katjuri River.

With Banki Spill discharge reduced to 50,000 cusecs, Birnasi gap embankment having high level openings and Naraj waterway reduced by 20 per cent. the correct distribution of sand between the Mahanadi, Katjuri, and its branches was obtained.

A short embankment without obstructing the Birnasi gap channels ; would possibly give the optimum solution provided the Banki Spill discharge is reduced to 50,000 cusecs and Niraj weir waterway reduced by 15.5 per cent ; because it would, without materially vitiating the results obtained above, give a water front to Cuttack for which the embankment is primarily intended.

While these experiments were being carried out, a point arose for consideration whether the Khannagar Spur would still be necessary to protect the Khannagar bank in view of the Katjuri embankment developing a channel along the Cuttack bank. These experiments are in progress.

(ii) River Training Works

(a) Protecting the Right Bank of the Kuakhai River above the Bengal Nagpur Railway Bridge near Cuttack (Orissa).

The Katjuri river spills over its right bank, upstream of the Kuakhai head, the major portion of this Banki Road spill discharge finding its way into the Kuakhai above the railway bridge.

There has been erosion of the right bank above the bridge and the railway authorities pitched the right bank probably to meet the emergency as it arose ; the pitched right bank above the bridge now consists of two discontinuous portions with a gap in-between for a drain channel formed by the Banki Road spill waters.

It was feared that continued erosion would be a serious threat to the Railway embankment and the case was referred to this Station.

After experiment it was seen that the erosion was due to curved and diving flow, accentuated by the second *i.e.* upstream pitched bank protruding more into the river than it should with a proper alignment of the guide bank. This protrusion, therefore, acted like an attracting spur pulling the flow to it and causing erosion along side.

A 1,270 feet pitched guide bank normal to the bridge and joined to the Railway embankment by a 1,000 feet radius curve gave satisfactory conditions of flow at the bridge.

(b) *Protecting of the left bank of the Katjuri River at Khannagar upstream of the Katjuri Railway Bridge (Orissa).*

During the 1946 floods, chiefly owing to the sustained flood of about 12 lakhs cusecs flowing for five days, the attack on the right bank of the Katjuri upstream of the Kuakhai head moved downstream causing scour of the right bank at Kazipatana ; just downstream of the Kuakhai head, the flow was pulled by the Khannagar revetment sharply from the right bank at Kazipatana to the left bank near the Burning Ghat downstream of Cuttack causing severe damage. To prevent further damage to the embankment, extensive emergent protection works with sand bags, brush wood, temporary piles *etc.*, were done.

Suggestion was made for the modification of the alignment proposed for the retired embankment and the construction of a repelling spur near the Burning Ghat, the suggested length and alignment of the spur being subject to confirmation by model tests.

Experiments were carried out in the 1/400 : 1/66, vertically-exaggerated Mahanadi model. Various lengths and positions of the spur were tested and a 1,200 feet long spur pointing 60 feet upstream at the Burning Ghat—almost the same as suggested at site—was found to give optimum results.

(c) *Training of the Ganga River at Kanpur.*

Since 1900, the Municipal Board had been drawing water from the Ganga for the unfiltered water supply of Kanpur, situated on the south bank of the river. Up to 1912, the river course used to hug the south bank ; but since then it has been shifting northwards, necessitating the dredging of a channel to feed the pumps. During the last few years, the main current of the river has been flowing $1\frac{1}{2}$ miles to the north of the Municipal Board's pump house.

On his inspection of the river in 1941, Sir Claude Inglis had stated that the unfavourable meander conditions of the river indicated that no permanent remedy could be evolved. After the 1944 floods the river conditions appear to have improved and, accordingly, the measures suggested by this station, without model experiments, consist of a pitched " attracting " island about $1\frac{1}{2}$ miles upstream in the river and a pitched curved bank at the Pump House, provided with an adequate launching apron.

The island was suggested, because a part island—called *bund* when constructed in May 1947 by the Kanpur Municipal Board—had shown signs of improving the river curvature ; and the pitched embankment followed from the analogy of the Yamuna at Delhi where a similar design was shown by model tests to be effective in “ capturing ” the river near the Delhi Gate Pumping Station.

(d) *Kshipra River at Ujjain—Gwalior State Preliminary Note and Design of Model Scales.*

The infiltration gallery for the water supply of Ujjain is situated in the bed of the Kshipra River. In order to have an assured depth of water over this infiltration gallery, throughout the year, a barrage was constructed in 1931, half mile downstream of the gallery. The Barrage impounds water to a maximum depth of 14 feet above its sill and has only two scouring sluices at present. During the floods only the top 3 feet of *kurries* which bridge the piers of the Barrage, can be removed, thus having a permanent ponding of 11 feet of water over the barrage sill. This, however, has created a serious problem of accretion of fine silt and clay occurring upstream of the Barrage on falling floods, as also clogging of the infiltration gallery.

Moreover, the infiltration gallery is situated on the convex side at the apex of the meander and the river has been gradually receding away from it and eroding its concave right bank. This necessitates protection of the right bank, particularly of the historical observatory known as ‘ *Jantar Mantar* ’ and the proposed pumping site. To achieve this, a series of spurs on the right bank were proposed by the local officers and advice regarding their usefulness was sought from this Station in 1943.

The Station recommended construction of a single ‘ attracting ’ spur on the left bank immediately downstream of the infiltration gallery. This together with two repelling spurs on the right bank were constructed ; but before allowing sufficient time for the attracting spur to come into action the attracting spur proposed by this Station was demolished. Later, 4 additional small spurs were constructed on the right bank by the local authorities.

Hydraulic data : As in the majority of cases, the available hydraulic data are very meagre. Samples of bed sand near the infiltration gallery and a quarter of a mile upstream of the Barrage gave $n = 3.8$ and 5.75 mm. respectively the river bed slope in the reach under investigation is 1 in 2,500 approximately ; and the surface slope 1 in 4,400. There are no records of velocity and discharge observations. The maximum flood velocity, as estimated by eye by an officer, is reported to be 15 feet per second which appears much exaggerated. Similarly, the maximum flood discharge is reported to be 2.98 lakhs cusecs—presumably based on the overestimated flood velocity. The station estimate by various methods is :—

(i) From the meander length M_1 , the maximum discharge works out to 1.08 lakhs cusecs, according to the Station formula—

$$M_1 = 30\sqrt{Q_{max.}}$$

(ii) Q_{max} . according to Lacey's general flow formula

$V = 16 R^{\frac{2}{3}} S^{\frac{1}{2}}$, $V = 5.95$ feet per second and from the cross Section of the river 1,000 feet downstream of the railway bridge, Q_{max} . works out to 1.39 lakhs cusecs ;

(iii) Velocity with the Mississippi formula

$$V = [(3.0966 R \sqrt{S})^{\frac{1}{2}} - 0.0388]^2 = 5.10 \text{ feet per second.}$$

$$\text{and } Q_{max} = A V$$

$$= 2.34 \times 10^4 \times 5.10 = 1.19 \text{ lakhs cusecs.}$$

Dominant or bankful stage discharge. With the area of section up to R. L. 1575.5 i.e. bankful stage, $Q_{dom.} = 0.70$ lakh cusecs, as compared with 0.61 lakh cusecs according to the Station formula

$$Ml = 40 \sqrt{Q_{dom.}}$$

Model experiments.—With the twofold object in view, (a) of protecting the right bank and (b) of preventing fine silt deposition on the infiltration gallery, a model of the Kshipra river with horizontal scale = $\frac{1}{170}$ and depth scale = $\frac{1}{30}$ is constructed.

According to Lacey formulae, vertical exaggeration = 7.76 and slope exaggeration = 1.027 with $m = 0.5$ mm. and $m_p = 3.78$ mm.; when the model was run for proving it, it was noted that it did not reproduce prototype conditions of flow till the vertical exaggeration was 5.67 and bed slope exaggeration = 2.0.

Apart from the opinions of experienced local officers (the Sanitary Engineer and the Executive Engineer) who have satisfied themselves that the model reproduction of existing conditions is in close conformity with the prototype, there is factual evidence of the regions of attack and high velocities and the flow pattern being the same in the model as in the river.

Experiments for training measures are in hand.

(e) *Measures for arresting bank erosion near Bhadeli and Bhagda villages on Auranga River*

With a view to provide local protection to the properties on the banks of the Auranga River, near Bhagda and Bhadeli villages, groynes were constructed on both the banks from time to time. These behaved satisfactorily but the erosion, as usual, moved downstream ; and to prevent consequent damage, new groynes were proposed to be constructed on both the banks by local officers.

It was recommended by the Station that one 60 feet and two 100 feet long groynes, 330 feet, 440 feet and 440 feet apart respectively and pointing 45°, 60° and 60° upstream should be constructed on the left bank and their positions were indicated. All these groynes were provided with flat noses and adequate apron protection.

On the right side two groynes similar to those on the other bank but oriented normal to the bank were proposed. In addition to these, a third groyne inclined at 60° , pointing upstream was considered necessary to "throw off" the flood water away from the bank.

(f) *Protective measures for several Railway Bridges on Madras-Bombay Line of Madras and South Marhatha Railway, between miles 82 and 113.*

A number of bridges between Pudi and Urampadu on the Madras-Bombay line of Madras and South Marhatha Railway were severely damaged in December floods of 1946. Advice of the Director was sought on the remodelling proposed to be done. The recommendations on points common to the design of several structures are summarised below :

(1) In absence of observed flood discharge data and in view of the unreliability of the empirical formulae like Ryves', wherein much depends on the correct assumption of the coefficient, station recommendations were based on discharges computed by the proven station formula of normal floods.

(2) For the necessary bridge widths, natural stable widths of the waterway for the conditions obtaining on the particular rivers were estimated.

(3) Most of the bridges have open foundations carried to depths which have little relation to the conditions obtaining at the bridge. Maximum scour round piers in the station proposals was estimated at $2R$, where $R = 0.47(Q/4)^{1/2}$ and a further grip of R below this anticipated scour was suggested.

(4) High level pavements and pitching were suggested to be avoided.

(5) All piers to be newly constructed were recommended to be built with right-angled curved noses, being economical and easier to construct and not significantly less efficient than the design with 'equilateral arcs of a circle', where flow was expected to be axial ; and where flow might be skew, semi-circular cut-and-ease waters were suggested.

(6) A minimum free board of two feet above the maximum anticipated H. F. L. was recommended.

(7) All borrow pits on the downstream side, and within 200 feet of the embankment on the upstream side were suggested to be avoided.

In addition to these general observations, specific advice was given in particular cases. In some cases, river training measures were suggested without model experiments ; and in one case model experiments were recommended.

(g) *Training of the Tapti River at Surat (Bombay)*

A brief history of the damage caused by the Tapti river in the vicinity of Surat since 1937 and the remedial measures tried by the P. W. D. Officers, with little success, is given in the Report,

The Station was ultimately approached for advice regarding the appropriate measures for arresting the bank erosion at Rander and Bhatpur, the undermining of foundations of buildings on the Surat bank below the Hope bridge and the suitability of the site proposed for the Pump House of the proposed thermal electric power station.

A river model of the reach from Kathor to the sea is constructed at the Poona Station to evolve and test the necessary measures. The scales finally adopted are :

$$\text{Horizontal scale} \quad L = \frac{1}{330}$$

$$\text{Vertical scale} \quad D = \frac{1}{72}$$

$$\text{Vertical exaggeration, } V. E. = 4.58$$

$$\text{Slope exaggeration, } S. E. = 2.5$$

$$\text{Discharge scale} = LD\sqrt{D} = \frac{1}{202,000}$$

$$\text{Time scale} = 1 \text{ hour in river} = 3.22 \text{ seconds in the model.}$$

$$\text{Sand charge} = 0.04 \text{ part per 1,000 by weight at the dominant discharge of } 2.98 \text{ cusecs} = 500,000 \text{ cusecs.}$$

There was satisfactory bed movement in the model and flow lines observed in the river, when compared with those in the model, showed close conformity between the model and prototype.

The model indicated that the bank erosion at Rander and Bhatpur is due to high velocity flow hugging the bank ; while undermining on Surat bank below the bridge is due mainly to a direct attack by the main flow diving at the bank. The proposed location of the pump house near Umra was found to be in the transition reach where the main flow crosses over from the left to the right bank and thus somewhat downstream of the suitable position.

Exploratory tests indicated the following tentative training works :

- (1) A repelling groyne at Rander.
- (2) A similar groyne or an island in mid river somewhere between Makhi Khadi and the District Judge's Bungalow, below the Hope Bridge.
- (3) A pitched island or other training works for protecting Bhatpur bank.

Detailed experiments are in progress.

(iii) Scour and Erosion

(a) *Mid-season scouring operations of Right pocket of Sukkur Barrage—Sindh*

The Sukkur Barrage authorities have had under consideration the proposal of additional scouring operations of the Right pocket of Sukkur Barrage in the months of June, July and August *without closing the canals*, in the hope that these flushings would keep the pocket clear and thus continuously provide a silt trap where silt may deposit instead of being carried into the canals.

Waterway areas in the Right pocket, at various cross-sections at Right angles to the lines of flow, as observed in model before and after scouring operations similar to those done at the Barrage in September in the years 1945 and 1946 showed that considerable silting took place up to about 900 feet upstream of Barrage ; beyond 900 feet there was little change in bed levels. The analysis, however, showed that the stable section finally attained *i.e.*, before annual scouring operations, still provided sufficient cross-sectional area required according to Lacey's formulae.

Also, there was no such progressive reduction of area in the pocket as to threaten the working of the right bank canals. Original bed levels restored after the September scouring.

Flushings in June to August are, therefore, not necessary nor would they materially affect the sand charge in the canals, as the additional cross-sectional area obtained in the pocket after scouring will be quickly filled up. Moreover, the suggestion that the scouring should be done with canals open is demonstrably undesirable—as the Model clearly showed—because heavy sand charge is thereby drawn into the pocket, a large part of which enters the canals.

(b) *Apron design for the South guide Bank of the Alexandra Bridge on the Chenab, (N. W. Railway).*

The cold weather survey of 1947 of the Chenab river at Alexandra Bridge revealed that the apron of the left guide bank between chainages 6 to 9 and a chainage 12 had launched to a slope steeper than 2:1 for which it was originally designed. The Director's opinion regarding the necessity of providing additional stone to ensure adequate protection to the guide bank was, therefore, sought.

With parallel flow conditions, the stone pitching is expected generally, to assume a side slope of 2:1. In the present case, however, the main current after leaving the Pindi Spur nose on right bank about one mile upstream of the bridge flows across towards the left bank upstream of the left guide bank, creating severe curved flow conditions. The profile of the guide bank generally associated with such conditions is *curved* in cross section, as in the present case. This, in itself, should not be a source of anxiety unless accompanied by other signs of weakness or instability such as insufficiency of stone thickness of the launched apron

With curved flow, conditions similar to those at the head of a long-radius guide bank are obtained and as maximum scour in such a case is observed to be of the order of $2R$ Lacey the apron should be designed for scour below H.F.L.— $2R$, R being the Lacey normal depth—and which in this case = 45 feet below low water level.

It was, therefore, recommended that :—

(1) provided there are no signs of weakness, it is not essential to endeavour to maintain the launched apron to the unnatural slope of 2:1 in continuation of the permanent slope ; but

(2) additional stone apron should be provided up to a distance of

(a) 68 feet (1.5×45) from the present toe of the launched apron.

or

(b) to the bottom of the scour if it be deeper than 26 feet—8 inches below low water level— $1.5 R$ Lacey—whichever is more.

(c) Scour below weirs by N. K. Framji.

(Not included in this Report).

(vi) Tidal action including that in estuaries

(a) *Measures adopted to reduce turbulence in the Hooghly river downstream of the Knuckle at the Titagarh Jute Mills.*

The paper describes the experiments carried out with 1/300 : 1/60 scale model and the 1/150 : 1/80 part-length model of the Hooghly to test the effects on the flow conditions at the knuckle at the Titagarh Jute Mills of (a) a series of islands and (b) a continuous separating wall. The experiments showed that the conditions are so set that no practical solution at reasonable cost appears feasible.

(b) *Preliminary Note on the Cochin Harbour Model.*

Describes the problem and the method of selection of scales for the model.

4C--DAMS AND WEIRS

(ii) Design

(a) *Proposed design of Lower Sind Barrage at Kotri for effective sand exclusion from canals.*

Model experiments were carried out for determining the salient features in the design of the barrage such as (a) sills of head regulators, (b) design of left and right pocket and the optimum number of spans, (c) long pocket versus short pocket, (d) design of guide banks, (e) location of the left abutment, (f) left and right pocket divide wall, (g) river conditions after the construction of the barrage (h) regulation of the barrage and the necessity or otherwise of keeping the pocket gates higher than the other barrage gates ; and (i) necessity or otherwise of paving the bed of the pockets. Studies made on each of these items are described in detail.

(b) Regulation of the Kotri Barrage—'still pond' or 'semi-open flow' and consequent height of pocket gates

The design of the Kotri Barrage was for 'Still pond' regulation up to the normal highest river discharge of 565,000 cusecs, requiring the pocket gates to be four feet higher than the other Barrage gates.

A few quick tests indicated that "semi-open" flow regulation was quite as good for sand-exclusion as 'Still pond' in the Kotri Barrage design and was recommended as it would cause less heading up, reduce the differential head across the divide wall, reduce shoaling in and downstream of the pocket and keep flow active along the guide bank.

Further consideration and more detailed model examination were, however, necessary in view of the experience at the Sukkur Barrage where it was found necessary to raise the right pocket gates by adding pieces at the top in spite of the pocket gates being originally three feet higher than the river gates.

Restricted 'semi-open' flow is possible at Kotri on both the banks because conditions obtaining at Kotri are more favourable owing to (a) the higher $\frac{V_R}{V_P} / \frac{V_{RO}}{V_{PO}}$ ratio; (b) the curvature being accentuated by the Central Dividing Island, and (c) the left pocket being substantially shorter than that of the Sukkur Barrage.

Before recommending 'semi-open' flow regulation the proposal was again *critically* examined on the model to answer the following questions:—

- (i) Should the design be based on 'Still-pond' regulation for all river stages; if not, up to what river stage will Still pond regulation be necessary?
- (ii) Is it desirable to keep the pocket gates 2 feet (or more) higher than the river gates?

The experiments showed that conditions at Kotri were better than at Sukkur and that restricted 'semi-open' flow is as good as 'Still pond' flow for sand exclusion on both the banks. Further even with restricted 'semi-open' flow, it would be necessary to keep the pocket gates at least two feet higher than the barrage gates.

6C—SPILLWAYS

(a) Automatic gates on Tansa Waste Weir, Bombay-Experiments with half-size-model

In order to provide partial relief against the acute water shortage facing the Bombay City, it was decided to increase the storage capacity of the Tansa Lake by installing automatic gates on the waste weir. The paper describes the experiments carried out for the design of the automatic gates.

(b) Preventing scour below volute siphon spillways by fanning out jets with dispersers and ledges

In the experiments carried out, jet dispersers, with and without a tilting ledge, were fixed at the siphon outlets so that the jets were spread out evenly, and at the same time deflected upwards at various angles, before unpinging. This resulted in reducing the intensity of the jet and in lesser scour downstream. There was a small reduction in the coefficient of discharge.

8C—CANAL FALLS

Basic experiments were started with a view to (i) study the effect of expanding the hyper-critical jet above a fall, (ii) devise means of preventing the tendency to erode the banks which cause embayments downstream of flumed vertical falls and (iii) evolve an economical design of a non-flumed, baffle type fall.

Experiments are yet in progress.

10C—SILT EXCLUDERS AND EJECTORS

- (a) *Comparative sand-exclusion at the nose and at the raised sill of the Approach Channel under present conditions and with the outer bank extended to position. Q—Experiments in 1/80 : 1/40 part-width Sukkur Barrage Model.*

Under existing conditions, at the entrance of the Approach Channel, there is a scourhole about 75 feet deep at its maximum, with high velocity flow in the middle of the Approach Channel and return flow along the nose and the right bank. Berms which formed due to the slack return flow along the right bank 'slipped' into the deep scour hole in 1945 and 1946, and the Burder wall and Sukkur road were consequently damaged.

To prevent this, last year's model experiments showed that the extension of the Outer Bank by about 500 feet ending in a nose with 5:1 slope on the Approach Channel side would be a satisfactory solution.

Three experiments were carried out to test the effect of the extended bank on sand exclusion.

The experiments showed that the extension of the Outer Bank as recommended will not only prevent slips in the Right Bank but is expected substantially to improve exclusion at the nose and at the raised sill.

- (b) *Effect of change in regulation operations of the Right pocket on sand exclusion — experiments in 1/80 : 1/40 part-width, Sukkur Barrage Model.*

Since the construction of the Approach Channel, the usual practice is to carry out the annual scouring operations of the Right pocket with max. pocket discharge of 27,000 cusecs and tail channel discharge of 18,000 cusecs, and canals closed, in the middle of September. The pocket thus flushed remains clear up to the next floods when due to the excess silt charge it gets silted up very quickly. Even then a stable channel sufficient in waterway to carry the pocket discharge is maintained; there is no progressive reduction of area of the pocket and original bed levels are restored after the scouring operations.

The Barrage authorities, however, desired additional scouring operations of short durations in June, July and August, with the implied object of having a reserve for silt deposition on the bed of the pocket which, in their opinion, would be otherwise carried into the canals.

The conclusions arrived at from model studies were (i) Either increase in the pocket discharge or the reversal of pocket to Tail Channel discharge ratio would lead to deterioration in sand-exclusion from the right pocket, and (ii) scouring operations with canals open were undesirable.

(c) *Supply of sand-free water to Jamshedpur Power House.*

Water for the Tata Steel works is pumped through 4 feet C. I. Main with its open end located midstream, above a weir across the Subarnrekha river near Jamshedpur. In floods a heavy charge of bed sand is drawn in, which causes severe wear and tear of pump casings and impellers, necessitating restricted pumping and prompt removal of the accumulated sand in the suction chamber. The case was referred to the Station for suggestions as to how to insure relatively sand-free supply of water at all river stages. Two alternative designs suggested without model experiments have been described.

12 C—OTHER WORKS .

(a) *Experiments to test the suitability of the position of the Lock-span proposed in the Sind design for the Kotri Barrage.*

Experiments for testing the practicability of the position of the Lock-span proposed by Sind, just outside the left Pocket Divide Wall, were carried out in the 1/250 : 1/50 V.E. model with the length of the Fender Wall \approx 210 feet. It was observed that the Lock-span located outside the Divide Wall could not provide workable conditions required for safe approach by vessels owing to the curved, diving, persistently turbulent flow at the noses of the left Pocket Divide Wall and the Fender Wall.

The three following positions were, therefore, next considered :—

- (i) the Lock to be in the head reach of the Right Bank Feeder with two approach channels connecting to the upstream and the downstream river channels. This position, though sound economically and hydraulically, was ruled out owing to the possible interference to the working of the canal and the probable silting at the entrance and or exit of the approach channels ;
- (ii) the second position tried was at the extreme right end of the left arm barrage ; but this was also found unsuitable owing to the turbulence along the shanks of the Central Island, the misgivings about the availability of the draft downstream and the risks to be encountered in manoeuvring along the invisible slopes of the shank ;
- (iii) the third and best site was just inside the left Pocket ; its advantages being the relatively less turbulence, the availability of ample space, and the existence of the deep channel along the left guide bank.

Rigorous model tests were, none the less, made to insure that the required draft would be available, even when the Pocket gates silted to the maximum likely extent.

Experiments were also carried out for determining the optimum length of the Fender Wall with the main object of avoiding danger by suction and providing satisfactory approach conditions by ensuring sufficient draft at the entrance to and in the approach. A length \approx 230 feet was found suitable in these respects. A length \approx 290 feet was found suitable for the downstream Lock wall as its nose would then be about 155 feet from the nose of the downstream Divide Wall of the left Pocket and so sufficiently away from the danger zone of turbulent flow.

(b) *Proposal for a combined road and rail bridge over the river Ganjya at Patna or Mokameh Ghat.*

(see page 975).

SECTION F—WATER UTILISATION PROJECTS

1 F—STUDY OF INDIVIDUAL PROJECTS

(a) *The Sakri River Project (Bihar).*

An inundation canal of capacity of 1,000 cusecs, with scope for modification for future increased demands up to 2,000 cusecs, is proposed to be taken off from the Sakri River in Bihar. Advice was given by the Station on the various works connected with this project.

For suitable, effective and permanent sand exclusion the head regulator was recommended to be positioned towards the lower end of a suitably concave bank, the canal being made to take off as tangentially to the river as possible, so as to draw off only top, sand-free water.

The width of the head regulator was designed to pass proportionate river discharges at all flood stages. The sill of the regulator was kept six inches above the bed.

Various alternative canal designs were made; the one finally adopted being chosen in light of the several considerations guiding the canal design. The proposed canal has the following dimensions as recommended by the Station:—

Bed width—120 feet.

Slope—1 in 2,500

Depth for 1,000 cusecs = 3.22 feet.

Velocity with 1,000 cusecs in the canal = 2.61 feet per second.

The canal alignment suggested by the local officers appeared suitable except in one reach where being dangerously near the river, it was proposed to be sufficiently retired inland.

The *pucca* datam—i.e. a dwarf wall across the river bed—proposed by the Project Engineer with a view to maintain the river bed at the regulator sill level was advised to be provided with suitable protection against scour and undercutting.

The right bank above the regulator was proposed to be pitched and provided with necessary apron to maintain the present favourable and smooth approach.

(b) *Indus water to Cutch State—A note on the possibility of bringing.*
(See page 425).

Hydraulic Research Station Krishnarajasagar

SECTION A—HYDROLOGY

2A—RIVER BEHAVIOUR

Afflux observations of floods of the Cauvery river at its junction with the Krishnarajasagar Reservoir.

Observations had been conducted for a period of five years and these had shown that variations of afflux were due to various factors and the maximum possible afflux did not exceed six inches.

3A—MEASUREMENT OF FLOWING WATER

(a) *Design of a standing wave flume for measuring discharge in the main river. Distributory of the Irwin Canal*

Describes the design of the standing wave flume (for details see page 147).

5A—REGENERATION AND LOSSES

(i) Seepage Losses

Sweating from Krishnarajasagar Dam.

The Data collected during 1947 showed that there had not been any appreciable decrease or increase in the rate of sweating (for details see page 176).

(ii) Evaporation Losses

Experiments conducted at Krishnarajasagar

Studies were made to find (1) whether the evaporation from the lake was the same as that from a pan and (2) whether the size and type of pan had any effect on the result. The observations made revealed that the size of the pan has influence on the amount of loss and not the type. The rate of loss as recorded between six feet diameter and three feet diameter was 9 : 10. It was settled that for calculation of evaporation from a reservoir a correction coefficient of 0.85 should be applied to the results obtained from pan experiments (for details see page 195).

SECTION C—HYDRAULIC WORKS

5C—DAM APPURTENANCES

(i) Inlet and Outlet works

Bumping of plus 12 gates in Krishnarajasagar Dam.

(see page 809).

6C—SPILLWAYS

(a) *Further experiments on the dissipation of energy of flow from siphon outlets*

Three methods were tried for the dissipation of energy of flow from siphon outlets viz. (1) supporting the jet on an Ogee profile, (2) Formation of a standing wave and (3) submersion of outlet. It was found that No. 1 was expensive

and the flow did not fan out well, No. 2 was satisfactory but costly and No. 3 was very effective and in the 18-inch model tested the priming depth was only $\frac{1}{2}$ inch against the usual three inches.

(b) *Design of volute etc. in siphons.*

Mathematical solutions have been worked out for (1) the relation between the barrel diameter and the head, (2) design of the funnel, (3) volutes etc.

(c) *Experiments on the high-head siphon at Shimsha.*

(see page 892).

(d) *Further experiments on siphons with various funnels and outlets.*

With a view to improving the priming depth, investigations made with regard to the volutes and outlets were (i) in the light of mathematical solution given in (b) above, (ii) external volutes, (iii) turbine siphon, (iv) siphon with clockwise volutes and (v) siphon with rectangular outlet.

Experiments for (i) showed that while there was a uniform filament of water all round the throat having both twisted motion and creation of water seal, some filaments of water sticking the noses of the volutes, were deflected and thrown towards the centre, the whole thing appearing as a set of petals of a flower and behaving as a device to entrap and drive the air out effectively.

In (ii) the siphon primed early enough for a depth of $1\frac{1}{2}$ to 2 inches because of the absence of the funnel. It was found that the effect of volutes before priming is very little and after priming they induce terrible vibrations in the dome. The coefficient of discharge is low *i.e.* 0.65. Raising the dome by two inches, however, decreased the vibrations considerably.

It was found that (iii) required considerable priming depth and (iv) and (v) did not help in improving priming depth.

(e) *Design of a high co-efficient weir and scour preventer for the Tunga Anicut.*

A number of investigations were made with the help of small models in order to design a high coefficient weir for the Tunga Anicut, the idea being (i) to cut down effectively the length of spillage and hence the area of land to be acquired and (ii) to increase the storage in order to supply sugarcane crops with dry season. Various experiments conducted showed that (i) a parabolic profile at the crest of the weir gives a higher coefficient than the circular and elliptical one, (ii) rear slope should be 1.5 : 1 and (iii) the protruding lip at the top increases the coefficient of discharge negligibly. Also are described the experiments carried out for scour prevention downstream with upturned bucket.

13C—STAUNCHING OF CANALS AND EMBANKMENTS

Experiments continued with staunching of canals with surkhi mortar.

The observations show that the seepage losses through the concrete lining are practically steady year after year.

SECTION E—SOIL SCIENCE

1E—SOIL MECHANICS

(i) Fundamental Research

Economical limit of rolling by sheep's foot rollers.

Experiments have been conducted to find out how the compacted depth of soil decreases with the number of rollings. It has been found that the first 10 rollings will consolidate the soil 50 per cent. more than the next eighty-five rollings. It has been concluded that it is desirable to determine the economical limit of rolling for a moisture content and insist on the same thickness and number of rollings throughout the consolidation.

(ii) Earth dams and embankments

Hydraulic gradients through earth bunds.

Experiments were conducted to determine (a) the effect of berms, and (b) the position and the size of jelly drains on the hydraulic gradient in an earthen bund. It has been found that (1) the effect of adding berms is to depress the saturation gradient in a bund and it is better to add a number of berms of small widths in preference to a few of larger widths, and (2) the effect of jelly drains is to lower the saturation gradient considerably, providing a safe exit for the seepage water. In locating the position, care should be taken that the velocity of the seepage is not too large to carry away particles of bund-earth with it.

Further experiments conducted to determine whether stone revetment on the front face of the bund creates any loss of head at entry of the seepage water into the bund indicates that there is no such appreciable loss.

Hyderabad Engineering Research Laboratories

SECTION C—HYDRAULIC WORKS

2C—RIVER CONTROL

(ii) River Training works

Musapet Anicut System.

Two seasonal and flashy rivers, Kapeta Vagoo and Palkampali Vagoo separate immediately after meeting to join again a few miles downstream. About half a mile downstream of the separation, an anicut has been constructed across the right stream to supply water to a series of eight tanks in Musapet village of Mahbhubnagar district and a weir was constructed across the left stream just below the point of separation to assure adequate supplies of water reaching the anicut. During floods this latter weir has been outflanked and as a result the bed of the left stream has eroded and the bed of the right stream silted up so that every little water finds its way to the anicut and that only in high floods, and most of the water flows along the left stream. Describes the small pilot model experiments carried out to devise means to encourage the silting up of the left stream so that more water can be drawn from the anicut on the right stream.

4C—DAMS AND WEIRS**(ii) Design***Spillway dam of Mandir Irrigation Project*

While the foundations of the spillway dam were being excavated, it was found that for a length of nearly 250 feet a horizontal fissure with a *morrum* seam occurred in the sheet rock foundation. It was considered inadvisable to construct the spillway dam on such a poor foundation and it was decided to alter the profile to give a higher coefficient so that the length of the spillway dam may be reduced. Experiments carried out on models regarding the variation of the coefficient of discharge with different profiles and heights of the dams are described.

6C—SPILLWAYS*High coefficient weirs for irrigation tanks.*

Describes the experiments conducted to evolve a type of weir that will give a coefficient of discharge of 4.64 under a head of 2.5 feet.

7C—HYDRAULIC STRUCTURES ON PERMEABLE FOUNDATIONS*The lines of flow under causeways on sand foundations*

The aim of the investigations was to determine the lines of sub-soil flow of water under masonry structures founded on permeable foundations like sand by utilizing the analogy between electric flow and hydraulic flow. Describes the arrangement of the apparatus used and gives the results.

SECTION D—WATER POWER WORKS**2D—POWER HOUSE AND EQUIPMENT****(iv) Turbines***A simple turbine for small canal drops.*

Investigations were undertaken to evolve a suitable type of turbine that could be used on small drops and at the same time be simple and capable of being repaired and maintained by clever artisans of the rural areas. On account of simplicity impulse type of turbine was selected. Experiments were conducted with a six-inch runner working under a head of nearly 2.5 feet. The number of blades was varied from 32, 24 and 20 for finding their optimum number consistence with efficiency. Experiments are yet to be continued before a highly efficient turbine can be designed (for details see page 296).

SECTION E—SOIL SCIENCE**1E—SOIL MECHANICS****(i) Fundamental Research***Stabilised soil as a building material.*

Three soils *viz.*, (1) gravelly sandy loam, (2) gravelly sand and (3) soil by mixing locally available *morrum* and soils (1) and (2) in 2:1 proportions, were tested for determining the optimum percentage of cement with a view to see the suitability of these treated soils as a building material. It was found that the suitable percentage of cement for use with the above soils was 7.5 per cent., 8 per cent. and 9 per cent. respectively. The compressive test values of the stabilised soil moulds indicated that they compare well with the local burnt bricks (for details see page 321).

(ii) Earth dams and Embankments*(a) Testing for earthen dams.*

(see page 336).

(b) Experiments with soil samples of Nelligudda Reservoir.

(see page 337).

(iii) Roads and Runways*Stabilised soil roads.*

A preliminary experiment for the improvement of road berm was conducted on a 100 feet long and a 10 feet wide strip of a berm on a cement concrete road in the Hyderabad City. For determining the suitability and grading of soil, A.S.T.M. specifications were followed. The soil of the base cover was found to be of A.S.T.M. grade C. A soil in the vicinity with high percentage of gravel was selected and used with the proper percentage of cement stabilizer for wearing course. The work was conducted with modern earth moving and other machinery as far as possible. After actual use of the stabilised road it has been found that the use of cement as stabiliser with soil of low plasticity index or with low clay content disintegrates readily under traffic forming dust in dry weather.

Irrigation Research Institute East Punjab

SECTION A—HYDROLOGY

2A—RIVER BEHAVIOUR

Time lag as a function of discharge.

As a preliminary to determining the real generation in the Kalabagh—Ghazi Ghat reach of the river Indus, the time lag between Kalabagh and Ghazi Ghat was studied for the years 1931-32 to 1945. It has been found that in this reach time lag is a definite function of mean discharge in thousand cusecs.

5A—REGENERATION AND LOSSES

(i) Seepage losses

Data of seepage losses available in the East Punjab Irrigation Research Institute.

(See page 174)

(ii) Evaporation losses

Note on investigation on evaporation losses.

Describes the studies made on the following aspects :

(1) The depth of the water table from which water could be drawn to the soil surface by evaporation and how far the quantity of water so drawn could meet the requirements of moisture needed for cultivation.

(2) The effect of evaporation on the movement of water table in initially saturated, stratified and unstratified soil columns composed of various grades.

(3) The effect of particle size, depth and stratification of soil, on the intensity of evaporation from initially saturated soil columns.

(For details see page 185).

8A—QUALITY OF WATER IN RELATION TO

(a) Crops

Quality of irrigation water.

Describes the results of analysis of soils after first, second and third rice crops with respect to *pH* value, exchangeable basis, salt index *etc.* (see page 222)

SECTION B—THEORY OF FLOW AND DESIGN OF CHANNELS

1B—FLOW IN RIVERS AND CANALS

(ii) Flow in channels in incoherent and coherent alluvium.

Estimation of silt particle size from settling velocity.

So far the size of a silt particle has been estimated by observing its settling velocity in a water column, applying Stoke's formula and then a correction factor which is a function of the Reynold's number for the particle. The number is worked out with Stoke's diameter instead of the actual diameter, which is known, thus introducing an approximation of which the effect, however, was believed to be small.

In this paper a new method which gave the exact sizes in all cases has been formulated.

SECTION C—HYDRAULIC WORKS**2C—RIVER TRAINING****(iii) Scour and erosion**

Model of the bridge on the river Ravi at Madhopur.

(see page 671).

3C—SILTING OF RESERVOIRS.**(i) Sedimentation of Reservoirs**

Rate of silting of reservoirs.

The rate of silting of Elephant Butte Reservoir is shown to have gradually declined during the period 1915-1940.

4C—DAMS AND WEIRS**(ii) Design**

(a) Hydraulic design of the Nangal Barrage.

The design of Nangal weir as made out by the Central Design Office was scrutinized and a summary of the review regarding discharge coefficient, energy calculations for finding cistern level and glacis profile are given.

(b) Model experiments on Nangal Weir.

Model experiments to determine the suitability of the design in respect of (i) the coefficient of discharge, (ii) the depth of scour for various discharge intensities, (iii) pressure distribution on floor and (iv) regulation of double gates were carried out. The paper describes the experiments and tabulates the results.

6C—SPILLWAYS

Siphon Spillways Formulae.

Formulae have been derived for the maximum range of the jet and the corresponding elevation of the nozzle, and are reduced to simple geometrical constructions.

8C—CANAL FALLS

Mathematically it has been worked out that all elements of a standing wave can be expressed in terms of single parameter.

10C—EXCLUDERS AND EJECTORS

Model of Nangal Canal Excluder.

Experiments were carried out on a complete model of the Nangal Barrage to find out current direction, movement of bed material and ramp formation against the canal regulator, as a prerequisite to the design of the excluder. Experiments show that to have the desired curvature of flow in the pocket, the gates on the right should be given greater openings.

13C—STAUNCHING OF CANALS AND EMBANKMENTS**(i) Materials***Tests on materials for staunching of canals and embankments.*

The following materials were tested.

- (i) Bitumen and Tar-impregnated fabrics.
- (ii) Soil-cum-shell stabilizer.
- (iii) Soil-cement mix.
- (iv) Soil sand-cement mix.

The tests performed to examine their suitability as canal lining materials were (a) Determination of seepage losses under different heads of water and varying conditions of temperature ; (b) Deterioration tests under wet and dry conditions ; and (c) Coefficient of expansion with respect to moisture.

The device used for determination of seepage losses was so improved as to eliminate the sources of error inherent in the previous arrangement.

None of the Burmah Shell fabrics gave satisfactory results while six out of eleven Shalimar specimens gave no seepage upto 20 feet head of water. These latter samples showed no signs of deterioration after prolonged immersion but softened at high temperature on exposure to atmosphere.

The soil-shell stabilizer mix gave low seepage values and softened after continuous immersion in water.

The soil-cement (100 : 5) type of lining was found to be quite impervious up to 20 feet head of water and did not deteriorate on immersion in water. Cracks, however, developed in it (penetrating down to a depth of two inches) on drying in summer. These tests remain to be carried out in the field.

In order to reduce the tendency of cracking in soil-cement mix, a third constituent, namely sand, was added to it. Different proportions of soil and sand with 5 per cent. cement were tried with some success. Further experiments are to be continued.

(ii) Economics*Most economical section for a lined canal.*

The most economical section for a lined canal has been studied. The theory for the Haigh-type lined section has been worked out and its shortcomings located.

SECTION E—SOIL SCIENCE

1E SOIL MECHANICS

(i) Fundamental Research

Hardness of the soil crust.

The experiments showed that there was a significant and positive correlation between the dry bulk density, sticky point and cohesion. On the determination of partial coefficient it was concluded that the dry bulk density was independent of the sticky point and depended upon cohesion only.

(iii) Roads and Runways

Standardization of specifications of earth roads under Punjab conditions.

The study concerned itself with the investigations of the soil specifications for surface course of the earth roads under Punjab conditions. The most important conclusion was that all soils could not be classified adequately for road building purposes by physical tests alone and that the chemistry of soils should be considered in such cases.

2E—MOVEMENT OF MOISTURE IN SATURATED AND UNSATURATED SOILS

Effect of various soil factors on the field capacity in soils.

The effect of various salines and humus was determined. The results showed that there was an appreciable decrease in the field capacity of soils by the addition of sodium chloride, while sodium sulphate did not affect it very much. Calcium sulphate increased the field capacity to a very small degree. There was gradual increase in the field capacity with the increase in the humus.

3E—LAND RECLAMATION

(i) Saline lands

(a) The occurrence and significance of Boron in Punjab soils.

Soil samples bearing different types of natural vegetation were analysed and the main conclusions were : (1) Boron was present in the Punjab soils as a trace element even to a depth of 4.0 feet, (2) the calcium boron ratio of the deteriorated soils was considerably lower than that of the fertile soils.

(b) How far a leguminous crop could restore the nutritive elements in a soil depleted of its nutritive elements by the process of reclamation.

It was concluded that the gram crop proved great ameliorative and the nitrates and the available phosphates were sufficiently restored. For any successful reclamation, the inclusion of leguminous crop in the usual rotation is thus very essential.

(c) Correlation of the yield of gram with soil factors.

There was no relation between the yield of gram and the percentage of soluble salt-content of soils, pH and calcium carbonate.

Irrigation Research Station Madras

SECTION A—HYDROLOGY

3A—MEASUREMENT OF FLOWING WATER

(a) *Coefficient of discharge over anicuts—Shiriya Anicut.*

Experiments were carried out on models of the proposed Shiriya anicut to find (1) the afflux for various discharges over a broad-crested weir and over a high-coefficient weir for free over fall conditions and (2) the effect of submergence on the coefficient of discharge. It was concluded that with ogee profile a high coefficient of discharge was obtained which remained unaffected for small rates of submergence (for details see page 139).

SECTION C—HYDRAULIC WORKS

4C—DAMS AND WEIRS

(i) Investigation

Whirlpools over the Sangam Anicut across Pennar.

For studying the formation of whirlpools near the left abutment of the Sangam Anicut and its effect on the stability of the anicut, a full model and a part model with rigid beds were constructed and prototype conditions were reproduced on them. The performance of the model is described.

(ii) Design

(a) *Uttiramarur Anicut across the Cheyyar—downstream protective works.*

Model experiments were carried out to examine the adequacy, or otherwise of the protective works downstream of the anicut and to reduce the cost of construction as much as possible. A revised design was evolved as a result of these experiments which consisted of bucket and stilling pool.

(b) *Stilling basin for Malapuzha overflow dam.*

A series of experiments were carried out for obtaining an efficient design for a stilling basin for the Malapuzha overflow dam. This was a typical case of a dam with a small overflow depth. The observations made in the several experiments showed that a vertical sill induced a high standing wave accompanied by a dive and secondary waves that a sloping sill or a shallower cistern resulted in the bodily deflection of the shooting jet for certain discharge conditions. A stilling basin having a bucket on it upstream and a stepped sill at the bed followed by an apron was found to be satisfactory.

(iv) Investigations

(a) Cofferdam for the Ramapadasagar Project.

Experiments carried out on a 1/150 scale geometrically similar model of the Godavari river to test the design of the West Channel Cofferdam for the Ramapadasagar Project are described. This model has a better performance than the smaller 1/300 scale model tested in 1946 and confirmed qualitatively that the alignment was all right. For getting more reliable values of afflux, depth of scour *etc.* the studies were proposed to be repeated with simulation of bed movement effected by tilting the model. These studies are in progress.

(b) Ramapadasagar Dam—Seepage into the excavation pit.

A three dimensional seepage model of the Ramapadasagar Foundation Trench was constructed. Rock, clay and sand contours as surveyed by the penetrometer tests were reproduced to scale, coffer dams were fitted and excavation and pumping simulated. The observations showed that toe protection and pumping underneath the slope were both necessary for maintaining the slopes of excavation stable. The model also indicated the economics of pumping in various combinations.

5C—DAM APPURTEANCES

(i) Inlet and Outlet works

Ramapadasagar Dam—River outlets and density current.

Experiments were taken up on a model of the final design of the dam consisting of 16 vents of spillways (each 135 feet by 28 feet) and 160 sand sluices (each 10 feet by 20 feet) with a view to test its performance in the several aspects of design and specially in the disposal of density currents. A method was evolved after a series of trials of producing density currents whose characteristics could be measured and recorded.

(v) Other works

(a) Ramapadasagar dam sand sluices.

The tentative design of the Ramapadasagar provided for sand sluices 10 feet by 20 feet in the body of the spillway. It was proposed to have one such sluice under every fourth span of the spillway. The working of the sluice with different levels of sand bed upstream and downstream and under different conditions of spillway and sand sluice discharges was studied on a part model of the dam. The observations showed that the design of the shape and dimension of the sluices were satisfactory.

Sand sluices were seen not to be effective in scouring out sand and silt deposited upstream except to a limited extent. Their effectiveness lay in the disposal of rolling silt and density currents as they approached the sluice. This of course would be governed by the discharge passing through the sluices and as the silt entry in to the Ramapadasagar Reservoir would be substantial, the final design of the dam had a very large number of sluices introduced in it.

(b) *Ramapadasagar Dam—shooting bucket and high level sand sluices.*

The design was tested on a model to see the functioning of the bucket and sand sluices under various conditions of flow and development of scour downstream. Studies are described. It has been found that the design tested was satisfactory.

6C—SPILLWAYS

(a) *Scour downstream of a five-vented spillway dam.*

It has been found by experiments that scour was definitely reduced by the use of staggered blocks. Further the importance of working the shutter carefully with a view to preventing bed scour and erosion has been indicated. In operating the shutters care should be taken to eliminate or mitigate as far as possible the formation of lateral eddies.

(b) *Pressure distribution on ogee spillways—Lower Bhavani Spillway Dam.*

The pressures on the profile of the spillway dam were tested on 1/36 sectional models operated under maximum overflow conditions. It was found that the pressures exerted on the crest and near about were nearly zero.

(c) *Co-efficient of discharge on ogee spillways—Lower Bhavani Spillway Dam.*

The tests made on coefficient of discharge of the final profile which follows Creager's design showed that the coefficient of discharge increased from 3.6 for a head of 7.5 feet to 3.93 for the full designed head of 15 feet.

(d) *Co-efficient of discharge for Tungabhadra Spillway Dam.*

Experiments were carried out to see the scale effect on the co-efficient of discharge. It has been concluded that results obtained from one model of moderate size (say $\frac{1}{36}$ to $\frac{1}{60}$ for these dams of heights of about 100 feet and overflow depth of about 20 feet, could be relied upon for design purposes.

(e) *Ramapadasagar spillway dam-effect of piers on co-efficient of discharge.*

Two designs of piers for the Ramapadasagar Spillway Dam were tested on models to find out the effect of having the pier—cut waters projecting upstream of dam face and supported by corbelling on the coefficient of spillway discharge. The designs are shown in Figure 6C. 13. In one design the cutwater edge was flush with the upstream vertical face of the dam, while in the other the entire cutwater was projecting upstream of the dam face. It was found that by extending the pier cutwaters upstream the co-efficient of discharge could be slightly increased because of the improvement in the approach stream lines. The increase, however, was very small and could not be taken into consideration for design purposes.

(f) Spillway training walls for the Ramapadasagar Dam.

Spillway training walls for the Ramapadasagar Dam were tested on a small model. Pressure observations indicated possibilities of economising in the design by getting more accurate values of pressures from a bigger model.

(g) Stilling basin for Lower Bhavani Spillway Dam.

The experiments carried out showed that a stilling basin consisting of a simple bucket and sill and a row of Tee-shaped blocks was the most efficient.

(h) Tungabhadra spillway dam—three-dimensional models.

Two sets of designs evolved from the studies on sectional models were finally tested on full three-dimensional models. Describes the details of the experiments and results obtained.

12C—OTHER WORKS*The Hagari Aqueduct for the Tungabhadra Canal.*

Describes the model experiment conducted to study the scour round piers
etc.

SECTION E—SOIL SCIENCE**5E—SOIL SURVEYS***Soil investigation for Lower Bhavani Dam Area.*

(see page 469)

Poona Irrigation and Research Division

SECTION A—HYDROLOGY

4A—THE SAMPLING OF THE BED AND SUSPENDED LOAD

Silt Load in Flood Water Samples

The amount of silt in flood waters from several rivers in the Bombay Province was estimated. Excepting the Manyad and the Ghodnadi, there was practically no silt and the flood waters were clear. The waters of the Yerla, the Manyad and the Tapti rivers were occasionally saline. Silt in the flood waters entering the Ekruk and the Hotgi tanks in the Sholapur District was also negligible. (For details see page 161).

7A—SUB-TERRANEAN WATERS

(ii) Effect of pumping

Cone of depression in deep soil areas.

Water levels in wells in deep soil areas with sub-strata of pervious massive *kankar* (1) at Jinti, Nira Right Bank Canal and (2) distributary 5 Pravara Left Bank were kept nine feet below general sub-soil water table by continuous pumping. The cone of depression and the circle of influence were determined by observing water levels in bores. The circle of influence as a result of pumping maintaining the said depression head was limited to a radius of 200 to 300 feet. The effect was slight beyond this. This experiment showed the improbability of lowering the sub-soil water table in deep soil area by pumping.

(iii) Recharging the underground basin

Effect of cane irrigation on the sub-soil water table in a deep soil area.

Observations in the Jinti area (Distributary 18 Nira Right Bank Canal) were continued during the year. It was found that the sub-soil water level did not fall after the discontinuance of cane as rapidly as it rose when the area was brought originally under cane. The deep soil is thus not very safe for heavy cane irrigation.

8A—QUALITY OF IRRIGATION WATERS IN RELATION TO

(a) Crops

(a) *Sugarcane under varying doses of 'N' in the form of sewage irrigation with special reference to quality of gur produced.*

Sugarcane was grown under varying doses of Nitrogen contained in the sewage effluent. 350 lbs of 'N' per acre was found to be the best dose. Higher doses decreased the yield slightly, and *gur* from sewage irrigation absorbed more water during the monsoon as 'N' increased.

(b) Sugarcane experiments under sewage irrigation.

CO 475 and CO 413 gave good yield. The former was found to be a good ratooner. CO 423 and CO 475 although they contained a high percentage of glucose (8.5 to 11.5) were not responsible for the sweating of *gur* during monsoon.

(ii) Soils

Effect of sewage irrigation on soil profiles.

- (a) Sewage irrigated soils contained higher amount of soluble matter.
- (b) Mechanical analysis of the soil showed that soil disintegrated under sewage and became finer and more suitable for crops.
- (c) K_{20} , P_{205} and replacable Ca increased in sewage-irrigated soils.
- (d) pH was lowered by sewage irrigation i.e. soils became less alkaline.

SECTION C—HYDRAULIC WORKS**13C—STAUNCHING OF CANALS AND EMBANKMENTS**

Rui Deogaon Area.—A large area was damaged by canal seepage near the Godavari Left Bank. It was believed that seepage will reduce when canal gets silted up, but there was no improvement in damaged acres nor the water level did get lowered. Lining the canal by (sodium) clay was considered cheap and advisable.

There were no salt encrustations available for use in preparing sodium clay. An impervious sodium clay occurs naturally in the area. It does not allow water to permeate through a thickness of eight inches. It is proposed to use this clay for lining.

SECTION E—SOIL SCIENCE**1E—SOIL MECHANICS****(i) Fundamental Research**

A comparative study of soil samples from (i) Santa Cruz Airfield and Gangapur Storage.

The properties of the soils from the two sites were examined and compared.

2E—MOVEMENT OF MOISTURE IN SATURATED AND UNSATURATED SOILS**(a) Hydraulic Gradients in soils (Model Experiment).**

Model scale experiments conducted in a masonry chamber at Khadakwasla are described. It is shown that although the water gradient adjusts itself between the upstream and the downstream water levels, the nature of the gradient varies with the material depending upon whether it is sandy, silty or clayey. Gradients in the black cotton soil are compared with those that were obtained in the Solani (United Province) silt, the previous year.

(b) Hydraulic Gradients in soils (Laboratory Experiment).

A laboratory experiment confirmed the nature of hydraulic gradient curves obtained in the case of solani silt (convex curve) and the black cotton soil (concave curve).

(c) Hydraulic Gradients in canal banks.

These were observed at three sites in black (*Chopan*) soil embankments on the Nira Left Bank Canal. The gradients were steep (1 in 5) as in the model experiments at Khadakwasla and there was no possibility of canal bank becoming unsafe as it apparently appeared from the liquid mud formed at the toe of the embankments. This liquid mud was formed by water flowing through a pervious stratum of *murrum* cutting — higher up to a depression at the toe, where it collected and stagnated.

(f) Movement of sub-soil water table and flow Gradient.

Two cases (1) Distributary 6 Godavari Left Bank (2) — Distributary 5 Pravara Left Bank area were investigated. Water levels in pits penetrating into the same sub-strata were observed. Water contours were found to be almost normal to the ground fall (from Distributary to *Nala*). In other words water collected in the valley before it flowed *en masse* through it. The lines of flow were almost parallel to drainage. Water gradients were characteristic of the sub-strata.

3E—LAND RECLAMATION**(i) Saline lands***(a) Damaged areas in the Deccan Canal Tract.*

Damaged by salt and water-logging was closely related with cane. The ratio of cane to damage was, however, found to be the least on the Nira Right Bank Canal where principles of soil selection were introduced from the very beginning (1933).

(b) Improvement of soil tilth in drained lands.

Results of small scale experiments under pot and plot scale are given.

Various *g* organic, and mineral soil improvers were tried. Farm yard manure gave good results. Molasses in combination with Farm yard manure or with irrigation water gave better results. Farm yard manure being cheapest of all the treatments is recommended

SECTION F—WATER UTILISATION PROJECTS**1F—STUDY OF INDIVIDUAL PROJECTS***Don river Irrigation Project in the Bijapur District.*

The water of this river even during floods is saline and the salinity is 10 parts per 100,000. Hence it is desirable to use this water immediately which is not possible. If the water is stored, the salinity is likely to increase to 140 due to the continual addition to the storage of non-flood water, which keeps on flowing in between two successive floods and as a post-monsoon flow and which has salinity from 500 to over 1,000. Perennial irrigation is out of question and even *rabi* irrigation is not likely to be successful.

The lands over which this water has to be utilised are retentive and at some places highly so (*Karl soil*.) This is due to salinity in the soil itself and the sub-soil water as well. The catchment of the project again lies in a scarcity tract of uncertain rainfall.

This project has thus several limitations and cannot be recommended.

The River Research Institute, West Bengal

SECTION A—HYDROLOGY

1A—RAINFALL RUNOFF

- (i). Total volume of runoff including standardization of hydrographs and their analysis

(a) *Unit hydrograph of the catchment of the river Teesta above the Teesta Bridge.* (see page 82 of this report).

(b) *Unit hydrograph of the catchment of the river Mor above Khatanga.*

A unit hydrograph for the catchment has been prepared by working out average distribution from the percentage distribution of the seven floods picked up from the data for the years 1936 to 1941.

(c) *Average monthly runoff percentage of the river Barakar.*

(see page 86 of this report).

(d) *Average monthly runoff percentage of the river Mor.*

(see page 90 of this report).

(e) *Monthly discharge volume of the river Mor at Khatanga.*

(see page 90 of this report).

(f) *Discharge volume of the Damodar and Barakar rivers during the highest flood of 1947.*

(see page 90 of this report).

(ii) Maximum Runoff Discharge

(a) *Maximum discharge from a runoff plot in Midnapur.*

(see page 112 of this report).

2A—RIVER BEHAVIOUR

(i) Floods

(a) *Highest flood in the Damodar and its tributaries in 1947.*

(see page 118 of this report).

(b) *Highest floods in 1947 in the rivers Mor, Dwarka and Brahmani.*

(see page 118 of this report).

(c) *Highest floods of the river Teesta and its tributaries during 1947.*

(see page 119 of this report).

(ii) Stage-discharge relations

(a) *Rating curves of the river Damodar and its tributaries for 1947.*

(see page of 122 this report).

(b) *Rating curves of the rivers Mor, Dwarka and Brahmani for 1947.*

(see page 122 of this report).

- (c) *Rating curves of the river Teesta and its tributaries for 1947.*
(see page 122 of this report).
- (d) *Rating curves of the river Ganga at Paksey and Rajmahal for the years 1936-41.*
(see page 123 of this report).

3A—MEASUREMENT OF FLOWING WATER

(a) *Discharge observations of the Jaldaka river.*

Discharge observations in the Jaldaka river in connection with the Jaldaka hydro-electric scheme were started from January 1947. As the river is full of rapids and projected boulders, velocities observations by current meter were not possible. The span was divided into five compartments and velocity observations made by dropping floats in each compartment. To calculate the average velocity, a factor of 0.75 has been applied. The analysis of the data shows that the average minimum value of the discharge obtained is about 265 cusecs. It has been found that the value of the discharge has been significantly lowered by calculating it with more cross sections with the reach of the river over which velocity has been observed by floats. Also a significant fluctuation has been noticed in the sampling of the velocity in the different reaches of the river at the same time.

4A—THE SAMPLING OF BED AND SUSPENDED LOAD

(a) *Silt behaviour and silt analysis of the Damodar and the Mor rivers.*

Sampling of water and analysis of suspended silt were carried out at eight different sites in the Damodar Valley and at four different sites in the Mor Valley. Describes the analysis and gives the results.

SECTION B—THEORY OF FLOW AND DESIGN OF CHANNELS

2B—HYDRAULIC DATA OF TORRENTS IN ECULDER RIVERS AND STREAMS

(a) *Hydrological data of the river Damodar and its tributaries in the hill catchment for 1947.*

(see page 260).

(b) *Hydrological data of the rivers Mor, Dwarka and Brahmani for 1947.*

(see page 261).

(c) *Hydrological data of the river Teesta and its tributaries in the hill catchment.*

(see page 261).

4B—DESIGN OF DRAINS IN IRRIGATED AND TIDAL AREAS

Model Experiments for the revival of the Madaripur Bill Route and the Lower Kumdriver

After giving the history of the problem, describes the model constructed. The experiments are still being continued.

SECTION C—HYDRAULIC WORKS

2C—RIVER CONTROL

(i) Flood protection works

Bituminous reinforced hotmix revetment for river bank protection.

The paper describes the experiments undertaken for the preparation of bituminous reinforced hotmix canal lining for river bank protection. This type of revetment consists of two inches thick reinforced bituminous hotmix of fine asphaltic concrete or sheet asphalt type laid on a properly graded and compacted slope of natural soil. After the preliminary investigations in the laboratory, field work was carried out on the bed and side of the Damodar Canal downstream of the fall at Gatsi. The work has been completed and results are being watched with interest.

(ii) River training works

Model investigations for the proposed Mor Barrage.

In the Mor Project, a barrage is proposed at site called Tilpraghat near Suri in the district of Birbhum. The design prepared for the structure of the barrage and its tentative site was investigated by means of model studies. The paper describes the details and findings of these model studies.

(iii) Scour and erosion

(a) Prevention of erosion at the upstream nose of the right bank Bell Bund for the Anderson Weir on the Damodar.

The data has so far been collected. Model experiments are yet to be started.

(b) Model experiments for the prevention of erosion at Kurigram in the river Darla.

These experiments were started for devising measures to prevent erosion of the town of Kurigram by the river Darla. It has been found that by erecting three suitably placed spurs it will be possible to avoid all erosion by the river Darla at Kurigram.

(iv) Spill

(a) Model experiments for the revival of the river Chandana.

(see page 676).

(b) Model experiments in connection with the revival of Peali river.

(see page 683).

(c) Malta-Peali Tidal Model—Analysis of Data.

(see page 694).

7C—HYDRAULIC STRUCTURES ON FERMEABLE FOUNDATIONS

Model investigation for the proposed Mor Barrage Sectional Model.

Describes the experiments on sectional models carried out to test the design of the Mor Barrage for (1) its stability against uplift pressure and (2) determination of necessary protection like friction blocks to be constructed on the downstream floor.

10C—EXCLUDERS AND EJECTORS

(a) *Damodar River Model.*

(b) *Silt-exclusion experiments at the Headworks of the Damodar Canal at Rhondia*

A series of observations were carried out at the head-works of the Damodar Canal at Rhondia to find the effect of different methods of undersluice gate operation on the entry of silt into the canal. The analysis has shown that the entry of silt is the least, if the undersluice gates are opened more and more and from the left to the right, that is, away from the canal regulator.

SECTION E—SOIL SCIENCE

1E—SOIL MECHANICS

(ii) Earth dams and embankments

(a) *Testing of soil samples from Messenjore Dam site.*

(see page 336).

(b) *Testing of soil samples for afflux bund at Tilpara Ghat.*

(see page 336).

(iii) Roads and runways

Soil stabilisation of proposed second runway at Calcutta Air Port.

(see page 343).

2E—MOVEMENT OF MOISTURE IN SATURATED AND UNSATURATED SOILS

Locomotive Project Survey.

It is proposed by the Railway Board of the Indian Union to put up a Locomotive Workshop and shed for the East Indian Railway. A site near Rupnarayanpur was tentatively selected for locating the workshop. Laboratory tests were carried out to find out if a minimum supply of six to seven cusecs could be assured from the river Adjai for the Workshop colony area. Bed samples of the river near the site were tested for mechanical analysis and transmission contents. A number of borings was also carried out at the cross sections for finding out the depth of superincumbent sand on the rocky bed. Assuming that the sand all through the cross section was of the same texture and water was flowing through the whole section, the average discharge was found to be 16.35 cusecs and the minimum discharge 10.76 cusecs. These discharges were calculated on the assumption that the whole volume of sand on the river bed was tapped. But as this was not possible, it was not expected to get more than five to six cusecs during the dry part of the year.

5 E—SOIL SURVEYS

Survey and analysis of the Suri (Tilpara Ghat) soil for the purpose of land acquisition.

(see page 407).

6 E—MISCELLANEOUS

Routine analysis.

(see page 415).

SECTION G—GENERAL

1G—RIVER POLLUTION

Efficiency of the sedimentation tanks at Bantala

The sewage and storm water of Calcutta used to be thrown into the river Bidyadhari before it deteriorated. During 1937-38 a channel was constructed by the Calcutta Corporation to carry the sewage and storm water to a distant tidal river Kultigong. It was apprehended that this raw sewage, if dropped in water of Kultigong, might deteriorate that river. It was arranged that the sewage water be pumped into a high level channel and passed through sedimentation tanks constructed specially for that purpose at Bantala before passing the water to channel leading to Kultigong. To test the efficiency of the tank samples of sewage water were collected from inlet and outlet to the tank and analysed. The analysis shows a significant amount of the solid contents drops down as the water enters the sedimentation tank but as the water comes out *via* the exit channel some amount of solid particles are again taken up in the suspended state, so that the decrease in the solid content of the water after passing through the sedimentation channel is not significant.

7G—SOIL CONSERVATION

(a) Runoff and erosion experiments in trays.

Studies on relation between rainfall, runoff and erosion from experiments in trays were continued at the three sites, *viz.* Ramgarh and Sudamdih on the Damodar and Barakar (Giridih) on the Barakar. It has been found that the vegetation plays a more important part than variation in slope both for runoff and erosion.

(b) Analysis of rainfall at the run off experiments sites.
(see page).

(c) Runoff and soil erosion experiments with the help of artificial showers.

To study the phenomenon of runoff and soil erosion in experiments with the help of natural rainfall, it is very difficult to control the intensity, duration and the quantity of shower; consequently, the relationship between runoff and the soil erosion cannot be determined accurately.

Experiments were carried out at Barakar-Giridih to study the phenomenon of surface runoff and soil erosion with the help of artificial showers. The paper describes the details of the experiments and the analysis of the data collected. Further investigations are in progress.

United Provinces Irrigation Research Station Roorkee

SECTION A—HYDROLOGY

1A—RAINFALL RUNOFF

(i) **Total volume of runoff including standardization of hydrographs and their analysis**

(a) *Relationship between rainfall and runoff for Bundelkhand Catchments.*

Relationship between monsoon rainfall and runoff has been worked out for three categories of Bundelkhand catchment viz. steep bare catchments with hills, hilly catchments covered with forest and plain catchments. (For details see page 82).

(b) *Relationship between maximum flood discharge and catchment area for the United Provinces Catchments.*

(see page 84 of this report).

5A—REGENERATION AND LOSSES

(iii) Regeneration

Study of regeneration on the Hindan River.

Regeneration of the river Hindan passing through a tract subjected to intense tubewell pumping was worked out for a length of about 130 miles from its source near Dehra Dun to the head of Hindan Cut near Delhi. Mean annual regeneration per day for the fair weather months of November to May during pre tubewell period, 1916-17 to 1935-36, was found to be 558 cusecs, while the corresponding figure for the tubewell period, 1936-37 to 1945-46, was 493 cusecs.

Though there are some indications regarding a slight decrease in regeneration during the tubewell period, the data is not yet sufficient to establish significantly that the regeneration is being affected by tubewell pumping in the vicinity of river Hindan.

7A—SUB-TERRANEAN WATERS

(ii) Effects of Pumping

A statistical study of the behaviour of water table in Doabs 1 and 2 of the Meerut Tubewell Division.

A study of the behaviour of the water table as a result of tubewell pumping was carried out statistically for tubewell Division Meerut confining our attention to Doabs between Eastern Yamuna Canal and Krishni and between Krishni and Hindan rivers, where the most intense tubewell irrigation is done.

The following conclusions were arrived at :—

- (1) Pumping is not significantly affecting sub-soil water table for Doab between Eastern Yamuna Canal and Krishni.
- (2) Pumping has significantly affected the water table for Krishni-Hindan Doab where over pumping is clearly established, as a result of which water table will continue to recede at the present rate of pumping. (For details see page 214).

SECTION B—THEORY OF FLOW AND DESIGN OF CHANNELS

2B—HYDRAULIC DATA OF TORRENTS IN BOULDER RIVERS AND STREAMS

(a) *Analysis of hydraulic data of the Nayar River.*

An analysis of the data collected at the site of Nayar Dam for the years 1946 and 1947 had been made. The channel at the site of observation has uneven rocky sides with the bed consisting of shingle and smaller boulders with occasional small rocky cliffs jutting out of the bed.

The conclusions arrived at were the following :—

- (1) Rugosity coefficient by Kutter's may be taken to be the following for the Nayar :—

(a) 0.1 for discharges below 100 cusecs.

(b) 0.057 for discharges between 100 and 500 cusecs.

(c) 0.039 for discharges between 500 and 3,000 cusecs.

(d) 0.037 for discharges between 3,000 and 3,500 cusecs.

(b) *Analysis of Hydraulic Data for the River Ganga at Hardwar.*

An analysis of a number of observations on the river Ganga at Spur No. 1 (*Dudhia Bund*) above Laljeewala and on Kankhal Channel at chainage 1980 along *Kankhal Bund* was carried out with a view to forming an idea of the rugosity coefficient.

It was found that :—

- (1) The value of the rugosity co-efficient (Kutter's) for the river Ganga for discharge of the order of 75,000 cusecs is 0.04206.
- (2) The rugosity coefficient (Kutter's) for the Kankhal channel for a discharge of the order of 21,000 cusecs is 0.03124, thus indicating that the rugosity even in boulder channels if straight and regular in section is fairly small.
- (3) For this hydrological data Borne's formula for rugosity coefficient agrees most closely with Kutter's which was also established in 1942-43 for K. P. Channel.

SECTION C—HYDRAULIC WORKS

(ii) River training works

(a) *Protection of Kankhal town against floods in the Ganga at Hardwar.*

Below Hardwar, the main Ganga, commonly known as Bijnor Channel, takes a turn towards left leaving an opening on its outer curve near Mayapur towards Kankhal. Owing to the unfavourable position of this spill, it has continued to develop during the past 25 years till its increasing discharge has now endangered the safety of Kankhal town. From time to time in the past, flood protection works in the form of *bunds* and spurs were tried but no permanent relief was brought about.

Model experiments were carried out to find out a solution to the problem.

Various devices such as restoration of old alignment of Kankhal *bund* and extension of the existing Kankhal *bund* were tried. But none was found effective. The whole trick lay in developing Bijnor Channel which was shoaling year after year being at the inside of the curve. A 960 feet long spur constructed at an angle of 120° from chainage 1,400 of the existing Kankhal *bund* and ending at the point of contraflexure produced more favourable curvature of flow at the junction of Bijnor and Kankhal channels with the result that Kankhal channel now started shoaling up. The head of water that the spur shall be required to withstand is of the order of 16.5 feet. It is expected that the intensity of spill towards Kankhal is not likely to be more than 5 to 10 per cent. of the total discharge of the river with this device as against 75 per cent. without it, obtained at present.

(b) To train the river Ganga upstream of Bhimgoda Weir for equalising the flow on weir crest and preventing retrogression downstream.

Bhimgoda weir consists of six sluices each 50 feet long and six bays of open crest each 300 feet long. The natural course of the Ganga river was along its left bank, while the canal head and sluices were situated on the right. In order to feed the old and new supply channels, a cut known as BB cut was made along the right afflux *bund* and it was developed by raising the extreme left bays Nos. 3, 4, 5 and 6 of the open crest. This ultimately brought the entire river to the sluices, along the right afflux *bund*, which naturally resulted in creating excessive velocities at the sluices and which in turn started retrogression downstream. The distribution of supplies at a flood of 150,000 cusecs was found to be 53 per cent. at the sluices (6×50 feet) and 47 per cent. at the open crest (6×300 feet), at the model. The prototype gauges also indicated similar distribution.

To relieve the sluices of this disproportionate share of flood discharge the open weir crest was lowered to R.L. 948.30 against R.L. 952.0 in bays 5 and 6 and to R.L. 945.3 against R.L. 948.30 in bays 3 and 4. This improved flow conditions considerably, the supplies now passing at sluices being 33 per cent. and at the open crest 67 per cent. as experienced at a flood of 153,000 cusecs in the model. It is also expected that this will not disturb the regime of the river upstream.

(iii) Scour and erosion

To study the possibility of reducing scour below the sluices at Bhimgoda Weir.

This problem was once studied on a geometrically similar part model with two dimensional flow at the Indian Waterways Experimental Station, Poona in 1937. It was then recommended that a 2.0 feet baffle 10.5 feet downstream of the 1 in 20 sloping glacis, and 2.0 feet deflector sloping up 1 in 5 at the end of the granite floor would pull up the standing wave at low floods which are more damaging than the higher floods.

A three dimensional study on a geometrically similar model to scale $\frac{1}{40}$ of the sluices and bays No. 1 and 2 of open crest when run with discharges between 60,000 to 150,000 cusecs flood showed that the above proposals were fairly satisfactory even for the present conditions obtained at the prototype. However, in view of the proposals for silt excluder to be constructed at the head of the new supply channel, these devices, when worked in conjunction with an excluder, proved undesirable in as much as excessive piling of shingle and boulders was noticed on downstream floor of the under sluices especially before sluice No. 1.

It has been recommended that this study should be taken up after the shingle excluder has been tried at site and the channels downstream of the weir have stabilised after lowering the crests in bays No. 4 to 6.

4 C—DAMS AND WEIRS

(ii) Design

Model investigations regarding the design of Nagwa Dam.

The deep channel of Karmnasa river at the site of Nagwa Dam is 300 feet only while the weir is 600 feet long. Model experiments were carried out to study the effect of flow on high banks on either side and to centralise the flow into the deep channel by suitable devices.

The combinations of different positions and heights of baffles were tried both in the central deep channel and on the side banks and the most suitable arrangement which will give the minimum action downstream of the weir recommended.

(a) Battery of volute siphons.

Basic experiments were conducted upon a battery of volute siphons with a common outlet tunnel to perfect the design for escaping the flood discharge at Lalitpur Dam in Bundelkhand. The points studied were (1) best shape and design of the outlet tunnel; (2) optimum spacing of volute siphons; and (3) optimum number of volute siphons.

Three different designs were tested on models to scale $\frac{1}{24}$. Each consisted of four volute siphons of 12.0 feet diameter and

- (a) a gradually expanding elliptical tunnel having at the junction of each of the siphons the area equivalent to the number of volute siphons up to that point.
- (b) a rectangular tunnel in which sudden expansions were provided to increase the cross sectional area equivalent to the number of volute siphons upto that point.
- (c) same as (b) except that the sections were elliptical instead of rectangular.

It was found that—

(1) where as the priming depth was minimum for the rectangular tunnel battery the co-efficient of discharge was maximum for the gradually expanding elliptical tunnel ; the co-efficient of discharge of the former being 85 per cent. to 90 per cent. of the latter.

(2) 48 feet (four times the diameter) spacing between volute siphons gave the maximum co-efficient of discharge though minimum priming depth was obtained with nearer spacing.

(3) optimum number of volutes was found to be four, as the coefficient of discharge was affected only slightly upto the addition of fourth volute.

A single elliptical siphon with area of cross section 4 times the area of one volute siphon of 12.0 feet diameter did not prime independently. A little obstruction on the top of its outlet primed it, the co-efficient of discharge was observed to be 0.63.

(b) Saddle siphons for Lalitpur Reservoir.

A 15 feet by 10 feet saddle siphon for Lalitpur reservoir similar to one for Pahuj weir, was designed and tested in a model to scale $\frac{1}{18}$. The head available is 20.0 feet. Different shapes of crest with and without lip were tried, and it was found that a crest of 10 feet radius with $1\frac{1}{2}$ inches lip gave a co-efficient of 0.61 and priming depth of about 9 inches. The discharge through one saddle worked out to be 3,300 cusecs.

Pressure observation indicated a little cavitation at the crest of the siphon.

(c) Basic study of volute siphon.

Basic work was continued this year to study the effect on coefficient of discharge and priming depth in a 3.0 feet diameter barrel siphon built $\frac{1}{8}$ of actual size when (a) the diameter of the covering hood was varied, (b) the working head was varied, and (c) how the maximum negative pressures developed and varied with the variation of the working head. It was found that (a) maximum coefficient of discharge and minimum priming depth was obtained when the diameter of the covering hood was 3.33 times the barrel diameter ; (b) both the priming depth and coefficient of discharge decrease as the working head increases. The maximum head tried was 22.5 feet only and (c) the corresponding negative pressure increased as the working head increased, though the increase in the value of the former is bigger at higher heads and smaller at lower heads, thus indicating that Ganesh Iyer's volute siphon is more suited for higher heads.

8C — CANAL FALLS

Basic study on Sarda Type Fall.

The above study was continued this year to determine the optimum dimensions of the cistern below the fall. The discharges tested on a number of geometrically similar models varied from 50 to 8,000 cusecs and drops 2 feet to 10 feet.

It was recommended that the cistern of the following dimensions should be made an integral part of the design of Sarda type fall for ensuring minimum action downstream :—

$$\text{Length of cistern} = L_c = 5(H_c \times H_d)^{\frac{1}{2}}$$

$$\text{Depth of cistern} = D_c = \frac{1}{16}(H_c \times H_d)$$

where H_c = depth of water over crest

H_d = drop in water surface.

10C—EXCLUDERS AND EJECTORS

To design a suitable type of shingle excluder for the new supply channel at Bhimgoda Weir, Hardwar.

The Ganga canal is fed by two supply channels known as old and new supply channels taking off at the upstream and downstream of the B.B. cut above the weir. Both the feeder channels draw in huge quantities of shingle owing to which heavy expenditure is incurred every year in shal clearance for feeding the canal.

The straight approach in front of the sluices, a regulating gate in bay No. 1 for creating difference of head at the entrance of tunnels, plenty of drop available at sluices at all floods and above all any amount of escapage possible for exclusion went to suggest a shingle excluder at this site. A part model of the sluices and bays No. 1 and 2 of the weir to scale $\frac{1}{40}$ horizontal and $\frac{1}{24}$ vertical was constructed. The river bed was laid in Ranipur sand with a mixture of 10 per cent. of shingle varying from $\frac{1}{8}$ inch to $\frac{3}{8}$ inch.

On running the model with different arrangements of tunnels, it was found that three tunnel excluders (size 15 feet by 5 feet) with the flaired mouths of the tunnels starting from bays No. 8, 6 and 4 respectively of the head regulator in front of bay No. 1 of the undersluices proved very effective in excluding the shingle.

15 C—TUBEWELLS

(i) Types

Radial Tubewell.

Basic—Electrical analogy experiments on radial tubewell were conducted on a model to study the effect of staggering the radials in two planes within the strata of varying depths. It has been found that staggering, while introducing many constructional difficulties, does not add to discharge materially.

Specific—A proposal, of adding a vertical tube to four radials in one horizontal plane, was tested in the laboratory on the same apparatus.

The radials were 200 feet each and the strata 100 feet deep. It was found that the increase in the discharge of the tubewell was insignificant, as it was surrounded all round by the cone of depression created by the radials.

(b) Feeder Tubewells.

Controversy has been rife as to the real utility of the 30 feeder wells of three cusecs each constructed at distances varying from 450 feet to 1,200 feet from the bank of the Upper Ganga Canal for adding to the discharge of the canal.

In order to study the problem field experiments were launched on some of these wells in 1937 but no quantitative idea was obtained. The only conclusion arrived at was that the recoupment from the canal side was greater than that from other directions because of the steeper gradients observed on the canal side.

The results of the field experiments have been studied once again and analysed in conjunction with laboratory experiments made to obtain some quantitative idea. In the case of the three wells No. 3, 16 and 29 located at distances of 544, 660, and 1,143 feet respectively, the increase in the losses of the canal in the reach under influence of the tubewell was computed to be of the order of 0.21, 0.1 and 0.04 cusec for tubewell discharges of 2.63, 3.0 and 2.63 cusecs respectively.

As the field observations were insufficient the above results had to be based on certain assumptions and approximations. Laboratory experiments were, therefore, conducted to study the problem more completely.

It has been observed both by the analysis of the field observations and the laboratory observations that the optimum distance between the canal and the tubewell can be considered as about 1,000 feet. The increase in canal seepage with the well at this distance is insignificant and the tubewell virtually salvages all the natural seepage only passing down towards the drainage. Also the optimum spacing of such wells for the conditions as obtained at the 30 feeder wells of the Upper Ganga Canal can be taken as about four furlongs.

SECTION D—WATER POWER WORKS

2D—POWER HOUSE AND EQUIPMENT

(iii) Hydraulic Works

(a) *Model investigations regarding the design of Sarda Power House.*

The Sarda Power House is under construction at mile 7-6-60 of the Sarda Canal. The total drop available is 59·1. The design of the power house was tested at the station with a view to studying its hydraulic aspects. As a result of model experiment improvements for stream line flow, the minimum silting upstream of the power house and maximum dissipation of energy downstream of it were suggested.

For dewatering the foundation pit, an arrangement of 14 wells with 70 feet of six-inch strainers was recommended (for details see page 285).

(b) *Model investigations regarding the project of Mohammadpur Power House.*

(i) *Power House Forebay*

On studying the design on a geometrically similar model to scale $\frac{1}{25}$, it was noticed that there was likelihood of some hunting in the three machines owing to unsatisfactory vortex formation. This was likely to affect the efficiency of the machines.

Curved vanes in the turbine chamber of various shapes and radii were tried to improve vortex formation. The best vane for each of the three machines gave a total afflux of 1·5 feet in the model. These vanes may be tried one by one after the efficiency of the machines has been tested in the prototype.

(ii) *Mohammadpur Power House Subsidiary Fall.*

There are two drops in this fall and the floor of the first fall has been strengthened, subsequently, against uplift pressure, by the addition of masonry. On testing in the model this was found to result in severe bed scour and side erosion downstream on the right. Addition of a sloping crest one foot high on the right and at existing crest level in the centre prevented all action in the bed and the sides, as this provided the required depth for the formation of the standing wave upstream of the crest on the right.

SECTION E—SOIL SCIENCE

1 E—SOIL MECHANICS

(i) Fundamental Research

(a) Variation of Dry Bulk density of soil with different amounts of cement mixed with it.

Densities of the soil were measured with different amounts of cement mixed with it. It has been found that in the case of the particular soil under test the dry bulk density decreases with increase in the amount of cement.

(b) Comparison of the different deflocculating agents added to disperse the soil in the mechanical analysis of soils.

Five deflocculating agents namely, (1) sodium silicate, (2) sodium carbonate, (3) sodium hydroxide, (4) sodium oxalate, (5) sodium borate, which are commonly used to disperse the soil have been studied and compared.

It has been found that (1) the efficiency of the chemicals is as follows :—

Sodium carbonate—Sodium Silicate Sodium oxalate Sodium hydroxide, Sodium borate.

(2) Sodium carbonate is the best chemical to be used because ;

(a) smaller quantities are needed and

(b) it permits greater latitude in the allowable concentration of the salt.

(ii) Earth dams and embankments

(a) *The Usehal Bund.*

The experimental slabs of stabilised soil (Mixture 1 : 10) that were designed in the laboratory and placed below a distributory fall have now been exposed to wave action for more than a year without showing any signs of deterioration.

(b) The effect of changes in profile of dams founded on pervious foundations.

Experiments on models were conducted to study the effect of

I. (a) Flattening downstream slope ;

(b) Flattening upstream slope ;

(c) Increasing top width ;

(d) Increasing the number of berms on downstream slope ; on the position of the line of saturation inside an earth dam founded on pervious base. It has been found that the most economical devices for lowering the saturation line is again the addition of berms to the downstream slope, and flattening of downstream slope is the next most economical device, as obtained in the case of earth dams on impermeable base.

II. Relation between the size of the gravel toe and elements of the profile.

In order to find a suitable size of the filter toe which will prevent the line of saturation from appearing on the downstream slope of an earth dam founded on impermeable base experiments were conducted with—

- (i) Different downstream slopes ;
- (ii) Different upstream slopes ;
- (iii) Different top widths.

It has been found that the requirements of the gravel toe is guide by the downstream of the dam only and its size can be known from a curve prepared on the basis of the laboratory results.

4E—WATER REQUIREMENTS OF CROPS

Water requirements for Sugarcane, Wheat and Paddy crops.

Agricultural experiments were continued at Bulandshahr, Atarra (Banda) Tisui (Mirzapur) and Nagina Farms, and also initiated at Bahadrabad for the first time, to determine the water requirements for paddy and wheat crops for the maximum yield with the most economical use of water using randomized block system with various depths of irrigation and frequencies.

(a) *Paddy*

These were conducted at Mirzapur, Nagina, Attarra and Bahadrabad. A statistical analysis of the data did not bring out significant results except for Attarra where depth effect was found to be highly significant, 9-inch depth at two weeks interval giving the maximum yield.

(b) *Wheat*

These were continued at Barabanki and Bulandshahr farms with the object of—

- (i) studying the effect of a single watering of varying depths of zero inch, two inches, three inches, four inches, five inches and six inches applied in the middle of the 'Kor' period.
- (ii) finding the optimum time of irrigating wheat with two irrigations of two inches, three inches and four inches at varying intervals, with respect to the date of sowing.

Experiment No. 1 may be said to be finalised this year, as it was brought out significantly that three inches depth gives the maximum yield both at Bulandshahr and Barabanki.

For experiment No. 2 (with two irrigations), no statistically significant results were obtained at either place. For Barabanki, two inches irrigation at four weeks interval and for Bulandshahr, three inches irrigation at four weeks interval gave the maximum yield.

TECHNICAL PROCEEDINGS

Section A—Hydrology

1 A. Rainfall Runoff

PRELIMINARY NOTE

This subject has been on the agenda of the Board since 1942. As decided by the Board at its 1944 annual meeting, a form* was circulated to various provinces and States in India for the collection of data on the volume of rainfall runoff from catchments of various types as a check on existing formulas such as Barlow's and to serve as a guide, possibly in the form of formula, for estimation of yield from catchments in future projects in various parts of India. In response to this, data for 31 catchments in all have been received from Bombay (16), Bihar (1), Baluchistan (1), Baroda (1), Central Provinces and Berar (5), Ceylon (4), Punjab (1) and Orissa (2). Mysore, Madras, United Provinces and West Bengal have promised to supply data which they are at present collecting. The data for 31 catchments already received will be put up to the Research Committee at the time of the meeting.

In 1945 the Board passed a resolution on the subject which was amplified further at 1946 meeting so as to include collection of all kinds of basic hydrologic data necessary for the optimum development of water resources of the country. The resolutions were passed on to the Government of India and Provincial and State Governments for implementation and necessary action. Consequently a meeting between the Central Waterpower, Irrigation and Navigation Commission and the India Meteorological Department was held in August 1946 to (1) consider and lay down a general policy for the collection of hydrologic data *i.e.*, rainfall, snowfall, temperature, humidity, evaporation, wind velocity *etc.* by catchments all over India and (2) consider the extent of facilities in respect of item (1) that exist at present and to suggest further facilities *i.e.*, setting up of raingauge, snowgauge, temperature, humidity *etc.* stations which are necessary to be provided by catchments and to fix the order of priority of these. The decisions reached at the meeting were circulated to the members of the Board with a view to eliciting their opinion and seeking their co-operation. There was ready response for co-operation from Bahawalpur, United Provinces, Baluchistan, Bombay, Orissa, Bengal, Bihar and Madras.

As regards the implementation of the resolution of the Board, the replies received indicate that (1) West Bengal is taking action to implement the recommendations, (2) Bombay does not contemplate making any change in the present practice of collecting and compiling rainfall data until instructions were received from the Government of India, (3) N.W.F.P. contemplates installation of a few raingauges in some districts and flood gauges on certain *nalas* in the province and (4) the matter was under consideration of the Government of Madras and (5) Bihar contemplates constituting a Provincial Water Board whose first concern will be to collect hydrologic data.

*Proposed by a sub-committee appointed by the Board in 1943 and comprising Rai Bahadur A. N. Khosla, Mr. C. C. Inglis and Mr. Thomas, the then Secretary of the Board.

"Central Board of Irrigation Journal, April 1947, page 119."

The Board's resolution was also supplied to the Planning Committee for Geophysics set up by the Government of India, and was accepted by them. Item VII of the resolution related to the study of Water Balance of Catchments wherein it was recommended that to start with the Damodar Catchment be selected for the study and a sub-committee comprising Dewan Bahadur Ramanathan, Dr. Bose and Rai Bahadur A. N. Khosla was formed to work out details. The sub-committee has met so far four times. The investigations have been divided into the following sub-heads :—

- (i) Rainfall and evaporation
- (ii) Sub-soil flow and regeneration
- (iii) Runoff and erosion experiments and discharge observations
- (iv) Water requirements of crops and vegetation

Necessary estimates for items (i), (ii) and (iv) have been submitted to the authorities concerned for sanction. As regards (iii) it has been decided that as the River Research Institute, West Bengal is at present carrying on the work, the West Bengal may allow her to carry on with the same.

In 1947 the Board passed the following resolution.

“ Resolved that the Research Committee recommends to the Board that the India Meteorological Department be requested to examine the conclusions draw by Mr. Baker from theoretical considerations regarding the variation of rainfall on the windward and leeward sides of a hilly catchment. It is suggested that among other methods that the Meteorological Department may adopt for this purpose simultaneous observations be made on directional and standard raingauges installed at such places in some catchment.

“ Resolved that the Board notes with gratification that measures are being taken by the India Meteorological Department and Central Waterpower, Irrigation and Navigation Commission to implement the recommendations of the Board regarding rainfall and other Meteorological measurements made in the resolution on the subject passed at the Board's 1946 annual meeting. Further that the attention of all Provincial and State administrations be drawn to the portion of Boards resolution relating to stream-gauging and ground water supplies and they be requested to take steps to implement the Board's recommendations in this respect.

“ Resolved further that India Meteorological Department be requested to organize experiments on artificial rainfall in co-operation with other authorities. Cloud control was a subject worthy of study and consideration.

“ It was also decided to include Artificial Rainfall on the agenda of the Research Committee under section A—Hydrology.

The subject Rainfall Runoff is considered under the following two sub-heads :

- (i) Total volume of runoff including the standardization of hydrographs and their analysis.
- (ii) Maximum runoff discharge.

(i) **Total Volume of Runoff including the Standardization of Hydrographs and their Analysis**

PRELIMINARY NOTE

The following items were discussed at the 1947 Research Committee Meeting :—

- (1) Unit hydro-graph of the Brahmani Catchment above Nalhati.
- (2) Rainfall runoff experiments in trays
- (3) Unit hydro-graph of the Damodar Catchment above Chas Road Bridge site.
- (4) Runoff from catchment round Krishnarajasagar.

Recent Literature

- (1) Krimgold, D. B. :—Runoff as a phase of agricultural hydrology, *Agricultural Engineering*, Vol. 28, No. 2, January 1947.
- (2) Kinnison, H.B. :—Flood flow formulas, *Journal of Boston Society of Civil Engineers*, Vol. 33, No. 1, January 1946.
- (3) Statement of the actual rainfall in the Monsoon season, June to September 1946, 1947 (stencilled).
- (4) Malurkar, S.L. :—Abnormally heavy rainfall in India—temperature inversions in tropical air masses. *Current Science*, Vol. 16, No. 8, August 1947.
- (5) Hydrologic and hydraulic analysis flood—hydrograph analyses and computations. *Engineering Manual for civil works*, Pt. III, Chapter V, Water Department, office of the Chief of Engineers Washington, April 1946.
- (6) Shands, A.I. and Ammerman, D. :—Maximum recorded United States point rainfall. U. S. Department of Commerce, Weather Bureau, Division of Climatological and Hydrologic Services, Technical Paper No. 1, September 1946.
- (7) Seshachar, C. :—A discussion of hourly rainfall and associated wind direction at Bangalore. *India Meteorological Department, Scientific notes*, Vol. IX, No. 102, 1946.
- (8) Glasspool, J. :—The reliability of rainfall over the British Isles. *Water and Water Engineering*, Vol. 50, No. 617, July 1947.

- (9) Narsimhan, V. N. and Mohd. Zafar :—An analysis of the hourly rainfall records of Pocna. India Meteorological Department, Scientific Notes, Vol. IV, No. 110, 1947.
- (10) O' Kelly, J. J. :—Rainfall and runoff in relation to arterial drainage. Transaction Institution of Civil Engineers of Ireland, Vol. 72, 1946.
- (11) Adams, K. T. :—Hydrographic Manual. United States Department of Commerce, Special Publication No. 143, 1946.

THE YEAR'S WORK

The following items were discussed at the 1948 meeting of the Research Committee :—

- (1) Relationship between rainfall and runoff for Bundelkhand Catchments.
- (2) Relationship between maximum flood discharge and catchment area for the United Provinces Catchments.
- (3) Unit hydrograph of the catchment of the river Teesta above the Teesta Bridge.
- (4) Unit hydrograph of the catchment of the river Mor above Khatanga.
- (5) Average monthly runoff percentage of the river Barakar.
- (6) Average monthly runoff percentage of the river Mor.
- (7) Monthly discharge volume of the river Mor at Khatanga.
- (8) Discharge volume of the Damodar and Barakar rivers during the highest flood of 1947.
- (9) Some features of precipitational variations in the Upper Indus Catchment—a probability method of approach.

(1) RELATIONSHIP BETWEEN RAINFALL AND RUNOFF FOR BUNDELKHAND CATCHMENTS ⁽¹⁾

This investigation was carried out during 1943-44. The catchments were divided into three categories as follows :—

- (1) Steep bare catchments with hills.
- (2) Hilly catchments covered with forests.
- (3) Plain catchments.

(¹) Abridged from the United Provinces Irrigation Research Station Annual Report on Research Progress during the year 1947, pages 3—5.

This year, the relationship between rainfall and run-off has again been worked out in the light of further more rigorously classified and up-to-date data for Bundelkhand catchments. The larger catchments comprise, however, all the three classifications mixed up in one. Moreover, monsoon rainfall has been considered this year instead of annual rainfall. Opinion had been expressed by local officers that monsoon rainfall is alone responsible for the run-off.

Monsoon rainfall in inches has been plotted against run-off in million cubic feet per square mile of catchments in respect of all the three categories in Figure 1A.1 wherein a straight line fit has been attempted. The formulae now

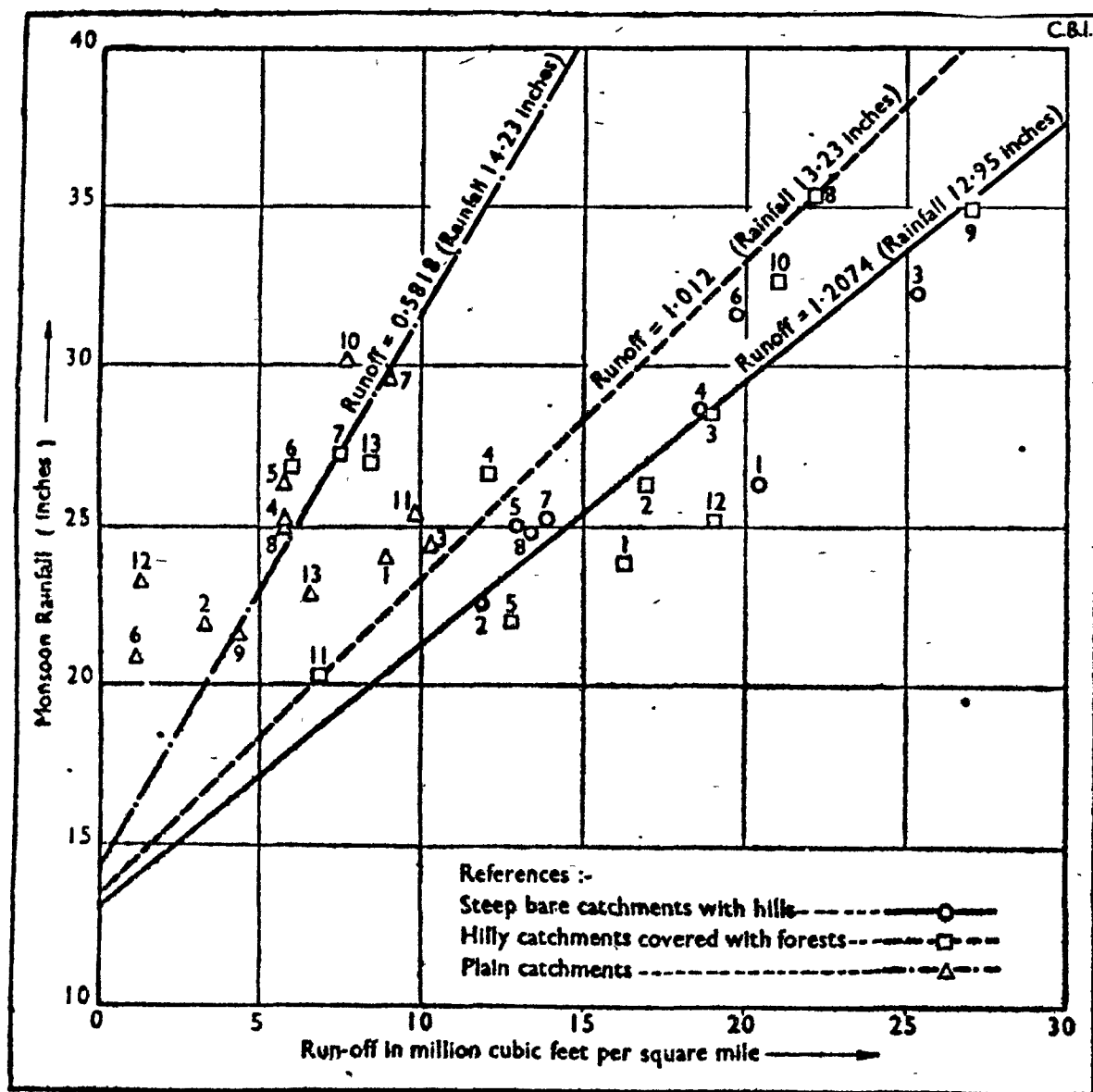


Figure 1A.1 : Showing relation between monsoon rainfall and runoff for (1) Steep bare catchments with hills, (2) hilly catchments covered with forests and (3) plain catchments.

worked out are given below along with those worked out previously wherein the annual rainfall was taken instead of the monsoon rainfall :—

| Serial No. | Type of catchment | Formula as previously worked out | Formula now worked out with more rigorously classified data and using only monsoon rainfall |
|------------|--|------------------------------------|---|
| 1 | Steep bare catchment with hills. | Run-off=1.71 (Rainfall —17.5 in.). | Run-off=1.2074 (Rainfall —12.95 in.). |
| 2 | Hilly catchments covered with forests. | Run-off=1.098 (Rainfall —15 in.). | Run-off=1.012 (Rainfall —13.35 in.). |
| 3 | Plain catchments | Run-off=2.5 (Rainfall —22 in.). | Run-off=0.5818 (Rainfall —14.23 in.). |

(2) RELATIONSHIP BETWEEN MAXIMUM FLOOD DISCHARGE AND CATCHMENT AREA FOR THE UNITED PROVINCES CATCHMENTS (2)

ABSTRACT

For computing maximum flood discharge of any catchment in the United Provinces, three graphs were deduced for catchments from 0 to 100 square miles, 100 to 1,000 square miles and from 1,000 to 10,000 square miles.

(3) UNIT HYDROGRAPH OF THE CATCHMENT OF THE RIVER TEESTA ABOVE THE TEESTA BRIDGE (3)

ABSTRACT

A storm of heavy magnitude occurred in the Teesta Valley from October 20 to 24, 1945. The magnitude of rainfall was very high on October 20, 21 and comparatively low on October 22 and 23 while it was very small on October 24. Describes the attempts made to get a unit hydrograph from this storm by separating out the effects of the rainfall on different days.

(2) The United Provinces Irrigation Research Station Annual Report on Research Progress during the year 1947, pages 5—6.

(3) Annual Report of the River Research Institute West Bengal 1947, pages 11—15.

(4) UNIT HYDROGRAPH OF THE CATCHMENT OF THE RIVER MOR ABOVE KHATANGA (4)

ABSTRACT

A unit hydrograph for the catchment has been prepared by working out average distribution of net flood runoff (unit 12 hours) from the percentage distribution of the seven floods picked out from the data for the years 1936 to 1941.

Observations of daily gauge heights and periodical discharges had been taken between 1926-41 in the river Mor at Khatanga where the barrage in the Mor Project was originally proposed to be constructed. The site of the barrage has been ultimately shifted a few miles downstream. The data for Khatanga show three-hourly readings of the gauge during floods for the years 1936-41. These floods have been utilised in an attempt to obtain a unit hydrograph for the site.

The flood hydrographs were generally the synthetic result of rainfall on several days. As such the natures of the hydrographs differed amongst themselves. However, it is found that generally the peak is reached on the second day and the runoff flood lasted for five or six days after the peak flow unless there was super-imposition of runoff from another rainfall. Seven suitable floods were picked out during the six years 1936-41, where the rising stage was not disturbed by overlapping of another storm and the falling stage was disturbed as little as possible.

If the flood is caused by rainfall on a single day of whatever amount, a unit hydrograph may be derived from this without any further consideration of the amount of the rainfall. Here though the runoff is caused by the synthesis of the runoff due to rainfall on two or three days—it is assumed that the runoff is caused by the rainfall that is of the largest amount, that is, the effect of the rainfall on other days has been neglected. The runoff is thus considered to be the result of a rainfall over 24-hours. The percentage distribution of the runoff on different days as observed here should then give the unit hydrograph on this assumption. This would be in error from the actual percentage distribution for the unit graph. But if such distributions from a large number of floods be worked out and averaged, these errors would tend to minimise. This is what has been attempted at here. Only seven floods could be picked out for this purpose and an average distribution has been worked out from these.

The rainfall has been supposed to have taken place during 24-hours. The flood discharges have been averaged for 12-hourly periods from 6 a.m. to 6 p.m. and from 6 p. m. to 6 a. m. These have been called day and night respectively. The observed hydrographs for these floods have been shown in Figure 1A.2. In the case when there has been a rise in the falling stage before the runoff from that storm appears to have ended, the graph in the falling stage has been extended by the dotted line in accordance with undisturbed falling stages of other floods. The base flow, also shown with dotted lines, is the flow as it would have been in the absence of the rainfall and increases a little to account for the addition by ground water flow.

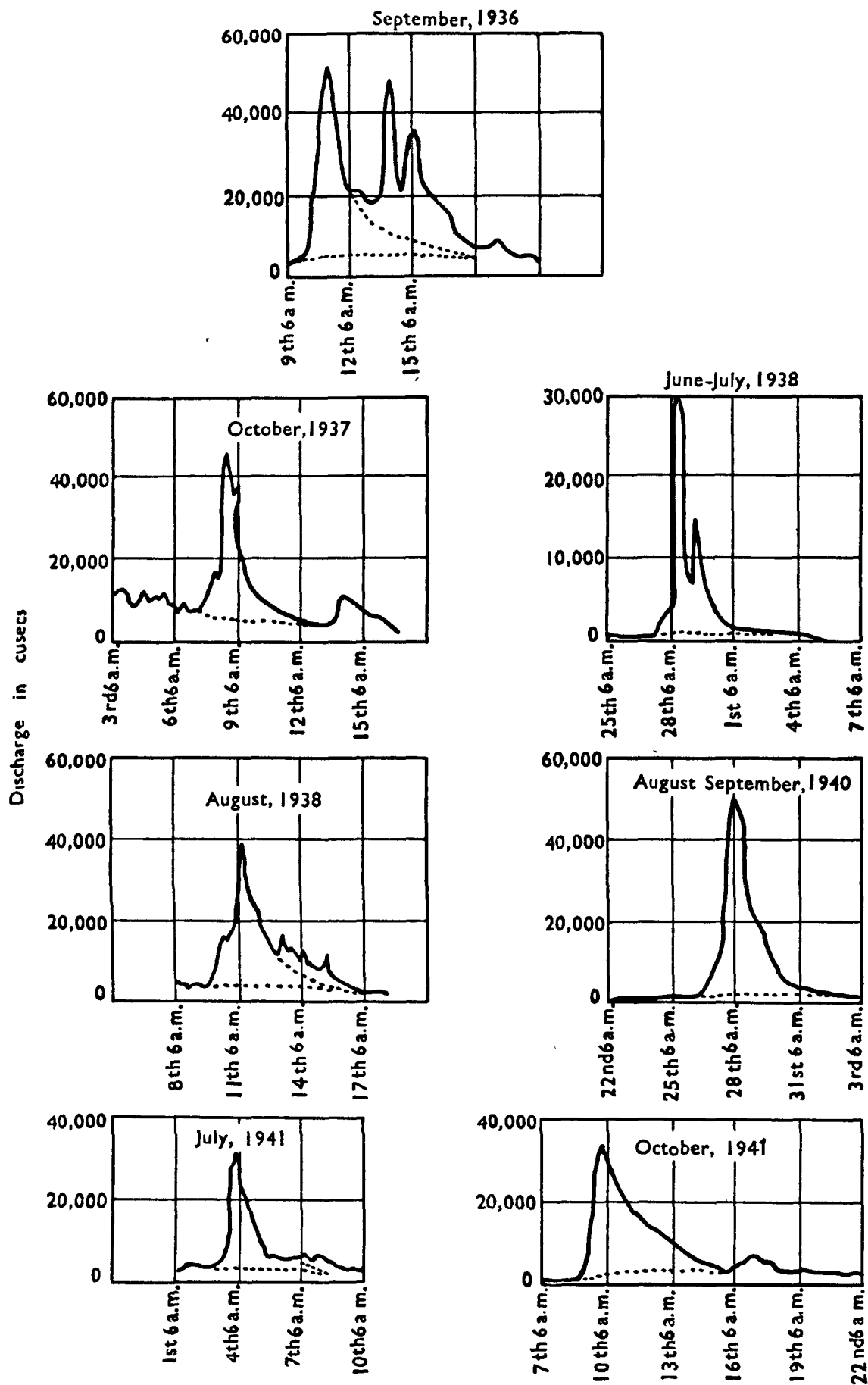
(4) Abridged from the Annual Report of the River Research Institute West Bengal 1947, pages 17-22.

Computations were made of the net runoff by subtracting the base flow from the observed flow for the seven floods. (In case, where there has been a rise in the receding stage of the flood and the falling stage has been extended as mentioned above, this extended curve has been taken for the observed flow). Table 1A.I gives the percentage distributions for all the seven floods and the average distribution worked out from these. The individual distributions for different floods are shown in Figure 1A.3 with the average curve shown in bold line. It is seen that the maximum runoff takes place usually in the fourth unit of time and occasionally in the third. For the average curve the peak is in the fourth unit of time.

TABLE 1A.I
River Mor at Khatanga
(Percentage of net runoff in different floods)

| Units of times in 12 hours | 1st flood, 9-9-36 | 2nd flood, 7-10-37 | 3rd flood, 26-6-38 | 4th flood, 9-8-38 | 5th flood, 26-8-40 | 6th flood, 2-7-41 | 7th flood, 8-10-41 | Average |
|----------------------------|-------------------|--------------------|--------------------|-------------------|--------------------|-------------------|--------------------|---------|
| 1 | 0.77 | 2.47 | 1.12 | 2.50 | 1.96 | 1.82 | 2.64 | 1.9 |
| 2 | 8.92 | 8.49 | 4.17 | 8.73 | 5.80 | 20.99 | 16.47 | 10.5 |
| 3 | 20.63 | 22.76 | 30.35 | 14.91 | 22.50 | 32.66 | 19.81 | 23.4 |
| 4 | 20.46 | 28.86 | 32.18 | 25.91 | 29.81 | 18.70 | 15.10 | 24.4 |
| 5 | 12.36 | 15.64 | 16.98 | 17.41 | 16.09 | 9.84 | 9.41 | 14.0 |
| 6 | 9.32 | 7.61 | 7.15 | 11.06 | 11.08 | 5.11 | 9.08 | 8.6 |
| 7 | 7.35 | 4.95 | 3.17 | 6.21 | 5.80 | 4.32 | 7.48 | 5.6 |
| 8 | 5.75 | 3.04 | 1.74 | 4.40 | 2.83 | 2.54 | 6.09 | 3.8 |
| 9 | 4.29 | 2.17 | 1.23 | 3.19 | 1.77 | 1.79 | 6.04 | 2.9 |
| 10 | 3.15 | 1.09 | 0.92 | 2.07 | 1.12 | 1.19 | 3.35 | 1.8 |
| 11 | 2.35 | 0.80 | 0.68 | 1.55 | 0.63 | 0.75 | 2.31 | 1.3 |
| 12 | 1.80 | 0.71 | 0.31 | 1.03 | 0.37 | 0.30 | 1.33 | 0.8 |
| 13 | 1.27 | 0.53 | 0.00 | 0.60 | 0.24 | 0.00 | 0.70 | 0.5 |
| 14 | 0.83 | 0.53 | 0.00 | 0.43 | 0.00 | 0.00 | 0.19 | 0.3 |
| 15 | 0.53 | 0.35 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.2 |
| 16 | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

This average distribution gives a unit graph for rainfall over 24-hours expressed in 12-hourly intervals. To obtain the distribution in 24-hourly intervals, that is, in days, it is only required to sum up these distribution percentages by two's. These daily percentage distributions are given in Table 1A.II. It is found that on the second day there is a high peak of 48 percent., of the total runoff.



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Figure 1A.2:- Showing observed hydrographs of the River Mor above Khatanga

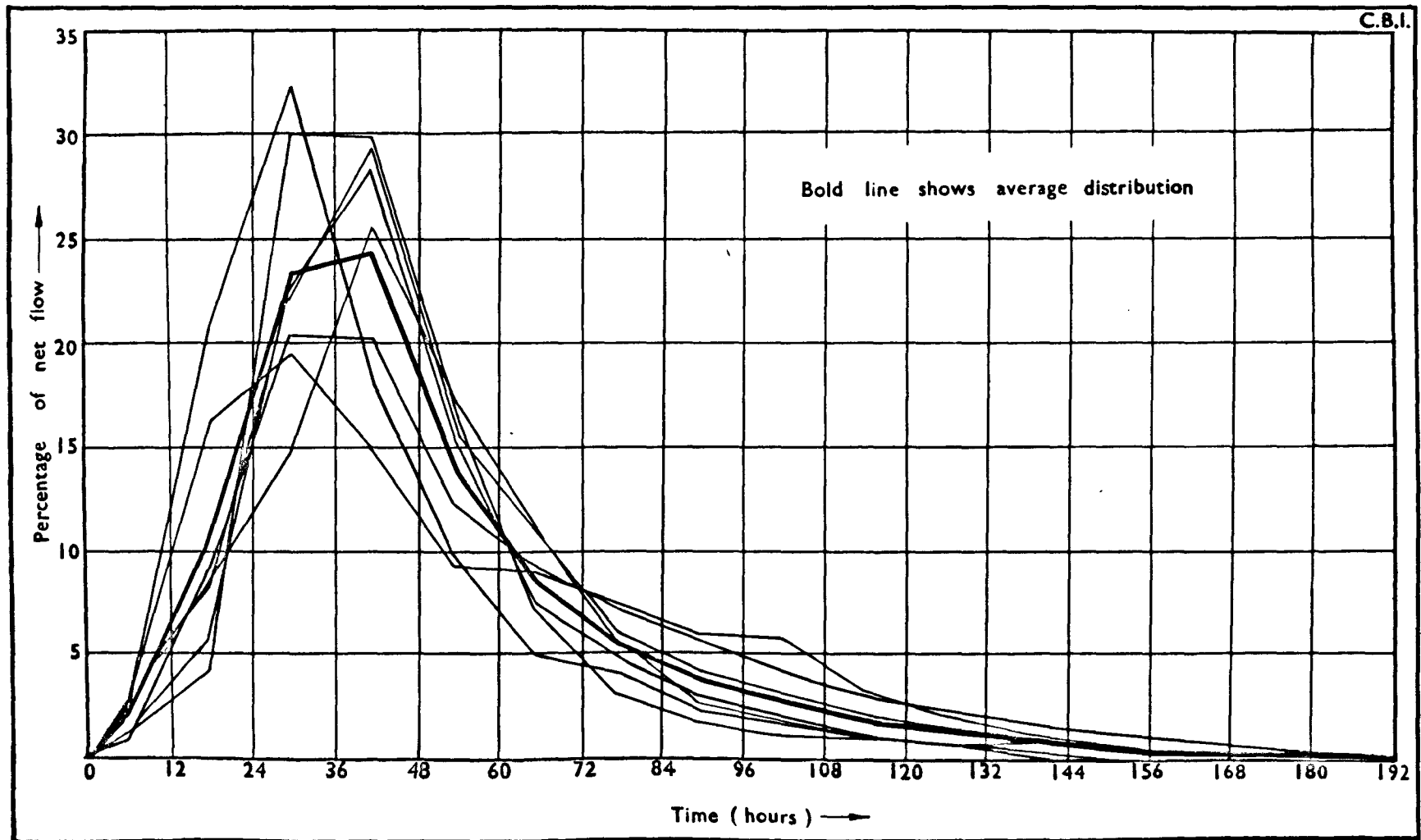


Figure 1A.3:— Showing distribution of surface runoff for different floods of River Mor at Khatanga

TABLE 1A.II
Unit hydrograph of river Mor at Khatanga.

| Days | Percentage | Ordinates of Unit hydrograph |
|-------|------------|------------------------------|
| 1 | 12.4 | 3,894 |
| 2 | 47.8 | 15,012 |
| 3 | 22.6 | 7,098 |
| 4 | 9.4 | 2,952 |
| 5 | 4.7 | 1,476 |
| 6 | 2.1 | 660 |
| 7 | 0.8 | 251 |
| 8 | 0.2 | 63 |
| Total | 100.00 | 31,406 |

The total catchment area of the Mor above Khatanga is 1,168 square miles. One inch of rainfall over this whole catchment running off totally in 24-hours would lead to a discharge rate of 31,406 cusecs. This, then, would be the sum of the ordinates of the unit hydrograph and should be distributed on the different days according to the percentages obtained above. The ordinates of the unit hydrograph are also given in Table 1A.II while the unit graph is shown in Figure A.4.

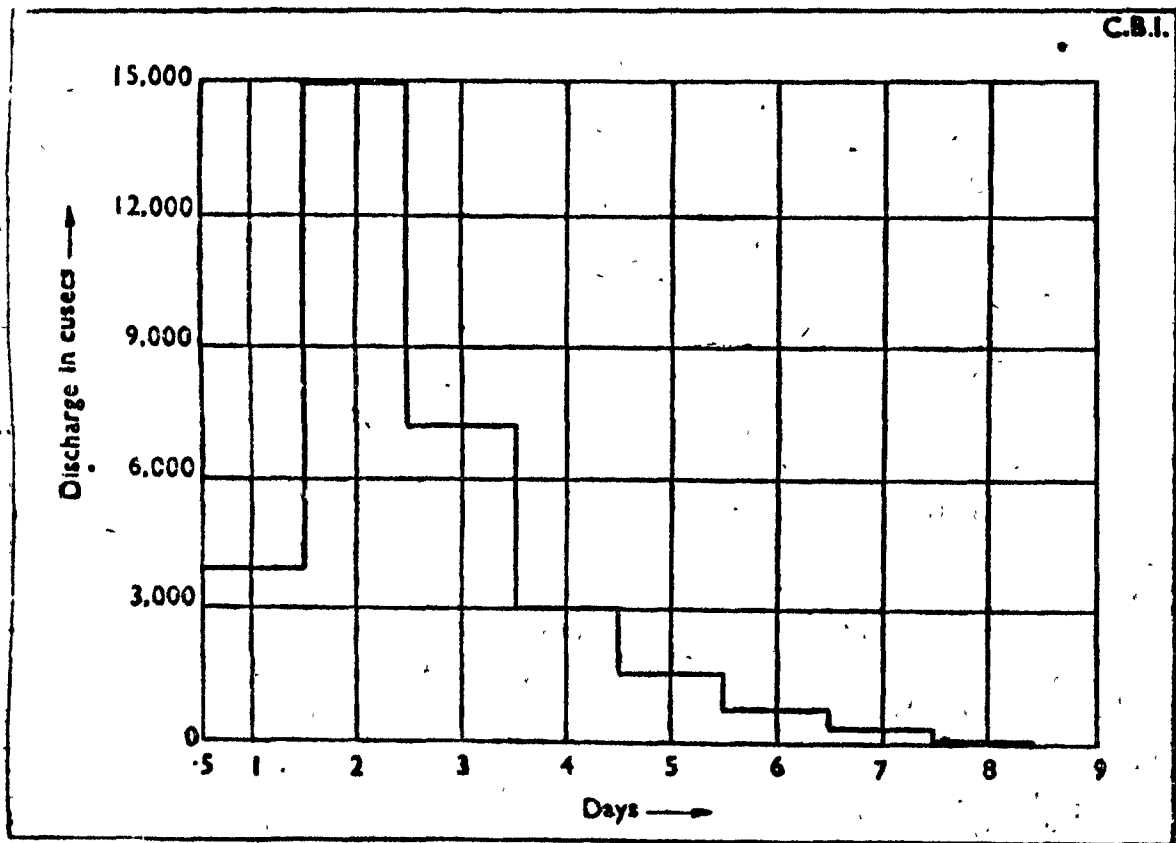


Figure 1A. 4: *Unit hydrograph of the river Mor at Khatanga.*

It has been found that the rainfall, though not taken into consideration for working out the unit graph here, usually takes place over three days, the amount on all these days being of fairly high order. Attempts are being made to separate out the unit hydrographs separately from each of the storms. These when averaged would give a distribution for the unit graph and would serve as a check on the average distribution obtained here.

(5) AVERAGE MONTHLY RUNOFF PERCENTAGE OF THE RIVER
BARAKAR ⁽⁵⁾

ABSTRACT

Hydrological observations of the rivers Damodar and Barakar were started in the year 1944. During the flood season of 1944 observations were taken on the Barakar at only one station *viz.*, Barakar-Giridih while the site on the G.T. Road near Barhi was opened in November 1944. In 1945 another stream-gauging station at the Barakar-Asansol Railway bridge site was opened. The monthly volumes of runoff have been calculated in acre-feet for the monsoon months (June to October) of 1944, 1945 and 1946.

The monthly volumes of runoff for the monsoon months (June to October) of 1944, 1945 and 1946 were calculated and are given in Table 1A.III.

TABLE 1A.III

Discharge volume of river Barakar

| No. | Name of the site | Catchment area in square miles | Month | 1944 discharge volume in acre feet | 1945 discharge volume in acre feet | 1946 discharge volume in acre feet |
|-----|--------------------|--------------------------------|--------------|------------------------------------|------------------------------------|------------------------------------|
| 1 | Barhi .. | 325 | June .. | .. | .. | 56,500 |
| | | | July .. | .. | .. | 180,800 |
| | | | August .. | .. | 37,600 | 118,000 |
| | | | September .. | .. | 81,900 | .. |
| | | | October .. | .. | 18,100 | .. |
| 2 | Barakar-Giridih .. | 1,550 | June .. | .. | 105,200 | 248,500 |
| | | | July .. | .. | 239,100 | 489,100 |
| | | | August .. | 565,900 | 235,200 | 518,000 |
| | | | September .. | 155,200 | 307,400 | 608,600 |
| | | | October .. | 75,600 | 184,500 | 256,300 |
| 3 | Barakar-Asansol .. | 2,500 | June .. | .. | .. | 360,500 |
| | | | July .. | .. | 342,400 | 704,600 |
| | | | August .. | .. | 359,500 | 761,300 |
| | | | September .. | .. | 593,300 | 885,500 |
| | | | October .. | .. | 358,000 | 315,000 |

The monthly rainfall data in the Barakar catchment are given in Table 1A.IV. In the Barhee catchment which is about 325 square miles there is only one rain-gauge station at Barhee, while another one at Kodarma falls outside the catchment a little downwards. The average of these two have been taken as representative of the rainfall in the catchment. Within the catchment above Barakar-Giridih (which is about 1,550 square miles) there are only six rain-gauge stations. The plain average of these have been taken for the average rainfall in the catchment. For the catchment area between Barakar-Giridih and Barakar-Asansol which is about 950 square miles there are six more rain-gauge stations. To get the average rainfall in the catchment area above Barakar-Asansol the rainfall in the six stations in the upper catchment have been given weights double of that in the six stations in the lower catchment. The average rainfall thus worked out is given at the bottom of Table 1A.IV.

(5) Annual Report of the River Research Institute West Bengal 1947, pages 22 to 25.

TABLE 1A.IV
Monthly rainfall statement in the Barakar Catchment

| Rain-gauge stations | 1944 | | | | | 1945 | | | | | 1946 | | | | |
|---|------|-------|--------|-----------|---------|-------|-------|--------|-----------|---------|-------|-------|--------|-----------|---------|
| | June | July | August | September | October | June | July | August | September | October | June | July | August | September | October |
| Barhi | 6.66 | 12.23 | 13.14 | 3.03 | 3.07 | 2.96 | 13.09 | 9.30 | 7.46 | 5.42 | 11.22 | 14.69 | 11.02 | 17.91 | 6.46 |
| Kodarma | 7.87 | 11.57 | 14.78 | 7.16 | 2.77 | 3.55 | 13.45 | 8.79 | 6.63 | 3.87 | 4.90 | 15.11 | 13.76 | 8.72 | 3.72 |
| Bagodar | 4.30 | 8.92 | 13.01 | 4.70 | 3.05 | 4.31 | 7.88 | .. | .. | 4.03 | 8.03 | 4.38 | 5.63 | 5.30 | 2.59 |
| Dhanwar | 7.25 | 12.97 | 12.10 | 2.37 | 4.78 | 2.72 | 19.26 | 8.23 | 7.93 | 1.92 | 9.37 | 8.88 | 5.53 | 1.63 | 5.39 |
| Giridih | 5.67 | 15.54 | 12.09 | 5.36 | 2.89 | 4.44 | 9.86 | 13.27 | 13.91 | 5.32 | 8.21 | 7.16 | 8.25 | 10.37 | 7.17 |
| Dumri | 5.41 | 16.72 | 16.78 | 4.89 | 1.37 | 4.89 | 8.41 | 9.38 | 9.27 | 7.03 | 11.12 | 10.63 | 9.67 | 3.62 | 8.34 |
| Tundi | 6.98 | 12.05 | 20.12 | 5.80 | 1.40 | 7.46 | 16.39 | 7.65 | 13.45 | 5.71 | 7.89 | 14.17 | 15.50 | 9.06 | 5.45 |
| Topechanchi | 7.91 | 16.48 | 14.43 | 4.52 | 2.27 | 10.27 | 11.05 | 8.08 | 7.88 | 7.20 | 7.75 | 15.80 | 11.19 | 8.17 | 7.18 |
| Dhanbad | 4.88 | 15.64 | 16.73 | 7.03 | 2.47 | 6.16 | 10.45 | 5.07 | 10.93 | 6.82 | 9.54 | 15.17 | .. | 9.90 | 3.85 |
| Govindapur | .. | 12.62 | 13.27 | 8.56 | 1.73 | 7.23 | 10.99 | 12.74 | 13.31 | 7.07 | 8.50 | 17.03 | 15.70 | 8.81 | .. |
| Pandra | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| Jamtara | 7.75 | 16.88 | 13.81 | 6.30 | 1.66 | 4.57 | 9.61 | 10.68 | 13.54 | 7.47 | 12.40 | 15.48 | 8.74 | 15.68 | 6.95 |
| Average monthly rainfall for the Barhi Catchment. | 7.27 | 11.90 | 13.95 | 5.11 | 2.92 | 3.26 | 13.27 | 9.05 | 7.05 | 4.65 | 8.06 | 14.90 | 12.39 | 13.32 | 5.09 |
| Average monthly rainfall for the Barakar-Giridih Catchment. | 6.19 | 12.99 | 13.65 | 4.59 | 2.99 | 3.81 | 11.99 | 9.79 | 9.04 | 4.60 | 8.81 | 10.14 | 8.96 | 7.93 | 5.81 |
| Average (weighted) rainfall for Barakar-Ancsol Catchment. | 6.37 | 13.50 | 14.25 | 5.13 | 2.67 | 4.79 | 11.91 | 9.48 | 9.97 | 4.85 | 8.93 | 11.73 | 9.92 | 8.63 | 5.67 |

(The rainfall in the upper catchment being given twice the weight of those in the lower catchment.)

Table 1A.V gives the rainfall in inches, average depth of runoff in inches and the runoff percentage for each of the three sites month by month. It is found that the runoff percentages as worked out for Barakar-Giridih and Barakar-Asansol for the month of September, 1946, are very high. It is seen from Table 1A.V that at one of the stations in the upper catchment, *viz.*, Dhanwar, the monthly rainfall magnitude for this month is very small and this has been given a double weightage. A rainfall contour map has been prepared on the basis of the monthly rainfall figures for this month at the different sites of the Damodar catchment, Figure 1A.5, and it is found from this map that only a very small area comes within the contour line of 2 inches rainfall, in which the Dhanwar site is situated. The average rainfall for the catchment worked out from this contour map would thus increase average figures as obtained here so that the runoff percentages would be lower.

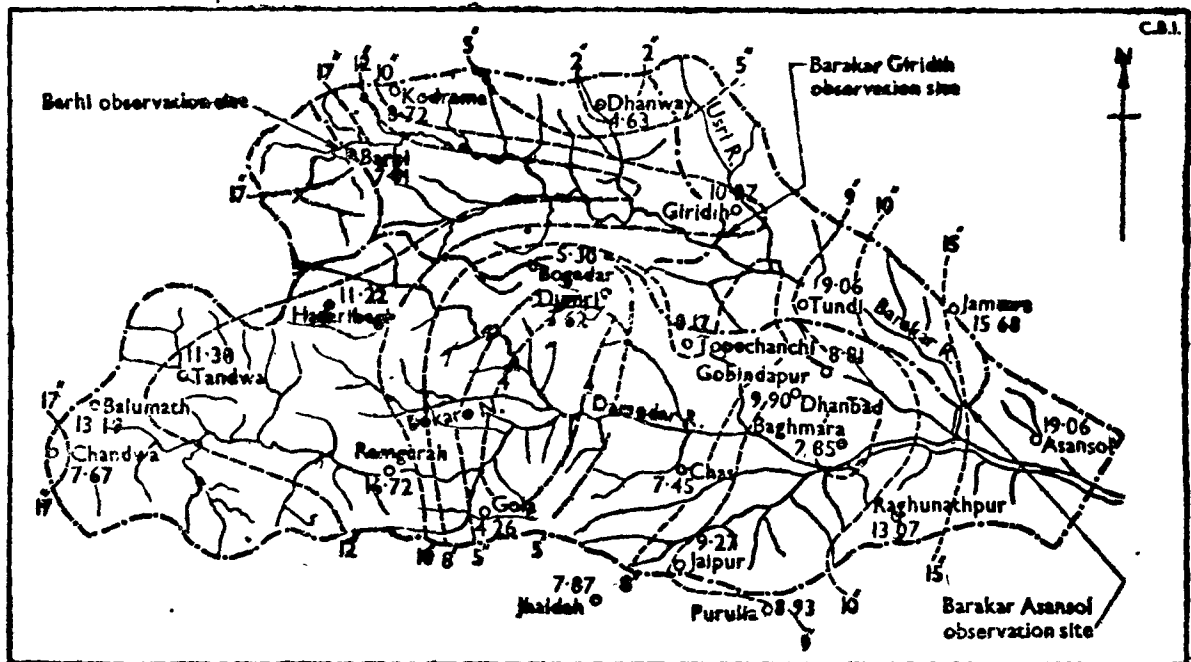


Figure 1A.5 : Rainfall contour map of the Damodar hill catchment for the month of September 1946.

Another feature noticeable in Table 1A.V is that for all the months of 1946 the runoff percentages at Barakar-Asansol are systematically lower than the corresponding figures for Barakar-Giridih. Thus the upper catchment gives more runoff than the lower catchment. This might be due to forestation and other topographical features of the upper and lower catchments. Further investigations are being done on this point.

TABLE IA.V
Runoff percentages

| Site | Catchment area in square miles | Month | 1944 | | | 1945 | | | 1946 | | |
|-----------------|--------------------------------|-----------|--------------------|----------------------------|-------------------|--------------------|----------------------------|-------------------|--------------------|----------------------------|-------------------|
| | | | Rainfall in inches | Discharge volume in inches | Runoff percentage | Rainfall in inches | Discharge volume in inches | Runoff percentage | Rainfall in inches | Discharge volume in inches | Runoff percentage |
| Barakar | 325 | June | 7.27 | .. | .. | 3.26 | .. | .. | 8.06 | 3.26 | 40.45 |
| | | July | 11.90 | .. | .. | 13.27 | .. | .. | 14.90 | 10.43 | 70.00 |
| | | August | 13.95 | .. | .. | 9.05 | 2.17 | 23.98 | 12.39 | 6.81 | 54.96 |
| | | September | 5.11 | .. | .. | 7.05 | 4.73 | 67.09 | 13.32 | .. | .. |
| | | October | 2.92 | .. | .. | 4.65 | 1.05 | 22.58 | 5.09 | .. | .. |
| Barakar-Giridih | 1,540 | June | 6.19 | .. | .. | 3.81 | 1.28 | 33.60 | 8.81 | 3.03 | 34.39 |
| | | July | 12.99 | .. | .. | 11.99 | 2.91 | 24.27 | 10.14 | 5.96 | 58.78 |
| | | August | 13.65 | 6.89 | 50.51 | 9.79 | 2.86 | 29.21 | 8.96 | 6.31 | 70.42 |
| | | September | 4.59 | 1.89 | 41.18 | 9.04 | 3.74 | 41.37 | 7.93 | 7.41 | 93.44 |
| | | October | 2.99 | 0.92 | 30.77 | 4.60 | 2.25 | 48.91 | 5.61 | 3.12 | 55.61 |
| Barakar-Asansol | 2,500 | June | 6.37 | .. | .. | 4.79 | .. | .. | 8.93 | 2.70 | 30.24 |
| | | July | 13.50 | .. | .. | 11.91 | 2.57 | 21.58 | 11.73 | 5.28 | 45.01 |
| | | August | 14.25 | .. | .. | 9.48 | 2.70 | 28.48 | 9.92 | 5.71 | 57.56 |
| | | September | 5.13 | .. | .. | 9.97 | 4.45 | 44.63 | 8.63 | 6.64 | 76.94 |
| | | October | 2.67 | .. | .. | 4.85 | 2.69 | 55.46 | 5.67 | 2.36 | 41.62 |

RAINFALL RUNOFF

(6) AVERAGE MONTHLY RUNOFF PERCENTAGE OF THE RIVER MOR (9)**ABSTRACT**

Discharge observations of the river Mor at Messenjore was started from the beginning of the year 1946. The monthly discharge volumes as also the average monthly rainfall in the catchment have been worked out. The average monthly runoff ratio has been calculated from these for the monsoon months (June to October) of the year 1946.

(7) MONTHLY DISCHARGE VOLUME OF THE RIVER MOR AT KHATANGA (6)**ABSTRACT**

Observations of gauge heights and periodical discharges of the Mor at Khatanga were taken during the monsoon months between the years 1926 and 1941. Records of gauge heights contain two or three readings a day upto 1935. From 1936 to 1941, the records show readings of gauge heights every three hours from 6 a.m. during to 6 p.m. floods, and two or three readings a day at other times, during the monsoon months (June to October). The readings in June begin from about the middle of the month. The discharge corresponding to each gauge reading had been computed from the periodical observations.

The discharge volume has been calculated month by month from July to October for the years 1936 to 1941.

(8) DISCHARGE VOLUME OF THE DAMODAR AND BARAKAR RIVERS DURING THE HIGHEST FLOOD (F 1947 (7))

The highest flood in the Upper Damodar during 1947 was recorded in the first week of September, while its main tributary, viz., the Barakar registered the maximum flood in the first week of August.

The total volume of water that passed through the Damodar and the Barakar rivers when these rivers were at their highest stages are given in Table IA.VI

TABLE IA.VI

| River | Name of site | Period | Volume of water in million acre feet |
|-------------|----------------------|--------------------------------------|--------------------------------------|
| Damodar .. | Chas Road .. | 3rd September to 7th September | 0.686 |
| Damodar .. | Sudamdih .. | 1st September to 14th September | 0.700 |
| Barakar .. | Barakar (Giridih) .. | 30th July to 5th August 1947 | 0.443 |
| Barakar .. | Barakar (Asansol) | 1st August to 8th August 1947 | 0.542 |
| Bokharo .. | Dania .. | 2nd September to 4th September | 0.028 |
| Damodar ... | Ramgarh .. | 3rd September to 6th September 1947. | 0.231 |

(6) Annual Report of the River Research Institute West Bengal 1947, page 26.

(7) Annual Report of the River Research Institute West Bengal 1947, page 27.

(9) SOME FEATURES OF PRECIPITATIONAL VARIATIONS IN THE UPPER INDUS CATCHMENT—A PROBABILITY METHOD OF APPROACH ⁽⁸⁾

ABSTRACT

An attempt has been made in this paper to study the recorded data of 75 years (1865-1940) of all the standard raingauge stations in the upper Indus catchment to be able to answer important questions relating to year to year variation of rainfall phenomena. For simplicity all raingauge stations have been given equal weightage in the analysis.

The distribution law governing the variation, for both the Kharif as well as Rabi season's rainfall, in these catchments, have been found out to subscribe generally to type I of the Pearsonian system of frequency curves, the skewness being positive. By integrating these curves, probability curves for directly reading off the probability of a season's rainfall not falling short of any specified measure, have been prepared. Together, these curves provide the answers to various questions on a statistical basis.

DOES THE YEAR TO YEAR RAINFALL PHENOMENA OBEY ANY LONG-TERM OR SHORT-TERM CYCLIC LAW? IF SO, WHAT IS THE MOST PROBABLE PERIOD OF THE CYCLE?

Temperature, humidity, hours of sunshine and other natural phenomena are, generally, governed by a periodogram law—sometimes subject to a combination of more than one periodic variation; for example, temperature is subject to the solar year as well as the solar day cycles. Is rainfall a similar *cyclic* phenomenon?

Rainfall is apparently irregular in frequency, duration and magnitude: rains are often early or late, it is either a dry year or a wet year, and so on, but, nevertheless, there is a current belief that rainfall variations repeat themselves after a period of 35 years. A successful estimate of the period T , if rainfall is cyclic, would be of great value for prediction of the *normal* expectation from the recorded data for any T successive years. For example, if R_1 and R_2 are the highest and lowest annual falls in a region subject to cyclic rainfall with period of cycle 35 years, rainfall would be a continuous function of time t with any year's fall very nearly expressed by

$$\frac{1}{2} (R_1 + R_2) + 2\frac{1}{2} (R_1 - R_2) \sin \frac{2\pi t}{35} \dots\dots\dots (1A.1)$$

where t assumes all integral values from 1 to 35.

Assuming that precipitational variations are governed by a periodogram law expressed by Equation (1A.1) above, all intensities of rainfall between R_1 and R_2 would ordinarily occur with the same frequency in a long series of years. Previous recorded data for several raingauge stations, however, disprove the

⁽⁸⁾ Central Waterways, Irrigation and Navigation Research Station Poona; Annual Report (Technical) 1947, Pages 7—18.

expectation and incidentally rule out the hypothesis of such periodicity. Nevertheless, 75 years, (1865—1940) actual recorded data of rainfall—*Kharif* and *Rabi* data considered separately—observed at seven raingauge stations in the Sutlej Catchment, where analysed for periodicities to see if there is any such indication in these data.

The method adopted was the usual one of calculating the mean phase values at each stage for all probable values of T , the length of a complete cycle. Taking all the alternative integral values of $T=2$ to $T=37$ years, the meagre data of 75 years permitted only two repetitions of the individual phase values for calculating their means at each stage. A comparison between the 36 ranges of variation of these mean phase values (for what they are worth) seemed to indicate a period of 22 years as more likely than any of the other 35 alternative values examined. [This finding is based on the analysis of the data for *Kharif* rainfall at one raingauge station, namely Kasauli ; but it is sufficiently indicative of the trends of other stations].

Values of T from 19 to 23 were next examined in greater detail, so as to produce at least one more repetition of the cycle from which to calculate the mean phase values. The ranges of variation between the mean phase values at Kasauli thus obtain were :—

| | | | | | | |
|---------------|------|------|------|------|------|------|
| T (Years) : | 19.0 | 20.0 | 21.0 | 21.5 | 22.0 | 23.0 |
| Range : | 30.0 | 33.9 | 40.2 | 46.2 | 41.3 | 31.9 |

The peak value of 46.2 indicates a precipitation cycle, if one exists, of about $21\frac{1}{2}$ years duration. In view of the very scanty data and the marked lack of any uniformity in the four repetitions little weight can be attached to the reality of any long-term period (such as 22 years) as this could be due to purely fortuitous causes alone.

A search for lower periodicities—2 to 15 years—according to the more exact method of the variations of the correlation ratio, based uniformly on five repetitions of the cycle, did not yield more fruitful results for any of the seven stations in the Sutlej Catchment, for either the *Kharif* season's or the *Rabi* season's rainfall.

IF RAINFALL IS NOT A PERIODIC FUNCTION OF TIME, WHAT IS THE SHORTEST PERIOD OF RAINFALL FROM WHICH THE MEAN NORMAL RAINFALL OF ANY PLACE CAN BE REASONABLY ESTIMATED—i.e. WHAT IS THE LEAST NUMBER OF YEARS FOR WHICH THE MEAN VALUE OF ANNUAL RAINFALL DOES NOT VARY APPRECIABLY FROM THAT OVER A LONGER PERIOD OF YEAR ?

While the investigation of periodicity must need be postponed until more data of rainfall becomes available, it is important to know the minimum number of years over which the calculated average yearly rainfall at any locality remains sensibly constant.

For this purpose, partial means for all possible 35-years and 45-years continuous periods were computed in the first instance. The 75 years data (for six raingauge stations in the Sutlej Catchment) provided, for each station, 41 successive mean values for 35-years periods, and 31 mean values for 45-years' periods. The 75 years' average being taken as the "normal", it was used as the yard stick with which to compare the several partial means and their percentage deviations from the "normal". The values of the largest *percentage* differences of such partial means from the "normal" are given in Table 1A. VII for each of the six raingauge stations.

TABLE 1 A. VII

| Season | Raingauge Station | "Normal" i.e. 75 years' mean rainfall | Standard Deviation | Percentage coefficient of variation | Percentage Deviation from 75 years' mean | | | |
|-----------|-------------------|---------------------------------------|--------------------|-------------------------------------|--|---------------|------------------|---------------|
| | | | | | of 35 years mean | | of 45 years mean | |
| 1 | 2 | 3 | 4 | 5 | Lowest 6 | Highest 6A | Lowest 7 | Highest 7A |
| Kharif .. | Kasauli .. | 56.02 | 16.14 | 28.8 | - 8.9 | + 2.3 | - 5.5 | + 1.1 |
| | Barauli .. | 41.38 | 13.67 | 33.0 | -10.1 | + 5.4 | - 8.4 | + 2.3 |
| | Simla .. | 52.51 | 12.02 | 22.9 | - 4.9 | + 4.5 | - 5.9 | + 2.9 |
| | Kot Khai .. | 31.86 | 12.48 | 39.2 | -18.6 | +19.2 | -17.9 | + 9.6 |
| | Kot Garh .. | 34.86 | 13.66 | 39.2 | -19.3 | +17.2 | -18.0 | + 8.9 |
| | Una .. | 31.51 | 10.14 | 32.2 | -3.2 | + 6.0 | - 1.4 | + 5.6 |
| Rabi .. | Kasauli .. | 10.32 | 5.18 | 50.2 | -14.8 | + 9.4 | -9.4 | + 7.0 |
| | Barauli .. | 9.61 | 4.80 | 49.9 | -11.7 | + 8.8 | -10.5 | + 4.5 |
| | Simla .. | 10.65 | 5.12 | 48.0 | - 1.4 | +13.1 | - 1.5 | +11.6 |
| | Kot Khai .. | 10.51 | 5.75 | 49.9 | - 9.4 | + 9.2 | - 7.1 | + 5.9 |
| | Kot Garh .. | 11.57 | 6.18 | 53.4 | - 9.7 | + 8.0 | - 7.1 | + 3.9 |
| | Una .. | 7.19 | 5.02 | 69.8 | - 3.6 | +16.3 | - 4.1 | +12.0 |

The 35-years' means do not generally deviate from the 75-years' mean by more than about ± 10 per cent for *Kharif* and ± 15 per cent for *Rabi* season's rainfall. The two exceptions, Kot Khai and Kot Garh in *Kharif*, do not show any material improvement even by including 45 years' data for calculating the partial means. On the other hand, the very large values of the coefficients of variation (in column 5 of Table 1A.VII) for the stations registering big percentage deviations perhaps indicate that dispersion is rather inherent in the stations themselves. In a similar manner, the same explanation answers why a wider measure of latitude is necessary in the *Rabi* season's rainfall.

It was, therefore, considered more appropriate to attempt to fit frequency curves to the rainfall data with a view to obtaining the extent of the probable deviations of the fall above and below the normal, their long-range frequencies, etc.

Starting with the *Kharif* rainfall at Kasauli a skew distribution of Pearson type I for the percentage probability of rainfall in any one year being equal to R was obtained as—

$$y = 11.68 \left(1 + \frac{R-56.36}{46.638} \right)^{4.002} \left(\frac{1-R-56.36}{84.389} \right)^{8.051} \quad (1A.2)$$

with *skewness* equal to 9.19. The curve is, therefore, not very far from being symmetrical with the total *probability* of rainfall exceeding the mean being 48 per cent.

Other general indications are also evident from this curve, such as : (a) years of scanty rainfall occur more frequently than very wet years ; and (b) the extent of the departures of rainfall in above-normal years is larger than in below normal years.

This method being thus evidently promising, it was applied to study the frequency features of precipitation in *whole catchments* rather than at individual stations, since it is the former that are more important in irrigation engineering.

The catchments considered in this study cover the four principal rivers of the Punjab, viz., the Indus (15 stations), Sutlej (7 stations), Chenab (12 stations) and the Beas (10 stations). The units of frequency considered are *station-years*, the total rainfall recorded at any raingauge station during each season being taken to constitute one *station-year*. The names of the raingauge stations in each catchment and the number of years for which the records were available for each station are shown in Table 1A.VIII. The data for the total number of station-years in each catchment were then analysed for the *probability* that the average rainfall in the catchment does not exceed any specified value during a season. This was done by the method of fitting appropriate Pearson type

TABLE IA. VIII

Analysis of rainfall data of Sutlej Catchment

| Stations | No. of years Data available for | Normal or mean rainfall in inches | Percentage of years above normal | Below normal | | Above normal | | Percentage falls in wettest year | Percentage average fall of the driest | | | | Co-efficient of Variation |
|----------|---------------------------------|-----------------------------------|----------------------------------|--------------|-------|--------------|-------|----------------------------------|---------------------------------------|---------|---------|---------|---------------------------|
| | | | | Mean fall | Range | Mean fall | Range | | 1 year | 2 years | 3 years | 4 years | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |

Kharif Season.

| | | | | | | | | | | | | | |
|------------|----|-------|------|-------|-------|-------|-------|-------|------|------|------|------|------|
| Kasauli | 75 | 56.02 | 46.6 | 43.72 | 33.57 | 70.00 | 44.50 | 179.9 | 38.2 | 41.3 | 43.6 | 46.6 | 28.8 |
| Barauli | 75 | 41.38 | 44.0 | 32.40 | 31.44 | 52.81 | 43.13 | 204.6 | 21.3 | 31.2 | 40.1 | 44.8 | 33.0 |
| Simla | 75 | 52.51 | 48.0 | 43.40 | 21.90 | 62.38 | 38.77 | 174.3 | 56.4 | 57.1 | 59.7 | 61.9 | 22.9 |
| Kot Khai | 75 | 31.86 | 37.3 | 24.21 | 16.94 | 44.70 | 38.99 | 223.5 | 46.6 | 47.0 | 48.4 | 49.4 | 39.2 |
| Kot Garh | 75 | 34.86 | 38.6 | 26.69 | 18.28 | 47.81 | 53.00 | 252.5 | 47.5 | 50.9 | 53.0 | 54.1 | 39.2 |
| Kilbe | 58 | 17.19 | 32.8 | 11.28 | 13.32 | 29.31 | 36.25 | 315.7 | 20.9 | 22.9 | 27.4 | 30.8 | 62.8 |
| Una | 75 | 31.51 | 44.0 | 24.02 | 17.70 | 41.05 | 25.35 | 181.5 | 42.2 | 43.9 | 45.7 | 47.3 | 32.2 |
| Swabi | 69 | 15.43 | 50.7 | 8.80 | 14.90 | 21.88 | 18.83 | 223.4 | 0.0 | 0.0 | 1.5 | 5.0 | 54.0 |
| Abbottabad | 81 | 31.00 | 48.1 | 25.55 | 12.72 | 36.87 | 29.01 | 193.9 | 58.1 | 59.4 | 60.0 | 61.5 | 24.5 |
| Kohat | 79 | 11.30 | 44.3 | 7.91 | 8.16 | 15.56 | 10.43 | 192.5 | 27.4 | 27.7 | 32.8 | 36.8 | 42.2 |
| Mansehra | 75 | 23.64 | 44.0 | 18.86 | 13.86 | 29.73 | 20.34 | 197.2 | 41.0 | 41.7 | 44.3 | 47.0 | 29.1 |

Rabi

| | | | | | | | | | | | | | |
|------------|----|-------|------|-------|-------|-------|-------|-------|------|------|------|------|------|
| Kasauli | 75 | 10.32 | 41.3 | 6.71 | 7.29 | 15.45 | 13.56 | 232.9 | 29.1 | 31.5 | 32.3 | 34.0 | 50.2 |
| Barauli | 75 | 9.61 | 45.3 | 6.03 | 8.75 | 13.93 | 13.89 | 245.3 | 4.2 | 6.2 | 12.8 | 19.2 | 49.9 |
| Simla | 75 | 10.65 | 41.3 | 7.11 | 9.15 | 15.69 | 13.03 | 228.6 | 14.1 | 17.4 | 19.1 | 20.8 | 48.0 |
| Kot Khai | 75 | 11.51 | 44.0 | 7.35 | 10.78 | 16.80 | 15.80 | 238.1 | 5.0 | 7.7 | 14.1 | 18.5 | 49.9 |
| Kot Garh | 75 | 11.57 | 49.3 | 6.82 | 11.50 | 16.46 | 20.86 | 281.6 | 0.0 | 6.7 | 9.1 | 10.7 | 53.4 |
| Kilbe | 55 | 13.15 | 36.4 | 9.13 | 10.35 | 20.20 | 16.42 | 229.1 | 18.8 | 18.9 | 19.9 | 22.5 | 51.2 |
| Una | 75 | 7.19 | 38.6 | 4.35 | 6.88 | 11.70 | 29.80 | 515.9 | 1.4 | 9.8 | 14.4 | 16.8 | 69.8 |
| Swabi | 69 | 8.06 | 42.5 | 4.11 | 7.90 | 12.15 | 16.57 | 310.1 | 0.0 | 0.0 | 0.0 | 4.0 | 61.1 |
| Abbottabad | 81 | 15.81 | 43.2 | 11.40 | 10.77 | 21.61 | 16.44 | 204.9 | 30.4 | 31.0 | 32.7 | 34.1 | 49.4 |
| Kohat | 78 | 6.33 | 44.9 | 3.93 | 5.60 | 9.28 | 13.90 | 322.2 | 7.9 | 12.6 | 14.8 | 16.9 | 56.5 |
| Mansehra | 74 | 13.12 | 41.9 | 9.19 | 10.00 | 18.56 | 30.83 | 338.8 | 23.6 | 26.7 | 29.5 | 32.0 | 48.7 |

RAINFALL RUNOFF

TABLE IA. VIII—contd.

Analysis of rainfall data of Indus Catchment

| Stations | No. of years data available for | Normal or mean rainfall in inches | Percentage of years above normal | Below normal | | Above normal | | Percentage falls in wettest year | Percentage average fall of the driest | | | | Co-efficient of Variation |
|----------|---------------------------------|-----------------------------------|----------------------------------|--------------|-------|--------------|-------|----------------------------------|---------------------------------------|---------|---------|---------|---------------------------|
| | | | | Mean fall | Range | Mean fall | Range | | 1 year | 2 years | 3 years | 4 years | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |

Khariif

| | | | | | | | | | | | | | |
|-------------|----|-------|------|-------|-------|-------|-------|-------|------|------|------|------|------|
| Haripur .. | 75 | 20.27 | 46.7 | 15.93 | 12.13 | 25.23 | 16.77 | 183.6 | 39.0 | 45.2 | 48.0 | 50.1 | 29.1 |
| Cherat .. | 42 | 16.49 | 38.1 | 11.50 | 11.51 | 24.60 | 19.55 | 231.9 | 30.0 | 35.4 | 40.2 | 40.5 | 47.3 |
| Malakand .. | 38 | 19.17 | 47.4 | 13.08 | 10.94 | 25.93 | 22.19 | 217.9 | 38.3 | 38.6 | 39.4 | 40.3 | 43.0 |
| Oghi .. | 39 | 26.95 | 53.8 | 21.58 | 19.08 | 31.56 | 9.24 | 134.8 | 28.5 | 43.1 | 51.6 | 55.9 | 23.5 |
| Leh .. | 63 | 2.11 | 41.3 | 1.27 | 1.70 | 3.32 | 9.18 | 538.3 | 18.5 | 18.9 | 19.6 | 20.7 | 74.4 |
| Kargil .. | 46 | 4.10 | 43.5 | 2.60 | 3.46 | 6.05 | 5.94 | 248.0 | 15.1 | 20.4 | 25.9 | 30.7 | 51.9 |
| Dras .. | 46 | 9.11 | 43.5 | 6.36 | 5.61 | 12.67 | 8.42 | 195.1 | 38.2 | 38.5 | 42.9 | 45.6 | 40.9 |
| Skardu .. | 49 | 3.67 | 30.6 | 2.28 | 3.13 | 6.83 | 21.50 | 690.3 | 14.2 | 14.6 | 17.3 | 18.8 | 99.2 |
| Gilgit .. | 48 | 3.39 | 47.9 | 2.45 | 2.07 | 4.41 | 3.41 | 203.4 | 37.2 | 37.8 | 41.4 | 43.8 | 37.2 |
| Murree .. | 73 | 41.77 | 42.5 | 33.86 | 23.80 | 52.48 | 34.34 | 182.6 | 43.0 | 48.9 | 51.1 | 52.4 | 27.4 |
| Kahute .. | 59 | 29.49 | 49.2 | 21.70 | 16.33 | 37.56 | 28.95 | 198.4 | 44.2 | 47.4 | 50.2 | 52.3 | 33.6 |

Rabi

| | | | | | | | | | | | | | |
|-------------|----|-------|------|-------|-------|-------|-------|-------|------|------|------|------|------|
| Hariphr .. | 74 | 9.84 | 45.9 | 6.16 | 7.18 | 14.17 | 13.71 | 240.6 | 26.4 | 26.9 | 28.5 | 29.3 | 50.2 |
| Cherat .. | 40 | 11.58 | 50.0 | 7.10 | 10.11 | 16.05 | 12.10 | 205.3 | 6.2 | 17.4 | 22.8 | 25.5 | 47.9 |
| Malakand .. | 37 | 14.99 | 54.1 | 10.19 | 9.76 | 19.06 | 11.47 | 182.1 | 26.9 | 30.6 | 36.6 | 41.3 | 36.0 |
| Oghi .. | 38 | 21.96 | 44.7 | 16.76 | 12.34 | 28.38 | 19.54 | 191.0 | 40.9 | 43.4 | 45.7 | 47.4 | 33.6 |
| Leh .. | 62 | 1.34 | 35.5 | 0.82 | 1.23 | 2.29 | 3.22 | 340.0 | 8.2 | 9.3 | 9.7 | 17.6 | 68.3 |
| Kargil .. | 46 | 5.87 | 39.1 | 3.90 | 5.07 | 9.08 | 15.78 | 371.9 | 9.9 | 18.5 | 23.0 | 26.5 | 62.3 |
| Dras .. | 46 | 15.99 | 39.1 | 11.07 | 10.05 | 23.65 | 23.59 | 255.4 | 34.9 | 36.6 | 37.9 | 39.4 | 50.1 |
| Skardu .. | 48 | 3.30 | 39.6 | 2.04 | 2.94 | 5.23 | 12.52 | 482.9 | 7.3 | 14.4 | 17.4 | 19.6 | 72.7 |
| Gilgit .. | 47 | 1.82 | 34.0 | 1.02 | 1.62 | 3.39 | 5.17 | 384.0 | 8.2 | 11.5 | 12.6 | 14.8 | 81.1 |
| Murree .. | 72 | 16.04 | 45.8 | 9.92 | 14.82 | 23.29 | 32.69 | 303.9 | 6.3 | 9.5 | 12.6 | 14.4 | 57.6 |
| Kahute .. | 58 | 9.95 | 48.3 | 6.17 | 8.99 | 14.00 | 14.18 | 246.3 | 7.9 | 14.7 | 18.9 | 23.4 | 48.4 |

TABLE IA. VIII—contd.
Analysis of rainfall data of Chanab Catchment

| Stations | No. of years data available for | Normal or mean rainfall in inches | Percentage of years above normal | Below normal | | Above normal | | Percentage falls in wettest year | Percentage average fall of the driest | | | | Co-efficient of Variation |
|----------|---------------------------------|-----------------------------------|----------------------------------|--------------|-------|--------------|-------|----------------------------------|---------------------------------------|---------|---------|---------|---------------------------|
| | | | | Mean fall | Range | Mean fall | Range | | 1 year | 2 years | 3 years | 4 years | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |

Kharij

| | | | | | | | | | | | | | |
|--------------------------|----|-------|------|-------|-------|-------|--------|-------|------|------|------|------|------|
| Jammu .. | 50 | 32.97 | 42.0 | 25.01 | 17.41 | 43.95 | 37.93 | 216.2 | 45.3 | 48.6 | 51.0 | 53.1 | 36.1 |
| Kishtawar .. | 50 | 16.91 | 46.0 | 12.85 | 7.53 | 21.67 | 18.30 | 210.9 | 54.3 | 55.5 | 56.0 | 56.8 | 32.2 |
| Ramban .. | 50 | 22.23 | 44.0 | 16.90 | 13.46 | 29.02 | 17.12 | 178.4 | 39.3 | 41.3 | 44.3 | 46.1 | 33.7 |
| Akhumr .. | 41 | 34.70 | 46.3 | 25.33 | 18.08 | 45.54 | 51.93 | 249.7 | 45.9 | 46.8 | 48.3 | 49.3 | 40.4 |
| Rampur Rajani .. | 41 | 39.46 | 43.9 | 32.21 | 20.12 | 48.73 | 23.96 | 162.9 | 47.8 | 48.8 | 53.2 | 55.4 | 25.8 |
| Ramnagar .. | 40 | 49.75 | 42.5 | 39.21 | 21.82 | 64.00 | 50.98 | 202.7 | 55.2 | 56.2 | 59.2 | 62.0 | 33.3 |
| Gulabgarh .. | 37 | 48.60 | 29.7 | 32.83 | 30.36 | 85.87 | 134.31 | 380.6 | 36.1 | 37.7 | 41.8 | 44.2 | 67.4 |
| Sambeh .. | 40 | 32.94 | 42.5 | 24.93 | 16.22 | 43.78 | 39.27 | 220.9 | 48.2 | 48.5 | 51.0 | 52.9 | 38.1 |
| Riasi .. | 40 | 49.20 | 45.0 | 37.76 | 25.26 | 63.17 | 41.40 | 185.1 | 47.1 | 51.3 | 54.1 | 57.6 | 31.6 |
| Udampur .. | 40 | 42.71 | 45.0 | 33.98 | 22.80 | 53.38 | 28.81 | 167.6 | 46.3 | 52.1 | 54.2 | 58.1 | 27.7 |
| Sri Ranbir Singh Pore .. | 40 | 27.50 | 42.5 | 19.93 | 13.83 | 37.74 | 30.45 | 215.3 | 48.8 | 49.8 | 50.1 | 50.4 | 41.0 |
| Kailang .. | 53 | 11.04 | 39.6 | 8.90 | 7.44 | 14.29 | 10.68 | 197.5 | 32.5 | 41.5 | 45.7 | 49.7 | 31.1 |

Rabi

| | | | | | | | | | | | | | |
|--------------------------|----|-------|------|-------|-------|-------|-------|-------|------|------|------|------|------|
| Jammu .. | 49 | 9.05 | 51.0 | 5.64 | 6.63 | 12.33 | 12.64 | 240.4 | 21.1 | 21.2 | 21.4 | 23.1 | 49.4 |
| Kishtawar .. | 49 | 19.31 | 51.0 | 13.31 | 12.80 | 25.07 | 19.35 | 200.8 | 28.5 | 31.6 | 33.7 | 36.7 | 37.8 |
| Ramban .. | 49 | 23.71 | 55.1 | 15.87 | 17.88 | 30.11 | 23.14 | 197.8 | 20.3 | 24.9 | 28.3 | 31.0 | 38.1 |
| Akhumr .. | 40 | 9.35 | 42.5 | 6.27 | 7.87 | 13.53 | 8.40 | 195.1 | 13.2 | 18.1 | 21.7 | 28.4 | 46.2 |
| Rampur Rajani .. | 40 | 16.00 | 52.5 | 11.20 | 12.92 | 20.35 | 15.07 | 195.0 | 17.9 | 19.3 | 26.2 | 30.4 | 37.1 |
| Ramnagar .. | 39 | 16.51 | 43.6 | 11.90 | 14.09 | 22.49 | 21.92 | 238.4 | 12.4 | 28.8 | 35.5 | 39.2 | 41.8 |
| Gulabgarh .. | 37 | 25.43 | 35.1 | 16.87 | 19.72 | 41.23 | 74.29 | 393.2 | 21.2 | 23.9 | 25.4 | 26.5 | 69.8 |
| Sambeh .. | 40 | 8.35 | 47.5 | 5.21 | 7.15 | 11.82 | 11.52 | 241.4 | 11.0 | 20.8 | 26.7 | 29.8 | 50.4 |
| Riasi .. | 40 | 15.21 | 45.0 | 11.24 | 12.60 | 20.05 | 18.23 | 223.3 | 16.8 | 21.0 | 26.6 | 30.8 | 39.2 |
| Udampur .. | 39 | 15.14 | 48.7 | 10.98 | 14.90 | 19.51 | 18.21 | 222.0 | 0.0 | 16.5 | 24.0 | 31.5 | 40.5 |
| Sri Ranbir Singh Pore .. | 40 | 7.50 | 42.5 | 4.85 | 6.77 | 11.09 | 15.75 | 312.0 | 6.1 | 14.4 | 18.8 | 22.0 | 55.0 |
| Kailang .. | 53 | 11.31 | 50.9 | 8.00 | 6.58 | 14.50 | 10.55 | 193.9 | 40.1 | 42.0 | 44.0 | 46.3 | 35.4 |

RAINFALL RUNOFF

TABLE IA. VIII—contd.
Analysis of rainfall data of Beas Catchment

| Stations | No. of years Data available for | Normal of mean rainfall in inches | Percentage of years above normal | Below normal | | Above normal | | Percentage falls in wettest year | Percentage average fall of the | | | | Co-efficient of Variation |
|----------|---------------------------------|-----------------------------------|----------------------------------|--------------|-------|--------------|-------|----------------------------------|--------------------------------|---------|---------|--------|---------------------------|
| | | | | Mean fall | Range | Mean fall | Range | | 1 year | 2 years | 3 years | 4 year | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |

Kharif

| | | | | | | | | | | | | | |
|---------------|----|-------|------|-------|-------|--------|-------|-------|------|------|------|------|------|
| Banjar .. | 73 | 29.93 | 48.0 | 24.01 | 24.40 | 36.35 | 20.45 | 168.7 | 18.4 | 23.1 | 32.1 | 39.1 | 27.0 |
| Kulu .. | 73 | 22.57 | 41.1 | 16.96 | 18.06 | 30.62 | 74.12 | 429.3 | 18.2 | 29.7 | 34.4 | 38.7 | 51.2 |
| Nagar .. | 57 | 38.08 | 50.9 | 22.36 | 12.14 | 33.59 | 16.14 | 158.0 | 56.6 | 58.1 | 58.7 | 59.9 | 24.1 |
| Palampur .. | 73 | 85.95 | 48.0 | 69.24 | 39.32 | 104.10 | 48.78 | 157.6 | 53.5 | 53.5 | 53.8 | 54.4 | 25.5 |
| Hamirpur .. | 73 | 42.66 | 45.2 | 32.54 | 27.78 | 54.93 | 43.80 | 202.8 | 34.7 | 38.6 | 42.2 | 44.2 | 33.7 |
| Dera .. | 73 | 43.38 | 41.1 | 34.06 | 25.73 | 56.74 | 33.55 | 182.7 | 40.6 | 40.6 | 43.6 | 46.4 | 30.5 |
| Kangra .. | 73 | 62.98 | 48.0 | 49.72 | 46.31 | 77.37 | 71.77 | 214.5 | 24.3 | 36.4 | 42.6 | 45.6 | 29.6 |
| Dharamsala .. | 74 | 99.69 | 47.3 | 81.20 | 53.46 | 120.29 | 80.49 | 181.5 | 45.7 | 46.0 | 46.7 | 49.9 | 25.9 |
| Nurpur .. | 73 | 48.65 | 50.7 | 36.49 | 24.73 | 60.47 | 47.59 | 198.9 | 48.2 | 49.5 | 49.9 | 50.3 | 31.1 |

Rabi

| | | | | | | | | | | | | | |
|---------------|----|-------|------|-------|-------|-------|-------|-------|------|------|------|------|------|
| Banjar .. | 72 | 11.57 | 54.2 | 7.74 | 8.33 | 15.09 | 13.29 | 214.1 | 25.6 | 29.9 | 32.7 | 36.3 | 37.7 |
| Kulu .. | 72 | 16.29 | 55.6 | 10.40 | 10.95 | 21.01 | 14.60 | 190.3 | 31.9 | 32.8 | 33.6 | 35.0 | 38.6 |
| Nagar .. | 57 | 20.55 | 52.6 | 13.74 | 12.16 | 26.67 | 18.64 | 191.3 | 37.7 | 40.1 | 41.2 | 42.9 | 37.8 |
| Palampur .. | 72 | 16.47 | 47.2 | 10.82 | 11.78 | 22.78 | 24.94 | 252.0 | 26.7 | 29.4 | 30.6 | 31.6 | 45.7 |
| Hamirpur .. | 72 | 8.74 | 43.1 | 5.84 | 8.04 | 12.57 | 15.00 | 273.5 | 4.6 | 14.7 | 19.6 | 23.1 | 48.4 |
| Dera .. | 72 | 8.31 | 44.4 | 5.47 | 8.01 | 12.99 | 19.23 | 318.9 | 8.9 | 9.5 | 13.6 | 16.5 | 55.7 |
| Kangra .. | 72 | 10.31 | 43.1 | 7.03 | 6.64 | 14.63 | 12.14 | 219.5 | 34.0 | 34.8 | 35.6 | 37.0 | 44.7 |
| Dharamsala .. | 74 | 16.38 | 47.3 | 11.40 | 12.76 | 21.92 | 15.91 | 197.3 | 22.0 | 27.1 | 29.7 | 31.7 | 40.7 |
| Nurpur .. | 72 | 11.57 | 40.3 | 7.85 | 9.88 | 17.09 | 17.10 | 249.7 | 14.5 | 20.7 | 22.9 | 24.4 | 50.5 |

frequency curves to the observed uneven distributions. The curves, Figure IA.6, turned out invariably to be of Type I with finite ends on either sides, their equations being of the form—

$$=y \left(1 + \frac{R - \text{mode}}{a_1}\right)^{m_1} \left(1 - \frac{R - \text{mode}}{a_2}\right)^{m_2} dR \quad (\text{IA. 3})$$

The values of the constants for each catchment are as set out in Table IA, IX.

TABLE IA.IX

| Catchment | y ₀ | Mode (inches) | a ₁ | a ₂ | m ₁ | m ₂ | Skewness | Mean Precipitation (inches) | Percentage Probability of fall exceeding mean | Mean fall in years (inches) | |
|--------------------|----------------|---------------|----------------|----------------|----------------|----------------|----------|-----------------------------|---|-----------------------------|--------------|
| | | | | | | | | | | Below Normal | Above Normal |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| <i>Kharij</i> | | | | | | | | | | | |
| Sutlej .. | 11.33 | 30.74 | 26.872 | 107.979 | 1.645 | 6.608 | 0.45 | 38.65 | 45.4 | 25.76 | 54.15 |
| Indus .. | 16.10 | 10.76 | 14.065 | 97.641 | 1.051 | 7.296 | 0.61 | 18.83 | 43.8 | 9.49 | 30.81 |
| Chenab .. | 12.92 | 23.05 | 21.785 | 254.835 | 1.845 | 21.584 | 0.54 | 32.22 | 43.4 | 20.28 | 47.79 |
| Beas .. | 9.35 | 18.72 | 4.120 | 185.624 | 0.074 | 3.340 | 1.12 | 62.24 | 41.1 | 31.78 | 81.50 |
| All four combined | 11.28 | 14.64 | 11.733 | 427.031 | 0.521 | 18.976 | 0.83 | 33.96 | 40.2 | 18.53 | 56.92 |
| <i>Rabi</i> | | | | | | | | | | | |
| Sutlej .. | 15.61 | 7.44 | 7.668 | 221.470 | 2.267 | 65.491 | 0.53 | 10.50 | 43.1 | 7.19 | 14.87 |
| Indus and Chenab | 16.04 | 7.36 | 10.134 | 156.757 | 1.886 | 29.165 | 0.55 | 11.79 | 43.0 | 6.18 | 19.23 |
| All four combined. | 11.88 | 8.01 | 10.106 | 185.614 | 2.212 | 40.626 | 0.52 | 11.92 | 42.9 | 6.70 | 18.88 |

The positive signs of skewness—skewness is a relative measure of the deviation of the *Modal* (i.e., the most frequently occurring) rainfall (Col. 3. Table IA.IX) from the *mean fall* (Col. 9. Table IA.IX) in terms of the standard deviation—all show that years of deficient rainfall are more frequent than wetter years. The large values of a₂ indicate that the relative frequency of years with rainfall in excess the of *modal* tails off very gradually to the limiting value of the rainfall. These and other features (e.g. the *probability* of years with varying amounts of annual rainfall) are evident from the form of the frequency curves for the various catchments. The high degree of contact on the right implies the decreasingly small *probabilities* of very wet years, which, however, cannot be ruled out as altogether *improbable*.

An auxiliary set of curves are presented in Figure 1A.7 for the *probability* that the total rainfall in a season will not be less than any specified amount. From the curves, which are obtained by plotting the ratio of the definite

integral $\int_R^{\infty} \text{Prob} (R) dR \div \int_0^{\infty} \text{Prob} (R) dR$, against R , the probability that the

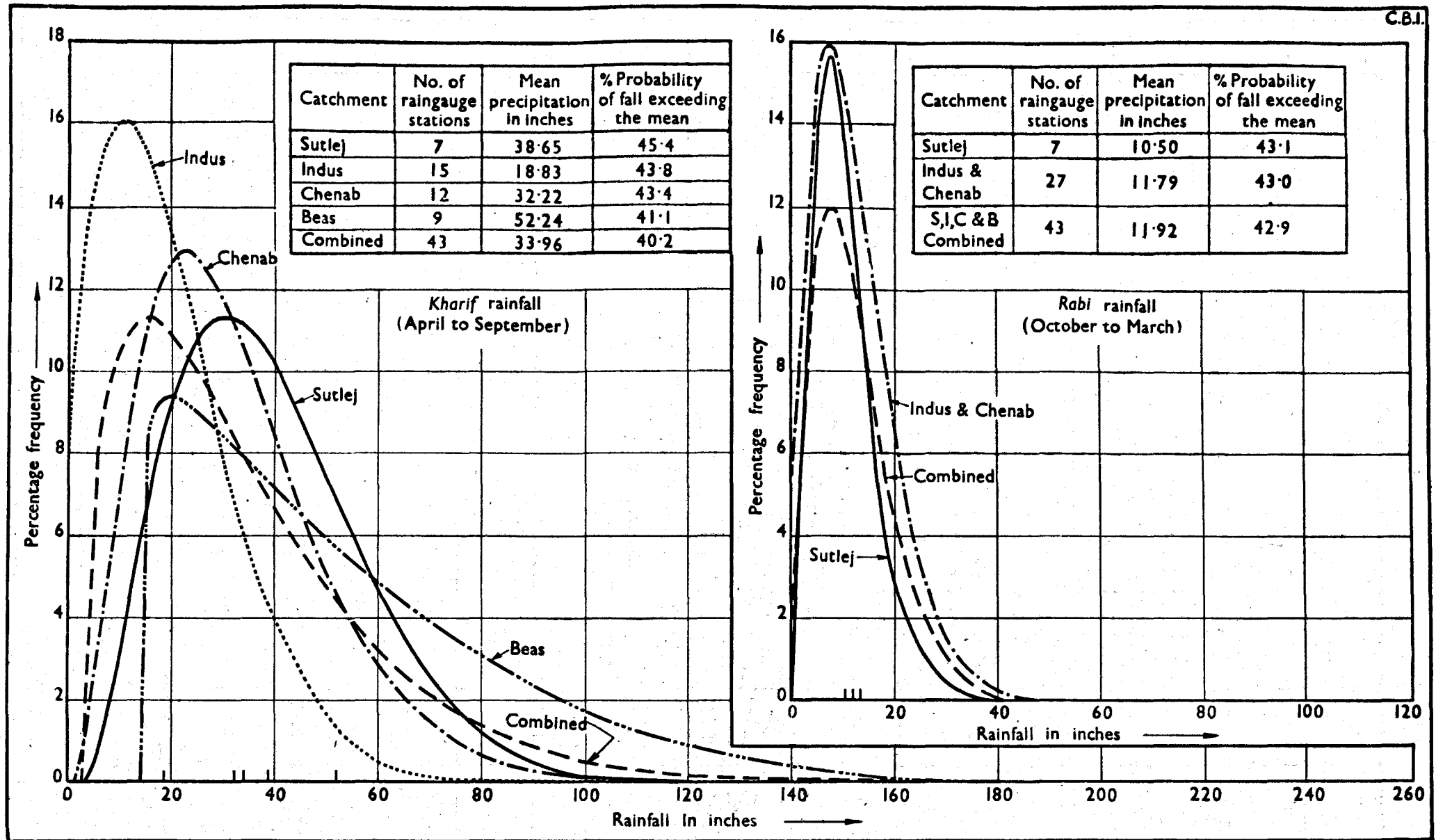
average rainfall will not be less of than a prescribed figure can be directly read off; for example, the *probability* of total, rainfall in any *Kharif* season being not less than 20 in., in the Sutlej catchment, is 85.8 per cent.

**WHAT IS THE EXTENT OF THE YEAR TO YEAR VARIATIONS FROM THE NORMAL ?
DO THESE VARIATIONS FALL WITHIN WELL DEFINED LIMITS ?**

It has already been seen above, that the 35 year *average* provides a reasonably good estimate of long term average for any raingauge station; from the point of actual fall to be expected during any season, however, the *modal* (or the most-frequently occurring value) is a better estimate. On the other hand, for all the eight cases considered in Table IA.IX the *modal* figures are seen to be less than the mean. Though the fall most often to be expected centres somewhere round the *mode*, any rainfall value lying between $mode - a_1$ and $mode + a_2$ may be *equally* expected to occur in an individual year with its corresponding *probability* expressed by the right hand side of equation IA.3 with the appropriate values substituted for R . These *probabilities* have a very steep rise from 0 at $R = mode - a_1$ to y_0 at $R = mode + a_2$ and a slow gradual fall again to 0 at $R = mode + a_2$, depending on the value of a_2 which is relatively large. Nevertheless, there is no year to year continuity in the values of R nor any certainty about the *probable* values in specific years.

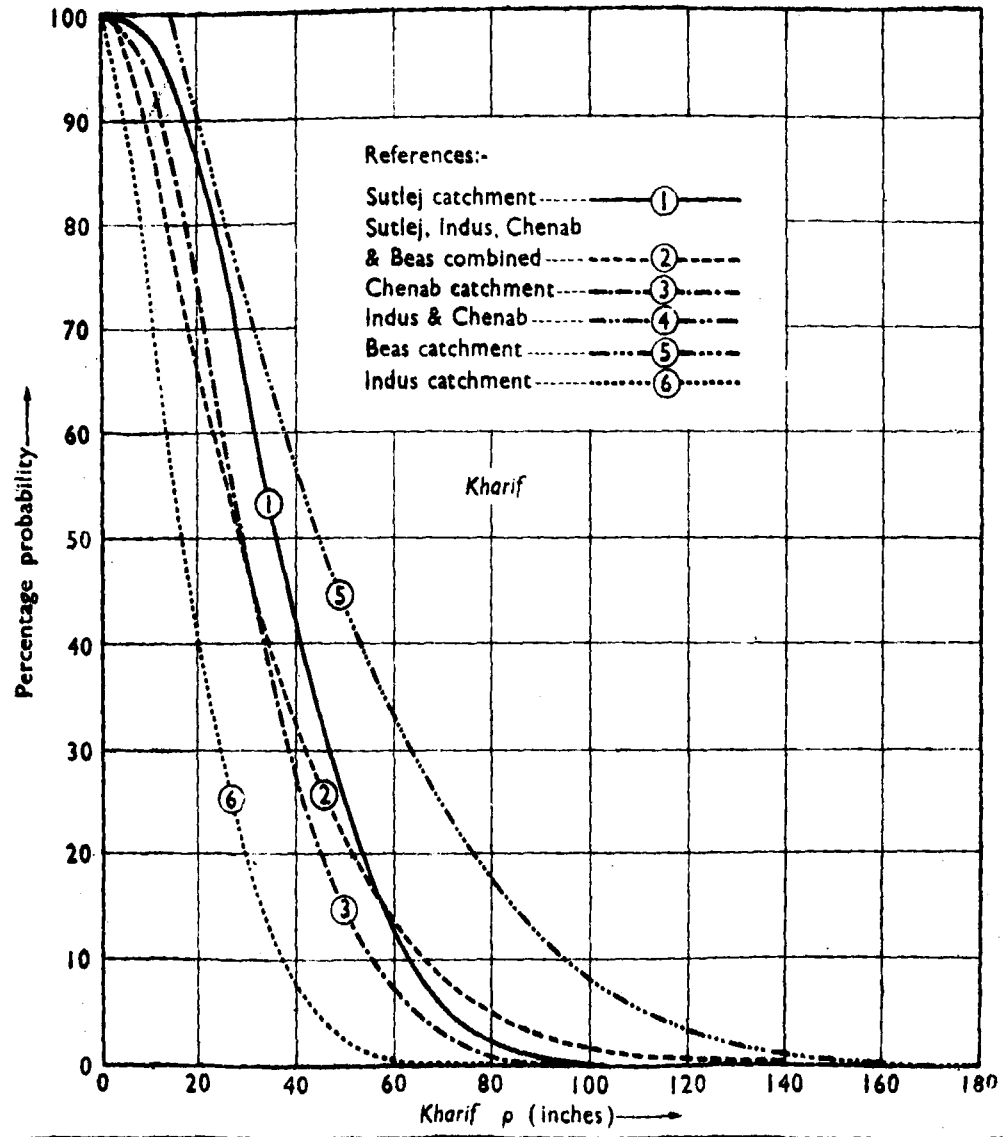
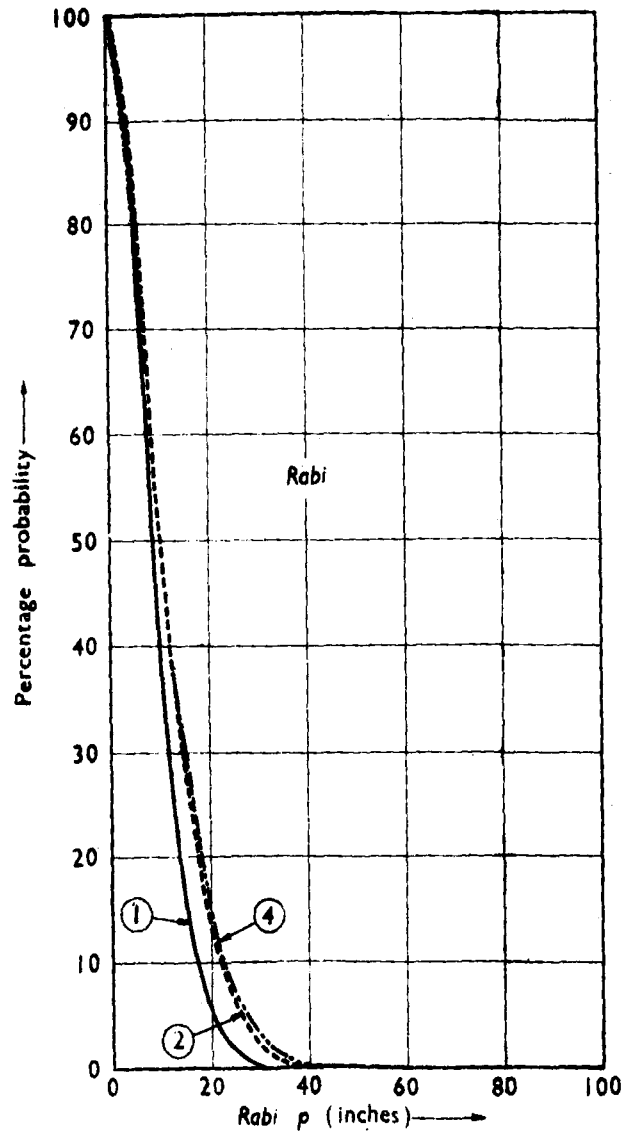
All that is possible to say is that the variations of a season's average rainfall in the catchments examined are ordinarily confined between two well-defined but widely different minimum and maximum limiting values.

Figure 1A.7 is very useful for estimating the *probability* that the average rainfall of the catchment during a season shall not be less than any dangerously low value, say, x in. The *probability* that the rainfall will actually be in defect of x in will be simply the complement *probability*, or the difference from 100 percent. of the *probability* that the rainfall shall not be less than x in. Thus, for instance, if 15 in. fall is assumed a low *Kharif* average in the Sutlej Catchment, the *probability* of the fall not exceeding 15 in. during any one season can be directly estimated as 6.42 per cent,



Reg. No. 2737 XDD (C) '50-1 210 (P.Z.O.).

Figure 1A. 6:- Showing frequency distribution of Kharif & Rabi rainfall



Reg. No. 2737 ADO (C) '50-1.250 (P.Z.O.)

Figure 1A.7:- Curves showing percentage probabilities of rainfall exceeding p inches during any season

But if it is desired to estimate the *probability* that there shall be 2, 3 or 4 such bad years with falls less than 15 inches say, within a specified period of 10 years, these could be further deduced by a simple application of the binomial law of *probabilities*. According to this law, the *percentage probability*

of there being r bad years out of 10 will be equal to $100 \left({}^{10}C_r p^r q^{10-r} \right)$

the coefficient of p^r in the expansion of the binomial expression $100(p+q)^{10}$ with the value of $p=(1-q)=0.0642$. Putting $r=0, 1, 2, 3$, or 4 so that there shall be 0, 1, 2, 3 or 4 years with rainfalls less than 15 inches within our specified period of 10 years, the *probabilities* respectively are :

| | | | | | |
|---|------|------|----------------|-----------------|-----------------|
| r | 0 | 1 | 2 | 3 | 4 |
| <i>percentage probability</i> | 51.5 | 35.3 | 10.9 | 2.0 | 0.2 |
| Multiplier for consecutive r bad year | .... | .... | $\frac{9}{45}$ | $\frac{8}{120}$ | $\frac{7}{210}$ |

The corresponding *probabilities* for a series of r ($r \leq 10$) consecutive bad years will be obtained by multiplying the above *probabilities* by their respective multipliers (also given above). Thus, the *probability* for as many as even 3 years out of 10 to record average falls below 15 inches remains very small indeed, being only 2 per cent and for 3 consecutive bad years being $2 \times \frac{8}{120} = 0.133$, therefore, such contingencies apparently, need not be considered while designing large storage projects in these catchments.

By a similar application of the binomial theorem, the *probabilities* of the fall being below normal on r occasions out of 10 are also derivable from the successive terms of the same binomial with $p = 1-q$ put equal to 0.5460 for *Kharif* and 0.5695 for *Rabi*. These probabilities, along with their expected annual average falls, are shown in Table IA.X below.

TABLE IA. X

| Number of years with rainfall | | Percentage Probability. | | Multiplier for r below normal years to come consecutively. | Expected annual fall under the contingencies specified (in inches). | |
|-------------------------------|-------------------|---|-------------|--|---|-------------|
| | | of rainfall in r years out of 10 being below normal | | | <i>Kharif</i> | <i>Rabi</i> |
| Below normal r | Above normal 10-r | <i>Kharif</i> | <i>Rabi</i> | | <i>Kharif</i> | <i>Rabi</i> |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 0 | 10 | 0.037 | 0.022 | | 54.15 | 14.87 |
| 1 | 9 | 0.45 | 0.289 | | 51.31 | 14.10 |
| 2 | 8 | 2.42 | 1.72 | 1/5 | 48.47 | 13.33 |
| 3 | 7 | 7.77 | 6.07 | 1/15 | 45.63 | 12.57 |
| 4 | 6 | 16.34 | 14.06 | 1/30 | 42.79 | 11.80 |
| 5 | 5 | 23.59 | 22.32 | 1/42 | 39.95 | 11.03 |
| 6 | 4 | 23.64 | 24.61 | 1/42 | 37.11 | 10.26 |
| 7 | 3 | 16.21 | 18.60 | 1/30 | 34.27 | 9.49 |
| 8 | 2 | 7.33 | 9.23 | 1/15 | 31.44 | 8.73 |
| 9 | 1 | 1.96 | 2.71 | 1/6 | 28.60 | 7.96 |
| 10 | 0 | 0.24 | 0.36 | 1 | 25.76 | 7.19 |

Columns 3 and 4 which contain the *percentage probability* values for a season's precipitation to be below normal only in 0, 1, 2,:10 years (and above

normal in the remaining years of continuous period of 10 years) show that the probability values attain their maximum for $k=6$. This brings out that it is *more likely* for precipitation to be below normal only in six years out of every ten than in any alternative combination.

WHAT IS THE PERCENTAGE OF ALL YEARS ABOVE AND BELOW THE MEAN IN EACH RECORD ?

For the eight cases of frequency curves fitted to the data in this paper, the proportional frequency of years with rainfall exceeding the normal—in other words, the probability of a season's rainfall exceeding the normal—can be estimated by taking the ratio of the area on the right of the mean line to the whole area enclosed under the frequency curves. These *probabilities*, which are already given in column 10 of Table IA. IX are all seen to be *below 50 per cent.* Similar figures for the *percentage* of years with above normal rainfall have been computed for each raingauge station on record in the 4 catchments considered here (*vide* column 4 of Table IA. VIII). These figures also generally work out to be smaller than 50 *per cent.* with a few isolated stations recording higher *percentages.*

WHAT IS THE AVERAGE FALL FOR DRY AND WET YEARS (i. e. THOSE BELOW AND ABOVE THE NORMAL) AND WHAT ARE THE RESPECTIVE RANGES OF VARIATION ?

The average rainfall for all dry or below-normal years and the range of individual year's variations during such years have been computed for each raingauge station on record (*vide* columns 5 and 6 in Table IA. VIII). Similar figures for wet or above-normal are shown in columns 7 and 8.

WHAT IS THE RATIO OF THE RAINFALL IN THE DRIEST (AND WETTEST YEAR TO THE NORMAL ? WHAT IS THE RATIO FOR THE AVERAGE RAINFALL IN 3 AND 4 DRIEST YEARS TO THE NORMAL ?

The *percentage* ratios of each station's wettest year's rainfall as well as driest year's rainfall to its normal fall have been given in columns 9 and 10 respectively. The *percentage* ratios of the average falls in 2, 3 and 4 driest years on record to the normal fall are, similarly, tabulated for each station in columns 11, 12 and 13 respectively. An important rainfall feature shown by figures in column 9 is that the variation of the maximum rainfall from the mean rainfall is as high as 690 *percent*; whereas in the driest year the ratio of $\frac{\text{minimum rainfall}}{\text{mean rainfall}}$ can, at the most, lower itself only to zero. This shows that variations of rainfall during wet years can be exceedingly larger than similar variation during lean years, which fact is also evident from the eight elongated positive skew-type frequency curves fitted to the catchments' data.

The *percentage coefficient of variation* which is defined as

$$100 \times \frac{\text{Best average measure of dispersion}}{\text{Mean rainfall}} = 100 \times \frac{\text{Standard Deviation}}{\text{Mean rainfall}}$$

suggests itself as the most appropriate means of testing this hypothesis. These coefficients were, accordingly, calculated for the several stations (*vide* column 14 in Table IA. VIII) and plotted against the mean rainfall of each station, Figure 1A.8. The evidence is only qualitative but substantiates the hypothesis.

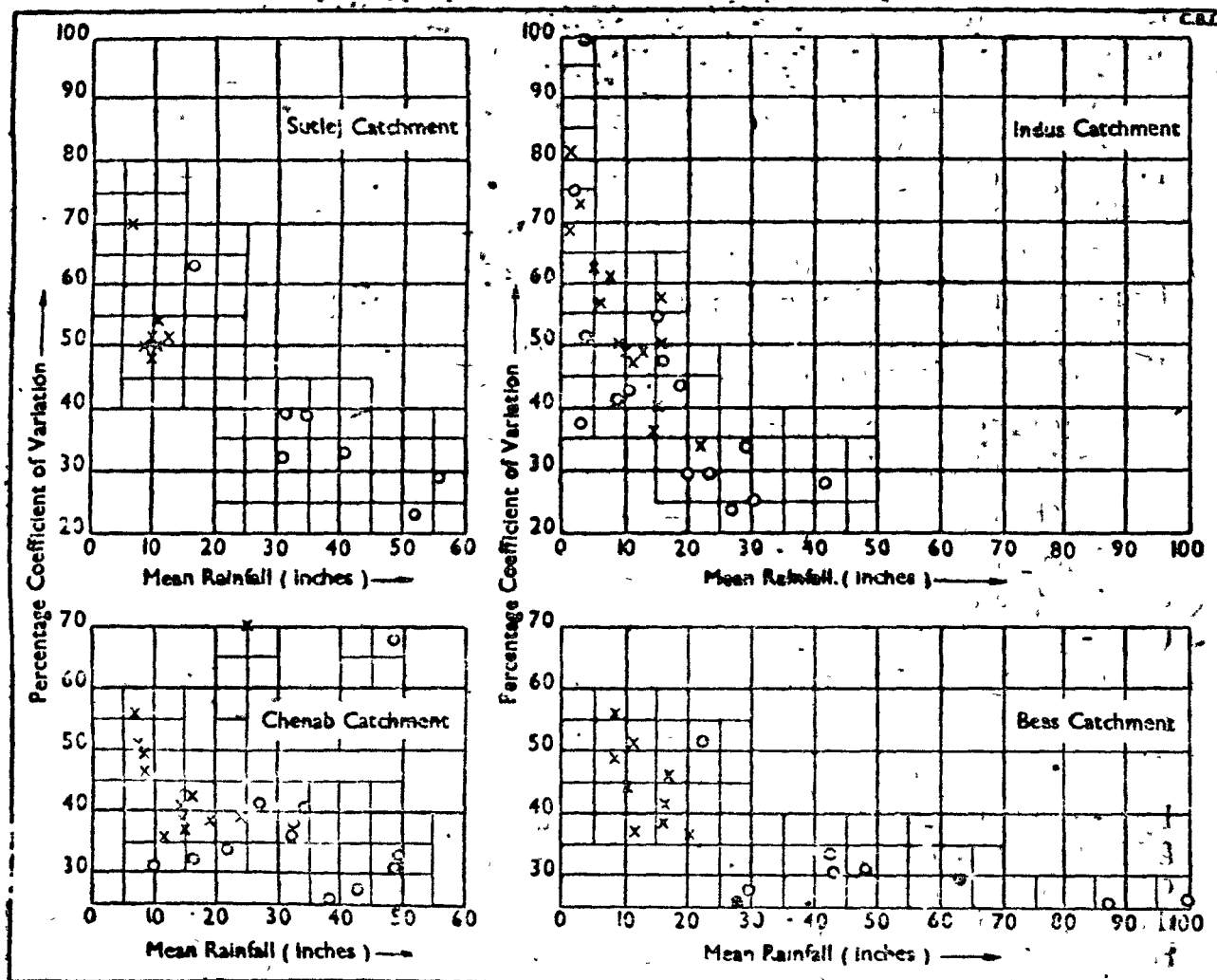


Figure 1A.8 : Dispersion of rainfall study—Percentage co-efficient of variation against mean rainfall in the four Punjab river catchments.

DISCUSSION BY THE RESEARCH COMMITTEE

THE PRESIDENT called upon Dr. Bose to report on the progress made by the Sub-Committee on the Damodar Water Balance Investigations.

DR. BOSE explained the work done to date and said that certain investigations could not be proceeded with for want of financial sanction which had been asked for from the Chairman, Damodar Valley Corporation. The India M/N21CBI

Meteorological Department had carried out a rough estimation of the evaporation losses from the catchment. Mr. Misra had presented a report on the subject and it was the intention to carry out detailed investigations on the lines recommended by the Director, India Meteorological Department on the basis of Mr. Misra's work*.

THE PRESIDENT asked Dr. Ramdas to state what had been done by the India Meteorological Department regarding the resolution passed by the Board last year.

DR. RAMDAS said that the India Meteorological Department had been putting in additional raingauges in order to fill in gaps. The study of rainfall on windward and leeward sides was still in the planning stage. This was being discussed in departmental meetings. They had not yet actually started the work.

DR. N. K. BOSE said that India Meteorological Department had set up in the Damodar Valley one B class observatory, two C class observatories and 18 raingauges over and above 21 raingauges that already existed. This would enable to make the distribution uniform.

MR. A. P. BHATACHARYA introduced item (1) and said that the catchments lying in Bundelkhand, Southern United Provinces were divided in accordance with the nature of the country in which the catchments were situated. Thus, three classifications were made as :—

- (a) Steep bare catchments with hills
- (b) Hilly catchments covered with forests
- (c) Plain catchments

Linear equations connecting runoff with rainfall were next evolved for the above types of catchments and graphs were drawn based on these equations (see Figure 1A 1).

Their importance lay in the fact that runoff could be predicted fairly accurately for any rainfall, knowing the type of the catchment.

Referring to item (2), he said that the investigation consisted of the preparation of a number of curves giving the maximum flood discharge for a given catchment area, based on which, draft instructions for the guidance of officers in the United Provinces had been prepared regarding the safe maximum discharge which could be taken for designing a river work. Catchments were considered under three classifications in accordance with their size :—

- (a) From 0 to 100 square miles
- (b) From 100 to 1,000 square miles
- (c) From 1,000 to 10,000 square miles

It was observed from the graphs drawn that they fell above the Inglis curve for catchments from 0 to 100 square miles and below for 100 to 1,000 and 1,000 to 10,000 square miles, showing thereby that Inglis formula gave a higher figure of maximum flood discharge for catchments up to 100 square miles, and lower for catchments ranging from 100 to 10,000 square miles.

* Printed on page 571 of this Report.

In introducing item (3), MR. G. SINHA said that a storm of heavy magnitude isolated either ways, in respect of time, occurred in the Teesta Valley from October 20, 1945 to October 24, 1945. The magnitude of rainfall was very high on October 21, 22 and comparatively low on October 20 and 23 while it was very small on October 24. Attempts were made to get a unit hydrograph from this storm by separating out the effects of the rainfall on different days, that is, by breaking up the net resultant hydrograph into component parts. The effect of the rainfall on October 24 was neglected as it was very small. The breaking up was sought to be effected in two ways—(i) neglecting the effect of the rainfall on the first and fourth days ; and (ii) by taking the same into account, but making the unit of time as 48 hours.

Referring to item (4), MR. SINHA said that for getting a unit hydrograph they required rainfall on a single day which was difficult to get. Another simpler method of arriving at a unit hydrograph was to take the hydrograph of different floods resulting from rainfalls which might be composite (that is with a duration of more than one day) but centred more or less round one day. Of course, this composite rainfall should be avoided as far as possible. In cases where the effect of the rainfall on other days could be neglected, the hydrograph might be considered to be proportional to the unit hydrograph. The departures, if any, from the unit hydrographs would tend to minimise by superimposition and averaging of these individual curves. This was what had been attempted for the catchment of the river Mor above Khatanga. For convenience, the hydrograph had been taken in 12 hourly periods of time and later after averaging converted to 24 hourly units. Attempts were also being made to get the unit graphs separately from each flood. These would then be compared with the graph obtained here.

Referring to items (5) and (6), MR. SINHA said that stream gauging of the river Barskar was started at one site in 1944 and at two more sites in 1945 while gauging of the river Mor at Messenjore was started in December 1945. The monthly discharge volumes and runoff percentages for the catchments above different sites for the monsoon months (that is June to October) of the years 1944, 1945 and 1946 had been worked out.

MR. SINHA had nothing to say about items (7) and (8).

MR. G. M. PANCHANG introduced item (9) and said that it was a well known fact that rainfall was a very vigorous natural phenomenon. It was next to impossible to forecast exactly the year to year, or place to place, variations. He said that it might be interesting in this respect to call attention to the degree of accuracy which normally accompanied the daily weather forecasts issued by the India Meteorological Department. While a good many of them might prove nearly correct, yet one could never swear by the forecasts coming out 100 per cent. true or even 20 per cent. true for that matter. Natural weather phenomena were not known to be governed by any precise set of rules. All one had to be content with, was their probable measure of variation.

Continuing MR. PANCHANG said that this note might be accepted as a model for the analysis of similar rainfall data for all important river catchments in the country.

The findings in brief were :—

- (1) The data were not sufficient to establish any plausible periodogram.
- (2) The relative dispersion measures about the mean rainfalls were appreciably large and did not admit of the long term average annual rainfall being accepted as the reliable measure of precipitation to be expected in any random year.
- (3) The rainfall in a flood year could be several times the mean annual rainfall while that in a dry year could at the worst be in deficit by once the mean rainfall.
- (4) Flood years (including among them all years with rainfall exceeding the mean fall) were relatively of rarer occurrence than years with rainfall in deficit from the mean.
- (5) Divergences from normal rainfall were greater for stations in relatively dry zones than in zones susceptible to high intensity of rainfall.

Yet another point of interest which had been discussed in the paper was the method of estimating the probability of the rainfall in a sequence of year falling short every time of any specified low rainfall.

DR. RAMDAS referring to item (9) said that the accuracy of the weather forecasts of the India Meteorological Department was not a relevant issue. They prepared diagrams showing hourly distribution of precipitation in a single shower. They were also making weekly rainfall diagrams. For weekly rainfall a flood week was one in which the total of the actual rainfall was more than the normal rainfall by a margin greater than twice the mean deviation and a drought week was one in which the total was less than half the normal figure by the same margin. Floods were also referred to in the weekly reports of the Agricultural Department and flood weeks were those in which crops had been damaged on account of rains.

DR. J.K. MAHOTRA referring to items (1) and (2) said that three types of catchments, steep, hilly and plain had been taken. It would be interesting to see how the formulæ worked when whole catchments were considered, for usually the catchment of a stream consisted of all the three types. He suggested that the Central Board of Irrigation might consider how the slope of a catchment should be fixed and correlated with the runoff, so that a uniform set of formulæ could be developed for use in the whole country.

Referring to item (4) he said that the unit hydrograph represented rainfall for 24 hours. He wanted to know if they were justified in estimating runoff from these unit hydrographs, for rainfalls of longer duration. The hydrograph could be different for rainfall on subsequent days. The applicability of the principle should, therefore, be further investigated.

Referring to item (5) he said that it could be noticed that the monthly runoff percentage slowly rose from June to September. This showed that the catchment runoff went on increasing as the season advanced and the ground became wetter. This would seem to show that the unit hydrograph would also change with a change in season, and this fact deserved further investigation.

Referring next to item (9) he stated that he had also collected such data under the direction of Rai Bahadur Kanwar Sain during the Sind-Punjab dispute. The object at that time was to show that the period between 1932-41 was a period of unusual rainfall years. The years 1942-47 had shown much better figures for river supplies, which indicated that the rainfall cycle was now moving away from its trough. The problem was of so great importance to East Punjab, that recently Sardar Bahadur Sarup Singh had also asked him to carry out similar work and he was doing it for Bhakra Dam.

RAI BAHADUR A. N. KHOSLA explained that he had been trying to establish a relationship between rainfall and runoff since 1941. He had worked out the following two formulae and would like the research officer to examine them—

(a) For values of T above 49°F

$$R = P - xT \dots\dots\dots (1A.4)$$

$$R_m = P_m - \frac{T_m - 32}{9.5} \dots\dots\dots (1A.5)$$

- where R = Annual runoff from a catchment in inches.
- P = Annual precipitation on the catchment in inches.
- T = Mean annual temperature of the catchment in degrees Fahrenheit.
- x = Constant which may be different for different catchments.
- R_m = Monthly runoff in inches.
- P_m = Monthly precipitation in inches.
- T_m = Mean monthly temperature for the catchment in degrees Fahrenheit.

The above monthly formula applies where T_m is above 40°F for values of T_m below 40°F , the loss $P_m - R_m$ will be as under.

| <i>Temperature</i> | <i>Loss in inches</i> |
|--------------------|-----------------------|
| 30° | 0.7 |
| 20° | 0.6 |
| 10° | 0.5 |
| 0° | 0.4 |

He had applied the formula in a number of cases and found it to be correct ; the deviation in any case was almost negligible. He had tried it in the case of 21 catchments in America, in Norway, Switzerland, in one catchment in France and in Kosi and Mahanadi in India and found it to hold good. The data, on which these were based, were meagre but if it could be established to be correct, it would be of immense use to the engineers. It was based on the fact that temperature was related to all factors affecting loss of precipitation and, therefore temperature could be taken to represent all those factors. Below 40°F. no transpiration takes place and, therefore, the values given above would represent the loss by evaporation only.

He suggested to all present to apply the formula to various cases that came their way and see to what extent they were universally applicable and report to him individually or at the Board Meeting.

RAO BAHADUR JOGLEKAR referring to items (1) and (2) asked how many years' data were covered by these investigation and, if the shape factor was taken into account while comparing the maximum flood discharge with Inglis formula.

RAI BAHADUR M. C. BIJAWAT referring to item (2) said that they should take catchment area and apply Inglis formula.

RAI BAHADUR S.D. KHANGAR referring to item (1) suggested that it would be better for comparison purposes if the runoff were given in inches instead of in million cubic feet, and complete information was supplied for the different catchment areas for which discharge had been reported.

DR. VAIDHIANATHAN referring to the formula presented by Rai Bahadur A. N. Khosla enquired as to how the value of 'x' was fixed.

RAI BAHADUR A.N. KHOSLA suggested that this could be done by taking the values for 3—4 years. He added that the value ranged from $\frac{1}{2}$ to $\frac{1}{3}$ in the cases analysed by him.

MR. N. S. GOVINDA RAO referring to items (1) and (2) said that the runoff depended not only on the catchment such as its being steep, afforested or plain but also on the shape of the catchment, temperature *etc.* For working out any formula the results should be spread over a number of years.

Referring to items (3) and (4) he said that the unit hydrograph began with a very high ordinate on the very first day of the rainfall, which was unnatural in a catchment of the size of that of river Teesta above the railway bridge (2,800 square miles). The method suggested could be adopted with great accuracy in the case of small catchments. In bigger catchments, there would be considerable time lag between the runoff from one valley and another. The peak flow of runoff depended on the nearness to the measuring point and the size of the valley over which maximum precipitation had taken place.

“ The average rainfall over a catchment is not the arithmetical mean as calculated. It is calculated by multiplying rainfall by the area of catchment

served by each gauge and dividing the aggregate of the product so obtained total area of the catchment. It is not known on what basis the weightages were given. The percentage dislocation has been shown the same both for 24 hours and 48 hours unit of time. This is based on the assumption that half the precipitation takes place in 24 hours and the other half in the next 24 hours. Such equal precipitation rarely occurs in two successive days. The result require further investigation ”.

Referring to item (9) he said that a statement had been made on page 109 that 75 years' average was taken as the normal to compare the duration. Though this was mathematically correct, yet in taking the average, extraordinary peak years of high and low rainfall should be omitted, as by the very nature of their peak appearance they could not be included in the calculations for the normal. This was a normal practice in analysing rainfall data for reservoir constructions.

A statement of 70 years rainfall might as well have been usefully added.

It was then decided that subject should continue to remain on the Agenda.

DISCUSSION BY THE BOARD

THE SECRETARY described the work done at the Research Committee meeting and said that there was no resolution on the subject.

MR. T. MYLAVAGANAM said that in Ceylon in certain catchments it had been observed that nearly 100 per cent of the rainfall appeared as runoff. In reply to Dr. K. N. Bose, Mr. Mylavaganam said that the catchment was entirely cultivated by tea.

THE SECRETARY pointed out that there must be some loss.

MR. T. MALAVAGANAM said that if the storm lasted for a long period, there might be some loss for the first few days, but latter 100 per cent. of the rainfall appeared as run-off.

RAO BAHADUR G. SUNDARAM said some times 140 per cent. or even 150 per cent. run-off was obtained. This only showed that the rain gauge stations were not properly located or representative of the actual rainfall.

It was decided that subject should remain on the Agenda.

(ii) Maximum Runoff Discharge

PRELIMINARY NOTE

The following items were discussed at the 1947 Research Committee Meeting.

- (1) Determination of the optimum number of rain recording stations in catchments for estimating runoff by Messrs. V. Satakopan and V.V. Sarma of India Meteorological Department.
- (2) Measurement of precipitation in hilly catchments with special reference to problems of runoff and other hydrologic studies by Mr. L.Y. Baker.
- (3) Maximum flood discharges from small catchments by Mr. A. R. Thomas.

Recent Literature

- (1) Kinnison, H.B. : Flood flow formulas. Journal of the Boston Society of Civil Engineers, Vol. 33, No. 1, January 1946.
- (2) An estimate of maximum possible flood producing conditions in the Missouri River Basin between Garrison and Fort Randall. United States Department of Commerce, Weather Bureau, Division of Climatological and Hydrologic Service, June 21, 1946.
- (3) Maximum possible flood producing Meteorological conditions in the East Muddy Creek Basin above Creek Dam site, Gunnison and Upper Colorado River Basin studies. United States Department of Commerce, Weather Bureau, Division of Climatological and Hydrologic Services, Report No. 2, August 1946.
- (4) Maximum possible flood producing Meteorological conditions in the Taylor River Basin above Almont Dam site Taylor Park Dam (Colorado), Gunnison and Upper Colorado river Basin studies United States Department of Commerce, Weather Bureau, Division of Climatological and Hydrologic Services, Report No. 3, February 1947.

THE YEAR'S WORK

The following items were discussed at the 1948 meeting of the Research Committee.

- (1) Maximum discharge from a runoff plot in Midnapur.
- (2) Maximum runoff formulae and their applications.

(1) MAXIMUM DISCHARGE FROM A RUNOFF PLOT IN MIDNAPUR (9).**ABSTRACT**

Runoff observations were proposed to be carried out in a plot of land in the district of Midnapore. The catchment area of the stream was 1.6 square miles. The maximum rainfall recorded near about the place was 12.8 inches in a day. It was proposed to set up necessary flumes in the exit channel from the catchment area in order to measure the runoff discharge for different intensities of rainfall in the area. It was, therefore, necessary to get an idea about the maximum discharge that could ever be expected to be measured in the flume. In the absence of any observed discharge figures, normal distribution of rainfall was assumed and discharges in different hours were obtained by superimposition of the individual runoff hydrographs for the rainfall in different hours.

(2) MAXIMUM RUNOFF FORMULAE AND THEIR APPLICATIONS (10).**ABSTRACT**

Various runoff formulae (Inglis Fan Catchment, whiting curve (Bombay), Dickens, Ryves' etc. have been summarised and their applications have been discussed.

(9) Annual Report of the River Research Institute West Bengal, 1947, pages 27--29.
 (10) Central Waterways, Irrigation and Navigation Research Station, Annual Report (Technical) 1947, Pages 19--22.

DISCUSSION BY THE RESEARCH COMMITTEE

MR. SINHA introduced item (1) and said that observations of runoff were proposed to be carried out in a small stream with a catchment area of 1.6 square miles. It was required to get an idea of the maximum run off discharge ever likely to occur from that plot. The only thing known was that the maximum rainfall in a day near about the place was 12.8 inches. Nothing was known about the distribution of the rainfall intensity. A normal curve for the precipitation was assumed and it was also assumed that the rainfall in one hour would runoff totally in the next seven hours. The maximum discharges, according to normal distribution of rainfall over 24 hours, over 12 hours and over 8 hours were worked out.

It was found that these figures were very high for the size of the catchment. Those, however, had been obtained on the assumption of total runoff.

RAO BAHADUR JOGLEKAR introduced item (2) and said that the object of his note was to summarize the various runoff formulæ.

The maximum runoff had to be corrected for the shape of the catchment the general formula worked out at the Station being—

$$Q = \frac{7,000 A}{\sqrt[4]{A+4}} \times K^*, \text{ where } K^* \text{ is the shape factor.}$$

Though the fan catchment formula, gave a good general indication of the maximum runoff, it did not give any indication whether a maximum flood would occur once, or 50 times, in a thousand years. The only way to decide this question was by judgment based on past experience and records. It should be borne in mind that maximum storms tended to occur more frequently in medium sized catchments than in very large or very small catchments. This was because in very small catchments the probability of the storm passing over the small catchment was remote ; while in very large catchments, the storms rarely covered the whole of the catchment.

The statistical formula for normal floods obtained from all the available data at the Central Station was

$$Q = \frac{4,000 A}{\sqrt{A+4}}$$

If too loose a waterway was provided, serious consequences of shoaling, oblique flow, and discharge concentrations resulted. While the waterway of the bridge might be designed according to this formula, allowance for afflux should be made and the free board upstream of masonry structures and the protective measures down-stream should be designed for the maximum ever discharge.

THE SECRETARY said that a formula which gave discharges that occurred once in a 1,000 years without indicating the frequency of expectation was not of much practical use.

RAI BAHADUR BRIJ NARAIN said that no formula applied to one catchment (Baitarni) he knew of in Orissa. The area was a few thousand square miles and the discharge was of the order of a million cusecs. Heavy rainstorms occurred in the catchment which was parallel to their passage and that perhaps accounted for the heavy discharge. The river had a regular channel, about 20 feet deep and 700 to 800 feet wide. On the banks themselves also depressions existed for a great length and during floods the sub-merged width was great. That was a particular problem to which the ordinary formulæ did not apply.

The river in question was the Baitarni and the site was about 30 miles west of Keonjargarh. The peak discharge was very much in excess of figures given by any known formula.

MR. K. F. ANTIA said that he would like to draw the attention of R. B. Joglekar to the necessity of establishing shape factors for all kinds of catchment in the country. If that were done, Dicken's formula would be of great help in all such cases.

MR. N. S. GOVINDA RAO referring to item (1) enquired if, in fixing the percentage distribution of runoff discharge, any account had been taken of the ratio of length to breadth of the valley forming the catchment.

Referring to item (2) he said that no distinction had been made between small and large catchments. He suggested that they should have different formulæ for small and large catchments.

MR. R. R. HANDA liked to know as to who observed the discharge of one million cusecs for the river about which Rai Bahadur Brij Narain was talking and at which site it was observed, and how it was observed, viz., the method of observation.

MR. B. P. SAXENA said that maximum should be defined. The Central Board of Irrigation should supply formulæ applicable to different zones, to calculate the discharge on a practical basis and should send directions to provinces accordingly.

THE PRESIDENT said that for the time being it was not possible to lay down hard and fast rules. Each individual case had to be studied on its merits. Some work had to be designed liberally as big stakes were involved. Meanwhile data might be collected and some results got out by analysis.

THE SECRETARY drew attention to the preliminary note on page 79 and stated that in accordance with the resolution of the Board a form for the collection of data for volume of rainfall and runoff was circulated in 1944. In response, data had been received for 31 catchments and additional data might be coming soon. He said that when these data were analysed it might give useful results. He asked if any one would volunteer to do the analysis.

SARDAR BAHADUR SARUF SINGH said that Dr. J. K. Malhotra would take up the work.

It was also decided that the subjects should remain on the Agenda.

DISCUSSION BY THE BOARD

THE SECRETARY said that two items were discussed at the Research Committee meeting but there was no resolution on the subject. In accordance with the resolution passed by the Board in 1944, data on the volume of rainfall runoff for 31 different types of catchments had been received. This data had been passed on to Dr. J. K. Malhotra of the East Punjab Irrigation Research Institute for analysis. The Secretary requested the members to make available any other data that might have since been collected.

DR. S. K. BANERJI said that he never realised, 15 years ago, that rainfall data would be put to so much use. It had been realised that the distribution of raingauges was not adequate enough to give a correct runoff relationship and a decision had been taken to so plan the raingauge stations as to obtain data of precipitation over a catchment within an accuracy of 10 percent. Dr. Banerji reported that in this direction a good deal of progress had already been made in different catchments. He described the work done recently in the Kosi catchment. It had meant a lot of trouble to set up observatories in mountainous area and a great difficulty was being found in maintaining them in inaccessible and difficult areas.

DR. BANERJI then explained the work done in setting up new raingauge stations and observatories in the Mahanadi and Damodar basins. He also exhibited the new maps prepared by catchments which showed the rainfall data so far collected, both average and maximum.

DR. BANERJI then reported that at the last meeting of the Board a resolution had been adopted recommending that the Indian Meteorological Department should arrange for periodical inspection of rain gauge stations. This matter had received adequate attention.

THE CHAIRMAN thanked Dr. Banerji for the great interest he was taking in the subject.

It was decided that the subject should remain on the agenda.

THE PRESIDENT said that he liked to seek a certain amount of help from the members on a particular item of investigation. At the last Research Committee meeting he mentioned the runoff formula which he had evolved. He had calculated discharges in various rivers both in India and abroad with this formula (given on page 109). It had been tried for 21 catchments in the United States of America, and for the Mahanadi, the Kosi,

the small catchment of Dochi and one other catchment in India. In the meantime he had asked his Director of Hydrology to prepare a statement of the water resources of India as a whole, divide it into catchments and apply this formula and see how it worked out. He had now got some tentative figures which were fairly impressive. The total run-off according to that in the whole of India, excluding Pakistan, came to 1.9 million cusecs or in terms of acre feet it was 1,328,000,000 acre feet out of which roughly one fourth was for the Brahmaputra, a little less for the Ganga, and then the rest for the Godavari and others. He had also worked out from considerations of temperature and rainfall, the mean annual run-off of Godavari at Ramapadasagar and he got a figure of 83.5 million acre feet as against 85 given by the Madras report. He requested all the engineers present to let him have complete data of discharges at a certain place for as long a period as they could get for all their respective rivers. If they could give him some record of actual discharges at one particular point, then he could get the rainfall data from the India Meteorological Department and with the existing data he could check and see how the formula worked.

2A. River Behaviour

PRELIMINARY NOTE

This subject first appeared on the agenda of the Research Committee in 1942 under the head 'River Behaviour, Training and Control'. In 1947 'River Behaviour' was taken up as a separate subject with (i) Floods (ii) Stage discharge relations, as its two sub-heads.

(1) Floods

PRELIMINARY NOTE

The collection and study of statistical data pertaining to river flood control was on the agenda of the Research Committee in 1939-40. In 1947 a comprehensive resolution was passed by the Board (1).

In response to the resolutions of the Board, Bombay Government have issued specific orders to the officers concerned for the collection of data. Cochin and Bhopal have undertaken to collect data in their respective states. Jodhpur intimates that in view of the characteristic of the region in which the State is located, results to be obtained from collection of hydrologic data as desired in the resolution are hardly commensurate with the cost involved.

There was no item for discussion at the 1947 Research Committee Meeting.

Recent Literature

(1) Kinnison, H.B.—Flood flow formulas, Journal of Boston Society of Civil Engineers, Vol. 33, No. 1, January 1946.

(2) Cross, W. P.—Floods in Ohio—Magnitude and frequency. Ohio Water Resources Board, Bulletin No. 7, October, 1946.

(3) The floods of June 1946 in Wayne and Holmes Counties, State of Ohio, Department of Public Works, Water Resources Board, Bulletin No. 9 March 1947.

(4) Proceedings of the fourth Provincial Flood Conference held at Cuttack, on January 7, 1947. G. E. Strecher and Co., New York, 1945.

(5) Hydrologic and hydraulic analysis, flood hydrograph analysis and computations. Engineering Manual for Civil Works, Part III, Chapter 5, War Department, office of the Chief of Engineers, Washington, April 1946.

THE YEAR'S WORK

The following items were discussed at the 1948 meeting of the Research Committee:

- (1) Highest floods in the Damodar and its tributaries for 1947.
- (2) Highest floods in 1947 in the rivers Mor, Dwarka and Brahmani.
- (3) Highest floods of the river Teesta and its tributaries during 1947.

(1) The Central Board of Irrigation journal, January 1948, page 66 and C.B.I. Publication No. 40, Annual Report (Technical) 1947.

**(1) HIGHEST FLOOD IN THE DAMODAR AND ITS TRIBUTARIES
IN 1947⁽²⁾**

ABSTRACT

The highest flood recorded during 1947 in the Upper Damodar (above its confluence with Barakar) occurred in the first week of September when however, the floods in the Barakar river, which is the main tributary of the Damodar was not so intensive. The maximum flood in the Barakar occurred in the first week of August 1947, when the Damodar sites did not show heavy flood. Table 2A.I gives a comparative chart of the peak of the highest floods in 1946 and 1947.

TABLE 2A.I

Damodar Sites—Comparative study of high flood level in 1946 and 1947.

| River | Site | Date | 1946 | | | 1947 | | | |
|-----------|-----------|---------|---------|---------------------|---------------------------------|--------|---------|---------------------|---------------------------------|
| | | | Time | Highest flood level | Approximate discharge in cusecs | Date | Time | Highest flood level | Approximate discharge in cusecs |
| Damodar.. | Ramgarh | 17-9-46 | 12 p.m. | 1110.65 | 77,000 | 3-9-47 | 6 p.m. | 1111.03 | 114,000 |
| | Ayre | 17-9-46 | 3 p.m. | 831.92 | .. | 3-9-47 | 6 p.m. | 836.09 | .. |
| Bekharo | Daneo | 17-9-46 | 8 p.m. | 949.96 | 11,000 | 3-9-47 | 1 p.m. | 952.16 | 22,000 |
| Damodar | Chas Road | 18-9-46 | 3 a.m. | 520.83 | 155,000 | 3-9-47 | 10 p.m. | 522.83 | 247,000 |
| | Sudamdih | 18-9-46 | 2 a.m. | 440.08 | .. | 3-9-47 | 10 p.m. | 436.20 | 241,000 |
| | Sonalapur | 18-9-46 | 8 p.m. | 357.22 | .. | 3-9-47 | Night | 358.32 | .. |
| Barakar | Barakar | 18-9-46 | 11 a.m. | 344.70 | 123,000 | 1-8-47 | 6 p.m. | 348.20 | 220,000 |
| | Asansol. | 18-9-46 | 6 a.m. | 361.67 | .. | 1-8-47 | 6 p.m. | 365.56 | .. |
| | Maithon | 18-9-46 | 10 p.m. | 777.07 | 141,000 | 1-8-47 | 4 p.m. | 785.10 | 259,000 |
| Umi | Giridih. | 21-6-46 | 6 p.m. | 922.60 | 29,000 | 4-8-47 | 11 a.m. | 923.74 | 32,000 |
| Barakar | Barhi | 18-9-46 | 7 a.m. | 1211.12 | 82,000 | 3-9-47 | 6 p.m. | 1202.22 | 19,000 |
| | Tilaya | .. | .. | .. | .. | 3-9-47 | 9 p.m. | 1146.17 | .. |

**(2) HIGHEST FLOODS IN 1947 IN THE RIVERS MOR, DWARKA AND
BRAHMANI⁽³⁾**

ABSTRACT

The stream gauging (discharge) sites on these rivers are on the river Mor at the Messenjore Dam site and the Sainthia Railway Bridge site, on the river Dwarka at Gadadharpur and on the river Brahmani at the Nalhati Railway bridge, while at the Tilpara Ghat Barrage site on the Mor river only gauge readings are taken. The maximum flood for this year at all these stations passed on the July 31, 1947. Table 2A.II presents a comparative chart of maximum floods for 1946 and 1947.

⁽²⁾ Annual Report of the River Research Institute West Bengal, pages 29—35.

⁽³⁾ Annual Report of the River Research Institute, West Bengal, pages 36—38.

TABLE 2A. II

Mor Sites—Comparative study of the high flood levels (H.F.L.) and discharges between the years 1946 and 1947.

| River | Site | 1946 | | | | 1947 | | | |
|----------|-------------------|----------|-----------|--------|------------|---------|------------|--------|------------|
| | | Date | Time | H.F.L. | Dis-charge | Date | Time | H.F.L. | Dis-charge |
| Mor | Messenjore | 1-9-46 | 3 p. m. | 302.28 | 74,000 | 31-7-47 | 3 p. m. | 301.50 | 71,000 |
| | Tilparaghat | 1-9-46 | 4 p. m. | 206.65 | .. | 31-7-47 | Night | 205.04 | .. |
| | Sainthia | 1-9-46 | 8 p. m. | 157.47 | 204,000 | 31-7-47 | 10-30 p.m. | 155.67 | 128,000 |
| Dwarka | Gadadhar- pur. | 21-10-46 | 6-30 a.m. | 123.94 | 5,000 | 31-7-47 | 9-30 p.m. | 127.36 | 16,000 |
| Brahmani | Nalhati | 15-8-46 | 5-30 p.m. | 106.39 | 12,000 | 31-7-47 | 12 Night | 108.76 | 24,000 |

(3) HIGHEST FLOODS OF THE RIVER TEESTA AND ITS TRIBUTARIES DURING 1947 (4)

ABSTRACT

The highest floods during 1947 at most of the sites in the Teesta hill catchment occurred during the month of July on July 25, 1947. Table 2A.III gives a comparative study of the floods for 1946 and 1947.

TABLE 2A. III

Comparative statement of the high flood level (H.F.L.) and discharges of the Teesta Sites, for the years 1946 and 1947.

| River | Site | 1946 | | | | 1947 | | | |
|--------|-------------------------|--------|---------|--------|-----------------------|---------|---------|---------|----------------------|
| | | Date | Time | H.F.L. | Dis-charge in cusecs. | Date | Time | H.F.L. | Dis-charge in cusecs |
| Teesta | Mumring Bridge (Rangpo) | .. | .. | .. | .. | 25-7-47 | 6 a.m. | 932.46 | 76,000 |
| | Melli | 2-9-46 | 6 p.m. | 696.35 | 73,000 | 25-7-47 | 8 a.m. | 700.35 | 85,000 |
| | Teesta Bridge | 4-9-46 | 12 noon | 669.44 | 146,000 | 25-7-47 | 10 a.m. | 671.44 | 111,000 |
| | Coronation Bridge | 2-9-46 | 4 p.m. | 501.72 | 120,000 | 27-7-47 | 6 a.m. | 671.94 | 107,000 |
| Rangpo | Rangpo | .. | .. | .. | .. | 25-7-47 | 12 noon | 959.39 | 21,000 |
| | | .. | .. | .. | .. | 10-9-47 | 6 a.m. | 960.14 | 19,000 |
| Rangit | Nayabazar | .. | .. | .. | .. | 23-7-47 | 6 a.m. | 1004.41 | 30,000 |
| | Champa | 4-9-46 | 1 p.m. | 694.91 | 49,000 | 25-7-47 | 8 a.m. | 690.66 | 41,000 |
| Ramam | Singla | .. | .. | .. | .. | 1-8-47 | 6 a.m. | 691.66 | 40,000 |
| | | .. | .. | .. | .. | 1-8-47 | 6 a.m. | 1011.88 | 11,000 |

⁴ Annual Report of the River Research Institute, West Bengal, pages 38—40.

DISCUSSION BY THE RESEARCH COMMITTEE

MR. SINHA introduced item (1) and said that the maximum flood occurring in the Damodar was peculiar in as much as the upper Damodar above the confluence with the Barakar recorded the highest flood in the first week of September whereas the main tributary, Barakar, recorded the highest flood in the first week of August. Details of both these floods and comparison with previous years were given in the report.

MR. SINHA had nothing to say about items (2) and (3), while introducing them.

DR. BOSE added that in 1948 the Barakar had a maximum flood, while the Damodar kept low. If the two were in flood simultaneously, it might be disastrous.

It was decided to keep the subject on the Agenda.

DISCUSSION BY THE BOARD

THE SECRETARY described the work done at the Research Committee meeting and said that there was no resolution. Regarding the resolution of the Board passed last year for the collection and record of data, some of the replies received from the administrations addressed were given on page 117. Further intimation had been received from Jaipur, Baroda, Bihar and East Punjab that they had taken necessary steps for the collection of the data which would be supplied to the Board for information as soon as received from their local officers. Travancore had appointed a special officer to collect hydraulic data. Replies from others were still awaited.

It was decided to keep the subject on the Agenda.

(ii) Stage—Discharge Relations

PRELIMINARY NOTE

subject has been discussed at different times in the past under flow and canals. It was introduced as a distinct subject head in 1946. It was brought under "River Behaviour" in 1947.

Following items were discussed at the 1947 Research Committee Meeting:

- (1) Co-relation between the gauge heights at the Sainthia Railway Bridge site and the Tilpara Ghat Barrage site on the river Mor.
- (2) Gauge discharge curves for the river Brahmaputra at Jogigopa.
- (3) Co-relation between gauge levels of the river Damodar at Ranigunge and Rhondia and the gauge discharge curve at Ranigunge.
- (4) High floods in Krishnarajasagar.
- (5) Hydrology—the new science and its application by Dr. N. K. Bose.

Recent Literature

(1) Kinnison, H. B.—Flood flow formulas. *Journal of the Boston Society of Civil Engineers*, Vol. 33, No. 1, January 1946.

(2) Statement showing the average, maximum, minimum, gauges and discharges of the River Kabbini at for the year 1940-41 or 1945-46 (Typewritten).

(3) Statement showing gauges and discharges of Siwat River observed from 1935-1946 (Typewritten).

(4) Statement showing the maximum, minimum average discharges of the River Hemavathi at Akkihebbal gauging station during the years 1940-41 to 1945-46 (Typewritten).

(5) Statement showing the average, maximum and minimum discharges and gauges of the river Lakshmanatirtha at Enduvady during the years 1940-41 to 1945-46 (Typewritten).

(6) Flow of the Rio Grande and Tributary contributions. United States International Boundary and Water Commission, United States and Mexico, Water Bulletin No. 15, 1945.

(7) Youngquist, C. V. —Ohio Stream Flow Part II—Summary of stream flow records, in Ohio 1898—1944. *Ohio State University Studies*, Vol. 16, No. 1, May 1947.

(8) Highest and lowest annual stages Mississippi river and its outlets and tributaries to 1945. War Department, Corps of Engineers, U. S. Army, Vicksburg, 1946.

(9) Statement showing the average, maximum, minimum discharges of the river Cauvery at Chunchinakatte gauging station during the years 1940-41 to 1945-46.

(10) Comprehensive statement of gauging stations of rivers of Bengal (Typewritten 1947).

(11) An estimate of maximum possible flood producing between Garrison and Fort Randall. United States Department of Commerce, Weather Bureau, Division of Climatological and Hydrologic Service, June 21, 1946.

(12) Bagchi, K.—Hydrology in India. *Science and Culture* Vol. XIII No. 1, July 1947.

THE YEAR'S WORK

The following items were discussed at the 1948 meeting of the Research Committee.

(1) Rating curves of the river Damodar and its tributaries for 1947.

(2) Rating curves for the rivers Mor, Dwarka and Brahmani for 1947.

(3) Rating curves for the river Teesta and its tributaries for 1947.

(4) Rating curves for the river Ganga at Paksey and Rajmahal for the period 1936-41.

(5) Time lag as a function of discharge.

(6) Afflux observations of floods of Cauvery river at its junction with the Krishnarajasagar reservoir.

(1) RATING CURVES OF THE RIVER DAMODAR AND ITS TRIBUTARIES FOR 1947 ⁽⁵⁾

ABSTRACT

There are eight discharge sites in the Damodar hill catchment *viz* (i) Ramgarh, (ii) Chas Road and (iii) Sudamdih on the Damodar, (i) Barhi, (ii) Barakar-Girdih and (iii) Barakar-Asansol on the Barakar, Danae on the Bokharo, and Giridih on the Usri and four other sites *viz.* Ayre Dam site and Sonalapore Dam site on the Damodar and Tilaiya Dam site and Maithon Dam site on the Barakar where only gauges are observed (gauge-discharge curves for the eight discharge sites for the flood season of 1947 were prepared. For the Barhi site due to submergence of the gauge at the temporary wooden bridge site where observation had been started since 1946, gauges were observed at the previous site at the iron bridge on the Grand Trunk Road. Two rating curves got prepared for these two sites. Also rating curves at each of the four gauge sites were obtained by correlating the gauge at each site with the gauge of the nearest discharge site with allowance for proper time-lag.

(2) RATING CURVES OF THE RIVERS MOR, DWARKA AND BRAHMANI FOR 1947 ⁽⁶⁾

ABSTRACT

There are two discharge sites at Messenjore Dam Site and Sainthia Railway Bridge site on the river Mor, one at Godadharpur Railway Bridge site on the river Dwarka and one at Nalhati Railway Bridge site on the river Brahmani. Also there is one gauge site at Tilpara Ghat Barrage site on the river Olor. The gauge-discharge curves for the four discharge sites for the flood season of 1947 were prepared and the rating curve at the Tilpara Ghat Barrage site was obtained by correlating with proper time lag its gauge with the gauge at the nearest discharge site at Sainthia which is about 10½ miles downstream of the barrage site.

(3) RATING CURVES OF THE RIVER TEESTA AND ITS TRIBUTARIES FOR 1947 ⁽⁷⁾

ABSTRACT

There are eight discharge sites in the hill catchment of the Teesta river *viz.*—(i) Mumring Bridge (Rungpo), (ii) Melli Bazar, (iii) Teesta Bridge (Anderson Bridge), (iv) Coronation Bridge (Sevoke) on the river Teesta; (v) Rungpo Bridge on the river Rungpo; (vi) Naya Bazar (Singla), (vii) Champa Bazar on the river Great Rangit; and (viii) Sangla on the river Raman.

Cross sections could not be taken at any of these sites during the flood season. As such, discharges for the flood season of 1947 were calculated on the cross sections taken before the commencement of the flood season. It is expected that this would not materially change the value of the discharge

⁽⁵⁾ Annual Report of the River Research Institute West Bengal 1947, pages 41—43.

⁽⁶⁾ Annual Report of the River Research Institute West Bengal 1947, pages 43—44.

⁽⁷⁾ Annual Report of the River Research Institute West Bengal 1947, pages 44—45.

very much, as the bed near about the observation sites is of rocky nature and more or less rigid. These calculations are being repeated on the basis of the cross sections taken at the end of the flood season. Rating curves were prepared for all the eight sites based on the discharges already calculated. These would be modified after the calculations on the new cross sections are completed.

(4) RATING CURVES OF THE RIVER GANGA AT PAKSEY AND RAJMAHAL FOR THE YEARS 1936-41 ⁽⁸⁾

ABSTRACT

In connection with the scheme of improvement of the Bhagirathi and other distributaries of the river Ganga in Central Bengal, *e. g.*, Bhairab-Jalangi, Mathabhanga, *etc.*, it was proposed to study the gauge readings of these rivers and their relation with the gauge height and discharge of the river Ganga. Records of gauge-heights of these rivers exist for the years 1936 to 1941. Records of gauge readings of the Ganga above the offtake of the Bhagirathi exist at Rajmahal. But no discharge observation was taken at this site. The only site where discharge is observed on the Ganga is at Paksey where observations are taken by the B. A. Railway authorities. These observations are taken six times a month during the flood season and three times a month at other times. The two gauges at Rajmahal and Paksey with proper allowance for time-lag were correlated and correspondence between the gauge at Rajmahal and discharge at Paksey obtained.

(5) TIME LAG AS A FUNCTION OF DISCHARGE ⁽⁹⁾

ABSTRACT

As a preliminary to delivering the real regeneration in the Kalabagh—Ghazighat reach of the river Indus, the time lag, T , in days, between Kalabagh and Ghazighat has been studied for the year 1931-32 to 1945-46. It has been found that in this reach time lag is a deficit function of the mean discharge, Q (thousands cusecs). The process of analysis described in the paper can be applied to suitable reaches of rivers in India.

The evaluation of true gains and losses in any given reach of a river involves, among other things, the estimation of the time lag and valley storage for the reach. The time lag can be estimated either by dividing the length of the reach by the observed mean velocity or by finding the interval between the passage of a peak or trough from the upstream end of the reach to the downstream end.

Of these two methods, the first is the more suitable where the time taken for water to flow through the reach is short compared to the frequency of discharge observations at either end. For example, if the discharges are observed once a day and the reach can be covered by the flowing water in six hours, the passage of a peak at the upstream end may not be recorded as such at the downstream end. In such a case the average mean sectional velocity for the reach provides the only index for the correct evaluation of time lag.

(8) Annual Report of the River Research Institute West Bengal 1947, pages 45—46
 (9) Irrigation Research East Punjab Annual Report, 1947, pages 10—13.

If, however, the length of the reach is large compared to the frequency of discharge observations at either end, it may be possible to find the time lag by tracing a peak or trough down the reach. Obviously, the lag will be a function of the magnitude of the peak or the trough, though it may not always be possible to evaluate this function explicitly.

It is, however, generally easier to trace the peaks than to locate the troughs. sudden rises in rivers are usually far more common than sudden falls in level; and the troughs which are too close to peaks on either side are partly affected by them.

Again, a rising river is partly slowed down by the loss of volume due to storage in river bed between the two sites and the consequent reduction in velocity. Similarly, on a falling river, the flow is accelerated by water being returned from valley storage.

Where the difference between the discharges at the two sites is appreciable, therefore, the time lag for a peak at the upper site of a given magnitude would be more than if the same discharge were passing steadily. Similarly, the time lag with a trough would be less than at an equal discharge running steadily.

The effect of additions to valley storage on a peak and from valley storage on a trough is, however, mixed up with the effect of gains and losses between the two sites. The gains might be due to the inflow caused by rain, and might reinforce a peak.

In order to find the relation, if any, between the river discharge and time lag, it is, therefore, best to take the mean discharge for the upper and lower sites as that corresponding to the observed lag.

Further, as the river discharges are usually observed only once a day and the time lag might, therefore, be out by $\frac{1}{2}$ a day, it is advisable to group the discharges in different ranges, so as to have a sufficient number of values in each group for averaging and thereby reduce the error of variation.

In the absence of discharge records for East Punjab rivers, which were not received from West Punjab right up to the end of 1947, an investigation for a reach in West Punjab might be described. This was undertaken sometime before partition and is cited here by way of illustrating the application of the method discussed above.

The reach chosen was 'Kalabagh to Ghazighat' on the river Indus, and only the *rabi* (October 16—April 15) season was considered. A knowledge of the time lag in this reach during *rabi* would be useful for regulation purposes, if and when the Punjab inundation canals taking off the Indus river were linked to a barrage. It would also be useful, combined with a similar knowledge of the time lag from Panjnad—*cum*—Ghazighat to Sukkur, for verifying the value of the Kalabagh—Sukkur time lag. The latter had been taken as 13 days—during *all* the *rabi* months, in the Sind calculations presented to the Indus Commission; and 15 days in the proposed Sind-Punjab agreement (1945) draft.

The time lag from Kalabagh to Ghazighat was determined as follows:—

(a) For each year from 1931-32 to 1945-46, the daily discharges at the two sites were written down in parallel columns, and the peaks or troughs marked separately for each site. Where the peak or trough was not very marked, it was rejected outright.

(b) All the peaks or troughs at Kalabagh which were followed by similar peaks or troughs at Ghazighat were then listed. The interval between the two gave the time lag. There were 102 such values.

The values of the lag were then averaged for different discharge ranges and the corresponding discharges were evaluated. The averages are given in Table 2A. IV.

TABLE 2A. IV

| Range of discharges (1,000 cusecs) | No. of values in the range | Mean discharge (1,000 cusecs) Q | Mean time lag (days) T |
|---------------------------------------|-------------------------------|--------------------------------------|-----------------------------|
| 20.1—30.0 .. | 18 | 25.5 | 7.17 |
| 30.1—40.0 .. | 20 | 35.0 | 5.70 |
| 40.1—50.0 .. | 19 | 44.5 | 4.95 |
| 50.1—60.0 .. | 15 | 54.9 | 4.43 |
| 50.1—80.0 .. | 12 | 65.9 | 3.83 |
| 80.1—100.0 .. | 11 | 88.6 | 3.28 |
| Above 100 : | 7 | 144.3 | 2.21 |

The plot of time lag against discharge indicated a definite relationship. From physical considerations this was taken to be of the form: $T = C Q^n$, n being negative. The values of C and n were found by a double log plot, and the relation came out as:

$$T = 62.4 Q^{-1} \quad \dots \quad (2A.1)$$

The values given by Equation (2A.1) compared with the actuals are given in Table 2A.V

TABLE 2A.V

| Q (1,000 cusecs) | T (actual) (days) | T (calculated) (days) |
|--------------------|---------------------|-------------------------|
| 25.5 | 7.17 | 7.19 |
| 35.0 | 5.70 | 5.83 |
| 44.5 | 4.95 | 4.97 |
| 54.9 | 4.43 | 4.32 |
| 65.9 | 3.83 | 3.83 |
| 88.6 | 3.28 | 3.14 |
| 144.3 | 2.21 | 2.27 |

The actuals as well as the values given by the formula are plotted in Figure 2A.1. Considering the sort of data analysed the fit was very close.

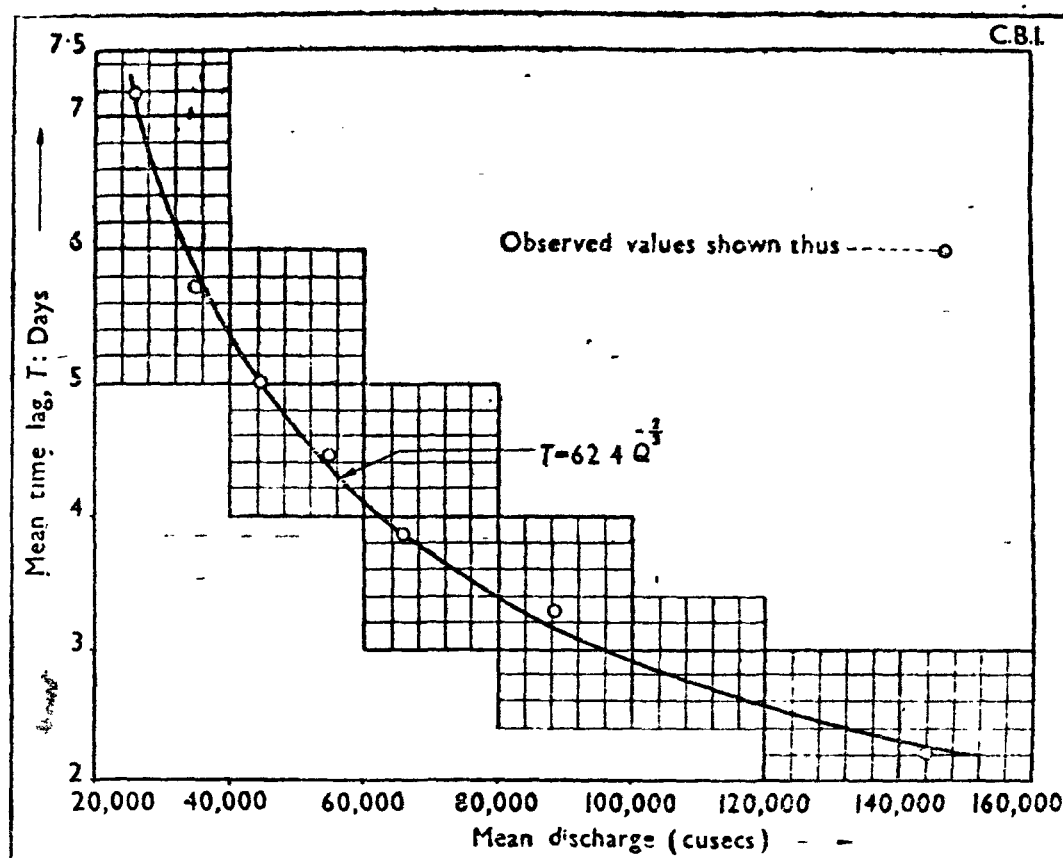


Figure 2A. 1 : Relation between the time-lag from Kalabagh to Ghazighat and the average discharge in this reach of the river.

The values given by Equation (2A.1) for some discharges in the range of values on which it was based were :—

| Discharge (1,000 cusecs) | Time lag (days) |
|--------------------------|-----------------|
| 20 | 8.47 |
| 30 | 6.45 |
| 40 | 5.33 |
| 50 | 4.60 |
| 100 | 2.90 |
| 200 | 1.82 |

Thus, in this case at least, the time lag was found to be a definite function of the river discharge. Whether this is true in other cases will be verified by analysing the data for other reaches in East Punjab. The complexity introduced by a variable time-lag in the determination of gains and losses will also be examined and, if possible, resolved.

(6) AFFLUX OBSERVATIONS OF FLOOD OF CAUVERY RIVER AT ITS JUNCTION WITH THE KRISHNARAJASAGAR RESERVIOR ⁽¹⁰⁾

The Krishnarajasagar reservoir is at the confluence of three rivers, the Hemavathi, Cauvery and Lakshmanathirtha. The former two are practically equal in-size while the latter is a small river. The points of confluence of the three rivers are practically equidistant being about 27 miles from the dam.

Observations were conducted for a period of about four years, 1938-1941 and again in 1947 to find out the difference in reservoir level at the dam and at a point a mile below the river Cauvery was joining the reservoir when it was full. The Cauvery discharges to a peak of about 40,000 cusecs in a normal year.

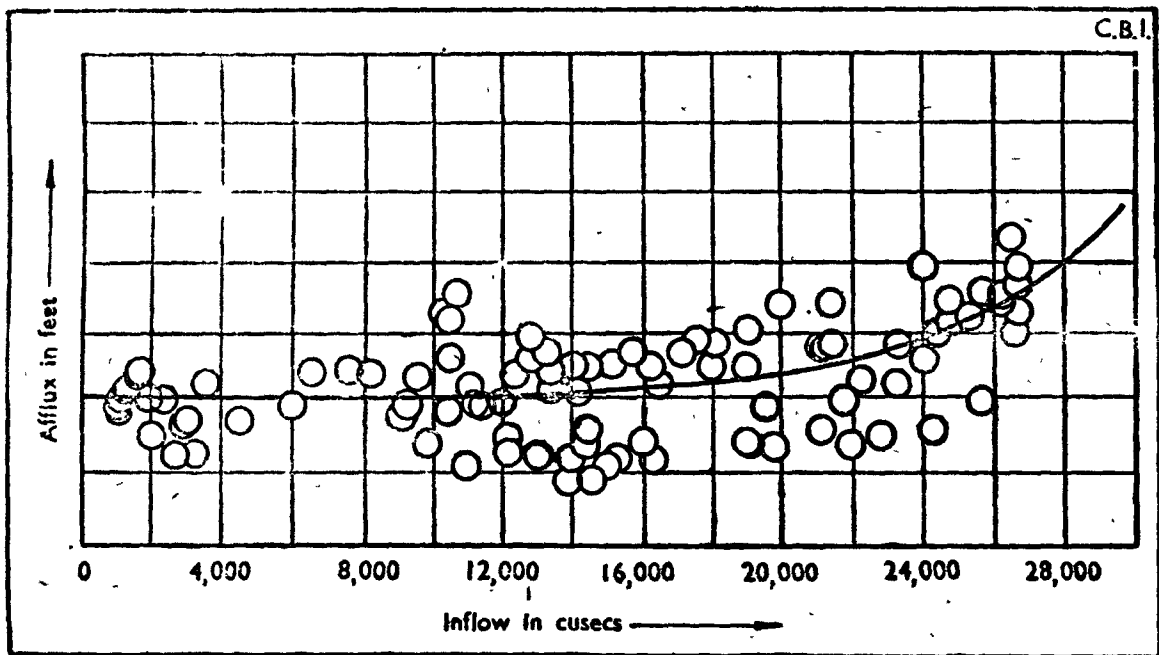


Figure 2A2. : Relation between afflux in feet at Yedatore Road Bridge and inflow in case of the river Cauvery.

Figure 2A. 2 shows that the maximum possible afflux does not exceed six inches. The variations of afflux with reference to intensity of floods are very large. These are due to variations in intensities of floods in the other two rivers even on days when the intensity of flood in the Cauvery is constant, the variation in reservoir levels when observations are taken for the same flood, and also due to variations in the intensity of discharges let down from the dam.

It is, however, possible to conclude that permanent acquisition of lands coming under submersion may be limited to the full reservoir level. Those that come temporarily under submersion due to afflux are very small. Any damages to the crops on account of afflux can be compensated by cash payments.

DISCUSSION BY THE RESEARCH COMMITTEE

DR. N. K. BOSE introduced items (1) to (4). Referring to item (4) he said that the only discharge site in the river Ganga was at Paksey at the Railway bridge but gauges were observed both at Paksey and Rajmahal, a distance of about 100 river miles. A gauge discharge curve for the Paksey site was first of all obtained and afterwards gauges at Paksey and Rajmahal were correlated by giving proper time lag. It was found that the correlation was very high : 99.2 per cent. This extremely high correlation was very difficult to explain. Between Rajmahal and Paksey the river Ganga received one big tributary on the left bank, that is, Mahanadi and had a number of spill channels both on right and left banks. As the correlation was highly significant this meant that contribution of the river Mahanadi to the raising of the gauge at Paksey was almost exactly compensated by the lowering of the gauge by other spill channels. This appeared to be very unusual. After carefully scrutinising there did not appear any flaw in the calculations. The gauge readings of the river Ganga at the intermediate points were also being correlated with the gauge at Rajmahal.

MR. N. S. GOVINDA RAO asked as to how the river gauges were fixed.

THE PRESIDENT enquired if the effect of those off-takes had been studied if not, it should be done.

DR. N. K. BOSE said that unless the gauges were connected by some other relation they must accept that the discharges added by the tributaries in this reach, must by chance, be equal to the amounts drawn by the off-takes.

DR. J. K. MALHOTRA introduced item (5) and said that he had very little more to add. For the evaluation of the gains and losses in a reach it was very important to have some idea of the time lag and in this particular case he had tried to link the estimated lag with the mean discharge in the reach. The reach chosen was Kalabagh to Ghazighat in the river Indus, and only the *rabi* season was considered. A knowledge of the time lag in that reach during *Rabi* would be useful for regulation purposes, if and when the Punjab inundation canals taking off the Indus river were linked to a barrage. It would also be useful combined with a similar knowledge of the time lag from Panjnad-Cum-Ghazighat to Sukkur, for verifying the value of the Kalabagh Sukkur time lag. The later had been taken as 13 days during all the months in the Sind calculation presented to the Indus commission, and 15 days in the proposed Sind-Punjab agreement (1945 draft).

The time lag from Kalabagh to Ghazighat was determined thus for each year from 1931-32 to 1945-46, the daily discharges at the two sites were written down in parallel columns, and the peaks or troughs marked separately for each site. Where the peak or trough was not very marked, it was rejected outright. All the peaks or troughs at Kalabagh which were followed by similar peaks or troughs at Ghazighat were then listed. The interval between the two gave the time lag. There were 102 such values, which were grouped according to the magnitude of the corresponding discharge and then averaged.

The averaged lag was then plotted against the average discharge and a curve drawn through the plotted point. This gave a very close fit with the actuals as shown by the table on page 125 of this report.

MR. N. S. GOVINDA RAO introduced item (6) and said that observation had been conducted for a period of five years and these had shown that variations of afflux were due to various factors.

The Cauvery discharged to a peak of about 40,000 cusecs in a normal year at the point of its junction with the reservoir at Maximum Water Level. The maximum afflux observed was only six inches for the peak discharge.

MR. S. L. MALHOTRA referring to item (5) regarding time lag said that it depended upon several factors e.g. season, pond level, state of the river bed *etc., etc.* If the river bed was saturated, the peak would pass in a short time but if the bed was dry, it would take a longer time to pass as it had to wet and fill the dry bed of the river.

MR. N. S. GOVINDA RAO referring to items (1) to (4) said that the larger variations noticed in the discharges at the higher stages in the curve required closer investigation. It was better to conduct vertical velocity observations at as many points as possible and ensure that the average velocity was the average of $0.2d$ and $0.8d$ observations or equal to the $0.6d$ observation. The discharges obtained in any year by extending rating curves with very few points required confirmation by repetition of observations in succeeding years.

Referring to item (5) he said that the correlation between time lag and discharge might not be possible where there were numerous inlets bringing in flood discharges spasmodically between the two points of observation. There should also be no change in meander length and slopes.

DR. N. K. BOSE replying to Mr. Govinda Rao said that vertical velocity observations were extremely difficult as current meters could not be used in such cases. They had to have recourse to surface floats.

DR. J. K. MALHOTRA replying to the same speaker said that time lag, as had been proved from analysis, was a function of discharge, and he was able to evolve a formula which fitted the data very well indeed. But he did not think that this particular formula would apply everywhere and would, therefore, help in calculating time lag in all cases.

DR. N. K. BOSE said that he did not think that inflow and seepage between the two points of observations had been taken into account in the calculations of time lag.

DR. J. K. MALHOTRA replied that he had taken the average discharge at the two points and correlated this with the time lag. The process of averaging automatically took account of inflow and seepage losses.

SARDAR BAHADUR SARUP SINGH said that to know about the time lag was very useful.

THE PRESIDENT suggested to Mr. Govinda Rao to send his data also to Dr. J. K. Malhotra who would analyse it and find a relation for determining the time lag.

MR. S. L. MALHOTRA said that the method suggested by Dr. J. K. Malhotra would prove very useful. They should co-ordinate the data actually for each period and each week.

It was then decided that the subject should continue to remain on the agenda.

DISCUSSION BY THE BOARD

THE SECRETARY said that six items were discussed at the Research Committee meeting but there was no resolution.

It was decided to keep the subject on the Agenda.

3A. Measurement of Flowing Water

PRELIMINARY NOTE

The subject previously called " Accuracy of different methods of taking discharges " has been on the agenda since 1940, and the main questions under investigations have been the comparison of current meter and velocity rod methods for observing discharges, the determination of the velocity rod method for small channels, which would give results consistent with current meter observations ; calibration of 0·8 velocity rods against calibrated flumes, rating of current meters and correlation of surface velocity with velocity or 0·6 depth *etc.* In 1945 with a view to issuing a Board publication on the subject it was decided that the research officers should continue to do work on the various aspects of the problem on the subject and Provinces or States who have published or intend to publish instructions on the subject should send copies to all Research Organisations and to the Secretary, Central Board of Irrigation.

In 1946 meeting a committee comprising Mr. Bhatia ; Executive Engineer, Discharge Division, Punjab ; Mr. Govinda Rao ; Sub Divisional Officer, Cauvery Gauging, Madras, and Mr. Framji (Convener) was formed to draw standards for (a) calibration, methods for current meters, and (b) discharge observations and equipment.

The Committee as it stands today comprises Shri R. D. Sondhi ; Shri Govinda Rao ; Sub Divisional Officer, Cauvery Gauging, Madras, and Mr. K. K. Framji (Convener).

Shri Govinda Rao has supplied a note and Shri Sondhi has supplemented the note supplied by Shri Govind Rao. The final draft has not yet been prepared by the Committee.

The following items were discussed at the 1947 Research Committee Meeting :—

- (1) Comparison of velocity observations by the float method and the current meter method.
- (2) Water surface profiles observed in a five feet wide standing wave flume with parallel sides for various stages of flow.
- (3) Rating of meters.
- (4) Co-relation of 0·6 *d* with surface velocity observation of Hemavathi river at Akkiheball.
- (5) Short note on experiments conducted to find the effect of temperature on the results of ratings of current meters.
- (6) Short note on some experiments done at Krishnarajasagar to study the effect of turbulence on the velocity records obtained with cups and propeller type of meters.

Recent Literature

(1) Roberts, E. B.—Roberts radio current meter operating manual—United States Department of Commerce, Washington, D.C. 1947.

(2) Automatic Water Level Recorders for river gauging. Commonwealth Engineer, Vol. 34, No. 5, December 2, 1946.

(3) Green, K.D.—River gaugings. State rivers and Water Supply Commission, Victoria, Technical Bulletin No. 3, 1947.

(4) McAdam, R.—Gauging of streams and pump discharges. Power and Works Engineer, Vol. 40, No. 470, August 1945.

(5) Bailey Open Channel Meters. Bailey Meter Co., Ohio, Bulletin No. 62

(6) Addison, H.—Hydraulic Measurements, a manual for engineers. Chapman and Hall Ltd., London, 1946.

THE YEAR'S WORK

The following items were discussed at the 1948 meeting of the Research Committee :—

- (1) Discharge observations of the Jaldaka river.
 - (2) Co-efficient of discharge in notch type and weir type falls on the Mahanadi main canal (Central Provinces).
 - (3) Co-efficient of discharge over anicuts—Shiriyā Anicut.
 - (4) Design of a standing wave flume for measuring discharge in the 24th mile distributary of the Irwin Canal.
- (1) **DISCHARGE OBSERVATIONS OF THE JALDAKA RIVER—EFFECT OF INTRODUCING A NUMBER OF CROSS SECTIONS WITHIN THE RUN OF THE FLOAT ⁽¹⁾**

ABSTRACT

The river Jaldaka is a hill stream rising in the glaciers of the Himalayas In its upper reaches it forms at stretches the boundary line between the Darjeeling district and Bhutan State. As the river is snow-fed, its minimum

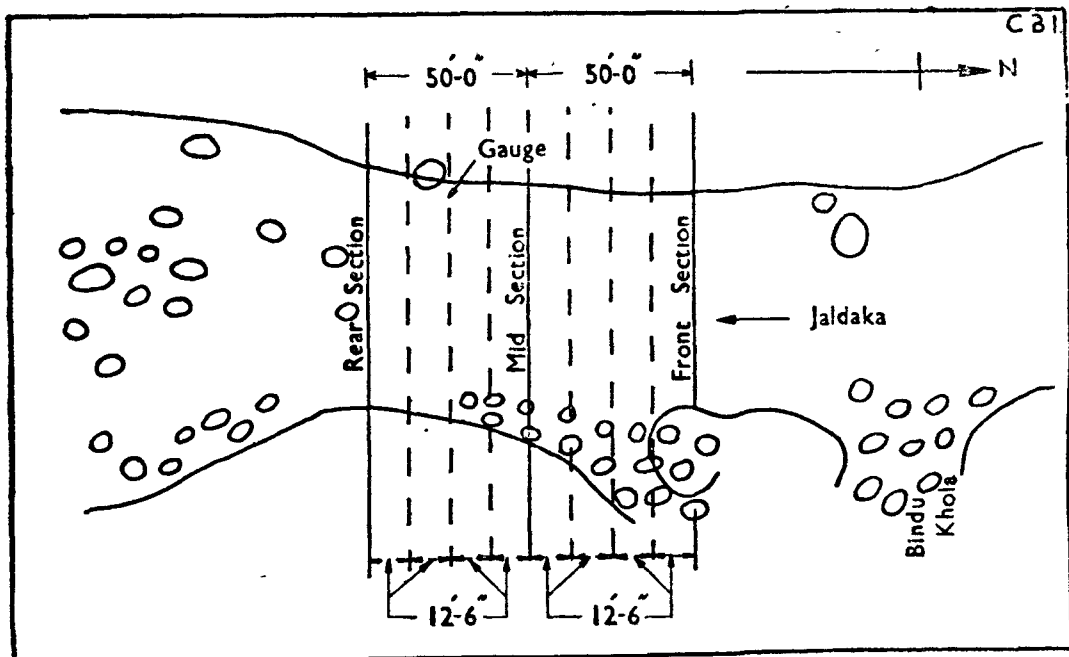


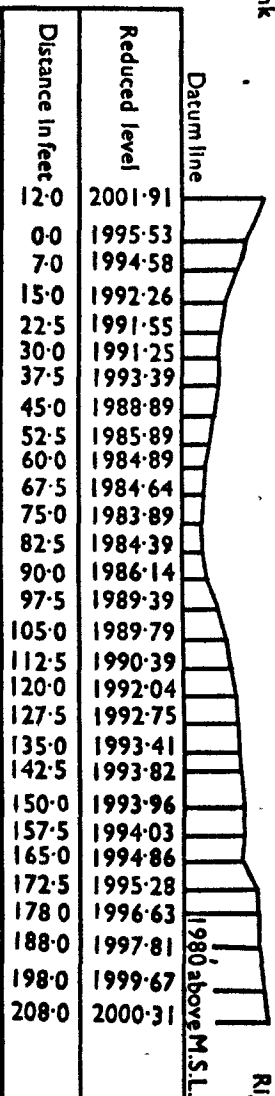
Figure 3 A 1: Plan showing observation sides at Jaldaka river (not to scale).

(1) River Research Institute, West Bengal, Annual Report 1947, pages 46-50.

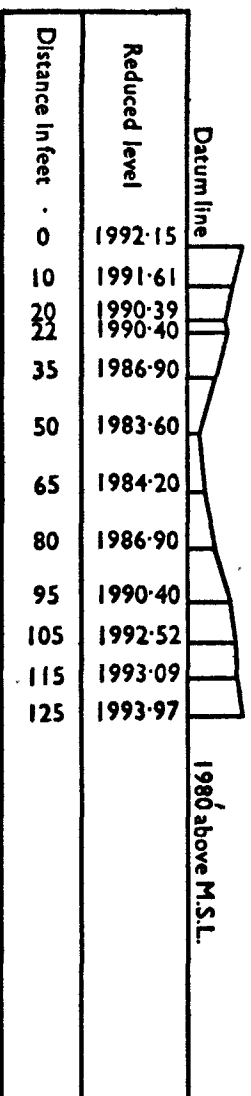
Left bank

Note :- All levels refer to an arbitrary datum

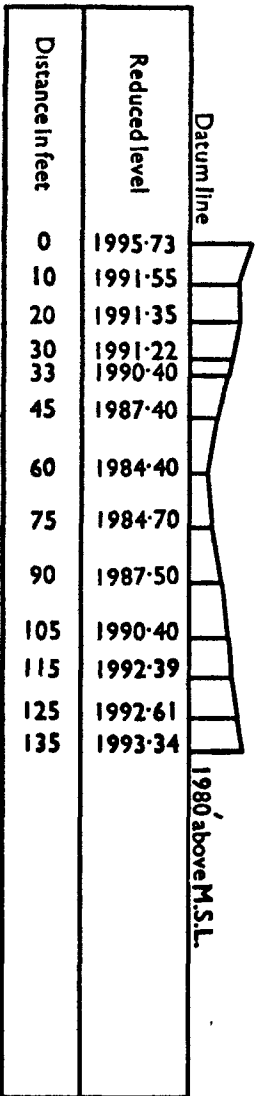
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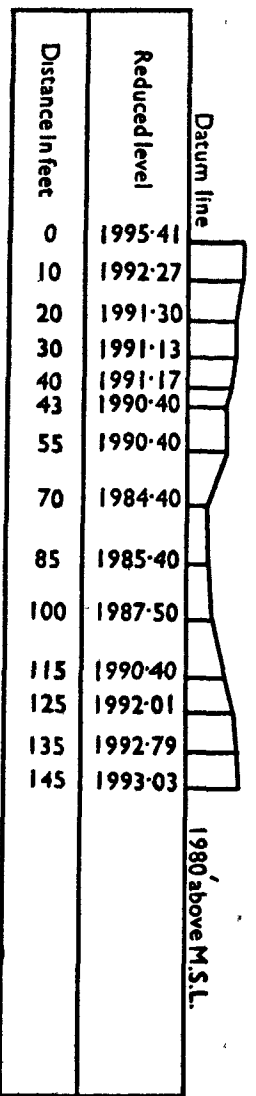
First Section



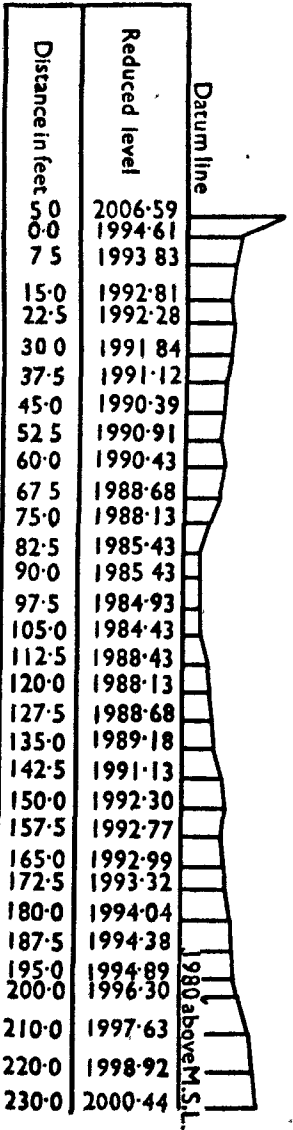
Second Section



Third Section



Fourth Section



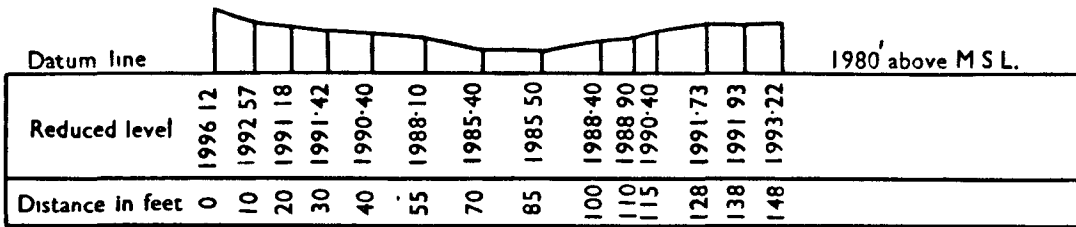
Fifth Section

Figure 3A.2(i):- Showing cross sections of Jaldaka River at observation site

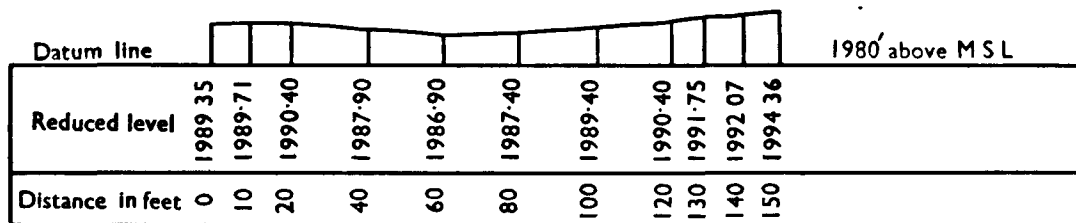
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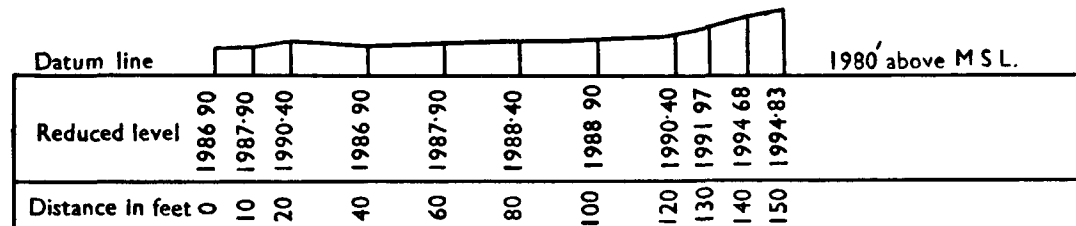
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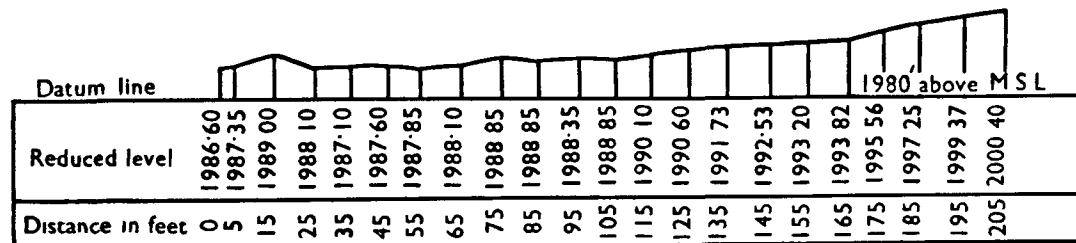
Sixth Section



Seventh Section



Eighth Section



Ninth Section

Figure 3A.2 (ii):- Showing cross-sections of Jaldaka River at observation site (Jaldaka hydro-electric scheme)

discharge is fairly high while in certain reaches the fall in the river bed is extremely steep (215 feet per mile). Investigations for the hydro-electric development of this river were undertaken in 1918 by Mr. T. L. Mathews. Of late fresh investigations have been taken up by the Electricity Development Department of the Government of Bengal and in this connection accurate observation of gauges, discharge and silt content of the river water during the dry season, that is, during the months of January to April, was undertaken by the River Research Institute, West Bengal. The site Figure 3A.1 chosen for carrying out these observations was immediately below a stream known as Bindukhola and, as such, is not very suitable for discharge observations during high stages of the river but as the present investigation was only concerned with the dry season discharge, this site was selected because of certain other advantages. Attempts were made to use a current meter at a lower site but it was not successful. The river is full of rapids and projecting boulders and it was not possible to set up arrangements for lowering the current meter in the middle of the stream. Between this site and the site actually selected below Bindukhola there was a stretch of the river which could have been used for velocity observation by the "Chemical method", but as the delicate apparatus required for this method were not available in the market at that time, this method was not adopted.

Discharge observations in the Jaldaka river in connection with the Jaldaka hydro-electric scheme were started with effect from January 12, 1947 while the reading of gauge height which was started earlier was continued. Silt content and pH determinations were taken up with effect from the January, 17, 1947.

The gauge site was on the right bank of the river Jaldaka just below its junction with the Bindukhola and stream gauging of the river was done by surface floats along the stretch just below the junction with the Bindukhola. This was at first done for a 100 feet run from this point, but later this run of 100 feet was broken up into two runs of 50 feet each, and velocity was observed for each of the runs. The width of waterway was arbitrarily broken up into five equal spans and the average surface velocity in each of the spans was observed by dropping floats in each span and noting the time taken to cover the run of 50 feet. The factor by which the surface velocity was multiplied to get the mean velocity in the vertical was estimated as 0.75 after inspection of the site on the April 15, 1947.

A point arose in connection with the fixing of this factor for determining the average velocity from the surface velocity. In ordinary stream the factor 0.89 is being used in the Punjab for arriving at the average velocity but the nature of flow in this river was entirely different from a river in the plains and as such it was thought that a lower value should be more suitable to the condition prevailing here. Without carrying out any comparative discharge observations by current meter it was not possible to assess the correct value of this factor. As the engineer-in-charge of this project was more anxious to know the minimum possible value of the dry season discharge it was agreed that a low value for this factor be used for converting the surface velocity. In consequence, a factor of 0.75 has been taken in the calculations. This factor has been fixed after taking into consideration the fact that the flow was very much disturbed by boulders on the bed.

The mean velocity of flow thus obtained is to be multiplied by the cross sectional area of waterway to get the rate of discharge. Cross sections plotted in Figures 3A.2 (i) and 3A.2 (ii) were taken at the beginning and end of each run and also at three intermediate equidistant points within each run of 50 feet. The whole stretch of 100 feet of the river was thus broken up by nine cross sectional lines at distances of $12\frac{1}{2}$ feet. The first run of 50 feet was from the 1st (front) to the 5th (mid) section, while the second run was from the 5th (mid) to the 9th rear section. The idea behind this was to get the average cross section for each length of 50 feet run over which velocity observation was taken.

The average velocity of flow in each span has been multiplied by the area of waterway in this span to give the flow in this span. These summed together for the five spans give the rate of discharge.

The river in the neighbourhood during dry season generally has rapids, meanders, bifurcations, boulders, etc., and the length of 100 feet of the river chosen for observation was the only stretch not seriously affected by these factors. However, even then it was found that there were boulders near the left bank of the river where the floats were often held up and this disturbed observations of velocity in the first span. Velocity observation in this span had ultimately to be stopped on account of this difficulty. The surface velocity in this span was found to be of the order of one foot per second in the low stage and this value of the velocity was assumed for this span for the low stage when no observations in this span were possible.

The silt intensity was very low (of the order of 0.01 gm. per litre) when observation was started, and the value was even lower and came down to practically nil (of the order of 0.002 per litre),—only during the freshet in the third and fourth weeks of April 1947 higher values 0.07 gm. per litre of silt intensity were recorded. The *pH* value was generally higher than 8.0 and it was only rarely (in March or April) that slightly lower values like 7.8 were recorded.

When discharge observations were started (on January 12, 1947) the water level was 1990.60 (R. L.) and the rate of discharge was about 400 cusecs. The water level slowly fell and was steady at the minimum level (1990.35) during the period from February 19, 1947 to March 12, 1947. The level then gradually rose and discharge increased.

As the idea behind these observations was to arrive at a correct estimate of the lowest discharge of the river and also to know when it occurs, these observations were continued upto the end of April and then discontinued.

The observed daily discharges within this period from February 19, 1947 to March 12, 1947 when the water level was steady at the minimum level, have been analysed to determine the minimum flow and also to study if there is any significant difference in the discharges by calculating it with more cross sections within the reach where velocity observations were taken.

EFFECT OF TAKING MORE CROSS SECTIONS INTO CONSIDERATION FOR DISCHARGE CALCULATION

As already mentioned, within the reach of 100 feet of the observations cross sections have been taken at intervals of $12\frac{1}{2}$ feet so that there are nine cross sections in all. Daily velocity observations have been taken for the *u*

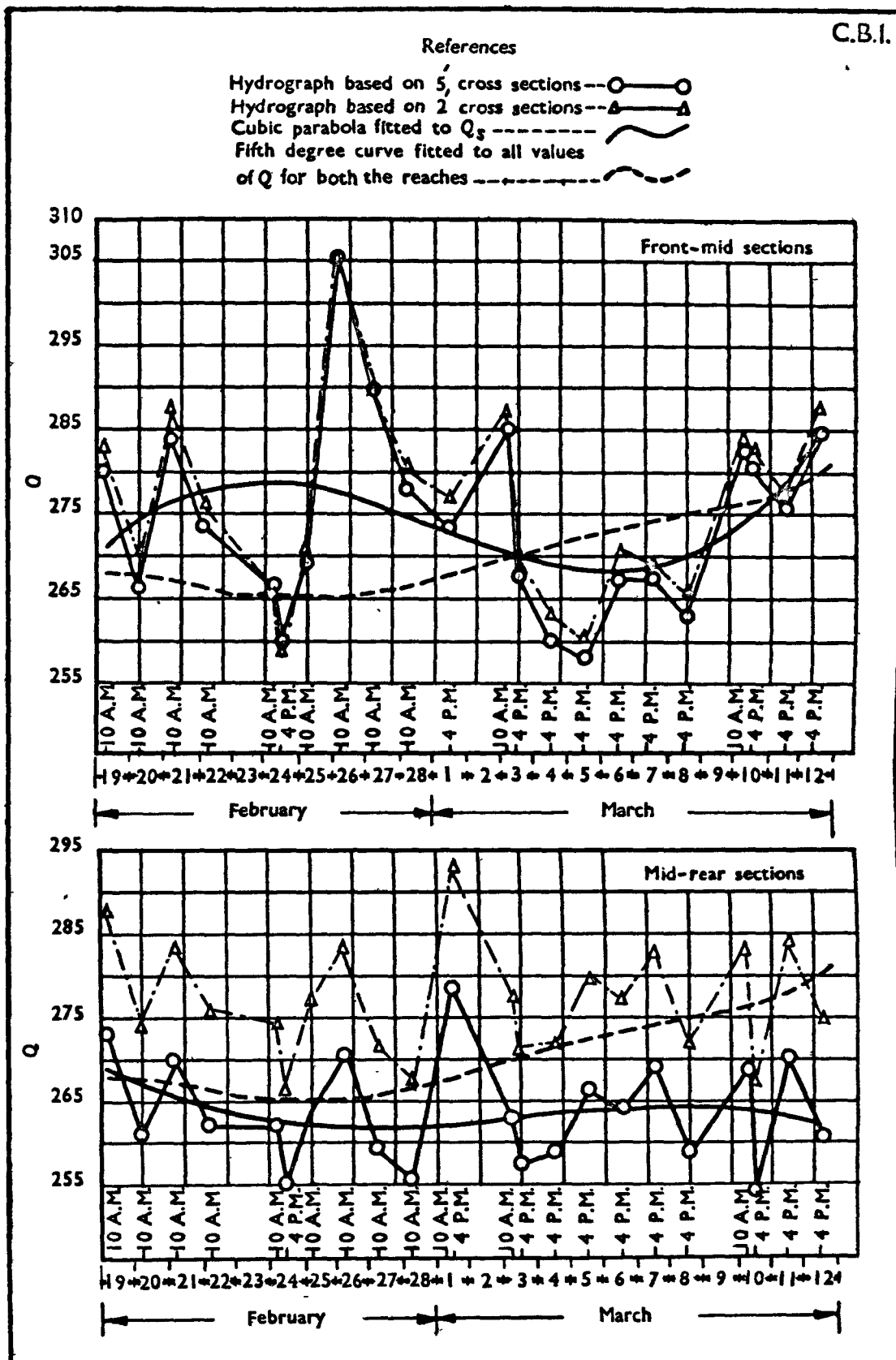


Figure 3A.3:- Showing discharge of the Jaldaka River below its junction with Bindukhoda [From 19.2.47 to 12.3.47]

feet run from the first (front) to the fifth (mid) cross section lines and also for the 50 feet run from the fifth (mid) to the ninth (rear) cross section lines. Discharges have been calculated for each of the runs by taking the area of waterway (*i*) as the mean of those based on the first and last cross sections of each run, and also (*ii*) as the mean of those given by all the five cross sections within the run.

The difference between the pairs of values of the discharge thus obtained has been tested by the Student's *t*-test. The values of *t* are given in Table 3A.I.

TABLE 3A.I

| Reach | Number of pairs of observations | Mean of difference in discharge in cusecs | Standard error of the mean difference | Student's <i>t</i> | 5 per cent. level of significance | Allowable difference on the 5 per cent. level |
|-----------------------|---------------------------------|---|---------------------------------------|--------------------|-----------------------------------|---|
| Front to Mid .. | 22 | -2.325 | 0.306 | -7.606 | 2.080 | 0.636 |
| Mid to Rear .. | 22 | -13.488 | 0.183 | -73.666 | 2.080 | 0.381 |
| Total observations .. | 24 | -7.907 | 0.869 | -9.098 | 2.018 | 1.753 |

In the above the difference has been taken as $Q_5 - Q_2$ where Q_5 = discharge based on five cross sections and Q_2 = discharge based on two cross sections.

It is found from the above that the difference between Q_5 and Q_2 is highly significant in both the cases and the level of significance is much higher for mid-to-rear reach than for the front-to-mid reach. Also the difference is negative, that is, Q_5 is less than Q_2 . Thus Q_5 is found to be significantly less than Q_2 in all the cases tested.

It is noticed that though the difference between Q_2 and Q_5 is less than 5 per cent. of the discharges for the front-to-mid reach, and less than five per cent. for the mid-to-rear reach, that difference of small order is highly significant. The reason is that this difference though of a small order is being almost constantly maintained throughout the period, as would be evident from the Figure 3A.

This is due to the fact that the mean of the area of waterway for the five sections is less than the mean for the two sections in either reach.

DAILY OBSERVATIONS OF DISCHARGE IN EIGHT SMALL REACHES OF 12½ FEET RUN EACH

In addition to the above, velocity observations were also taken about once a week in eight stretches, each of 12½ feet run within the 100 feet reach of the reach where observations have been taken. Only two such observations were made during the period under consideration, viz., on the February 26, 1947 and March 6, 1947. Discharges have been calculated from these by taking the mean area of waterway for the two sections at the beginning and end of the run of each stretch. Denoting these discharges by Q_1, Q_2, \dots, Q_8 , and taking the average of Q_1 to Q_4 , and also of Q_5 to Q_8 , we have

$$Q_{(FM)} = \frac{Q'_1 + Q'_2 + Q'_3 + Q'_4}{4}$$

and

$$Q_{(MR)} = \frac{Q'_5 + Q'_6 + Q'_7 + Q'_8}{4}$$

where (FM) denotes the average for front-to-mid reach and (MR) the average for mid-to-rear reach.

These have been compared with Q_2 and Q_5 (for front-to-mid and mid-to-rear portions). The actual values are given below:—

February 26, 1947

4 p.m.

$$\left. \begin{array}{l} Q'_1 = 235 \\ Q'_2 = 260 \\ Q'_3 = 243 \\ Q'_4 = 256 \end{array} \right\} , \quad Q'_{(FM)} = 248.5$$

$$\left. \begin{array}{l} Q'_5 = 266 \\ Q'_6 = 290 \\ Q'_7 = 230 \\ Q'_8 = 250 \end{array} \right\} , \quad Q'_{(MR)} = 260.$$

February 26, 1947

10 a.m.

$$Q_{2(FM)} = 306; \quad Q_{5(FM)} = 305;$$

$$Q_{2(MR)} = 284. \quad Q_{5(MR)} = 1.$$

February 27, 1947

10 a.m.

$$Q_{2(FM)} = 290; \quad Q_{5(FM)} = 289;$$

$$Q_{2(MR)} = 272; \quad Q_{5(MR)} = 259.$$

March 6, 1947

4 p.m.

$$\left. \begin{array}{l} Q'_1 = 226 \\ Q'_2 = 288 \\ Q'_3 = 239 \\ Q'_4 = 254 \end{array} \right\} ; \quad Q'_{(FM)} = 251.75$$

$$\left. \begin{array}{l} Q'_5 = 256 \\ Q'_6 = 288 \\ Q'_7 = 238 \\ Q'_8 = 243 \end{array} \right\} ; \quad Q'_{(MR)} = 257.5$$

March 6, 1947

4 p.m.

 $Q_{2(FM)} = 270$; $Q'_{2(MR)} = 278$; $Q_{5(FM)} = 267$; $Q_{5(MR)} = 264$.

It would be seen from the above that $Q' < Q_5 < Q_2$ for either reach but that while for the front-to-mid reach the difference between Q' and Q'_5 is greater than that between Q_5 and Q_2 the reverse is the case for the mid-to-rear reach. However, the data for Q' exist only for two days and hence no conclusive comparison could be made.

An analysis of variance had been carried out to test if the variation amongst Q' , Q'_2 etc., Q'_5 is significantly large or not. The analysis is given in Table 3A. II

TABLE 3A. II

| Variation due to | Sum of squares | Degrees of freedom | Variance = V |
|---------------------------|----------------|--------------------|----------------|
| Different reaches | 5,596.59 | 7 | 799.51 |
| Different dates | 1.34 | 1 | 1.34 |
| Error | 541.81 | 7 | 77.40 |
| Total .. | 6,139.74 | 15 | 409.32 |

Thus it is obvious that the variation due to different dates is not significant at all. For the variation due to different reaches, the value of Fisher's Z is—

$$Z = \frac{1}{2} \log_e \frac{\text{reach variance}}{\text{error variance}} = Z 2.2335,$$

while the five per cent. and one per cent. significance levels of Z are 0.67 and 0.97 respectively. Thus the variation from reach to reach is highly significant which means that the chance of getting a value of Z in a random sample higher than that obtained here is not even one per cent., so that this value of Z is high enough and cannot be accounted for by simply fluctuation due to random sampling.

This high level is of significance for the difference between Q'_1 , Q'_2 , etc., and shows that there is a good deal of fluctuation amongst these discharge values observed simultaneously. This is probably due to a not-too-small sampling fluctuation in the velocity observed in the different reaches.

MINIMUM FLOW

Next, to determine the minimum flow, the trend of the hydrograph has been sought to be ascertained by smoothing the data with some sort of an enveloping curve. A cubic parabola has been fitted on the values of discharges based on five cross sections separately for both the front-to-mid and the mid-to-rear reaches of the river. These cubic curves have been shown in the Figure 3.A.3 by a continuous line. The minimum flow as given by these curves are—

For front-to-mid reach

268 cusecs

For mid-to-rear reach

262 cusecs

Another curve of the fifth degree has also been fitted on to all the values of the discharges (both Q_2 and Q_3) obtained for either reaches and also the values $Q'_1, Q'_2, etc.$ The curve has been shown with dotted lines in the Figure 3A.3. From this curve the minimum discharge obtained is 265 cusecs.

SUMMARY

Thus from the above analysis the average minimum value of the discharge obtained is about 265 cusecs. This gives the most probable value for the minimum discharge that is likely to occur in this period. It has also been found that the value of the discharge has been significantly lowered by calculating it with more cross sections within the reach of the river over which velocity has been observed by floats. Also a significant fluctuation has been noticed in the sampling of the velocity in different reaches of the river at the same time.

(2) CO-EFFICIENT OF DISCHARGE IN NOTCH TYPE AND WEIR TYPE FALLS ON THE MAHANADI MAIN CANAL, CENTRAL PROVINCES (2)

The Mahanadi Main Canal, Central Provinces has 5.25 feet falls at R. D. 2,783 and 2,803. The upstream fall consists of three notches similar to the ones described in Buckley's Irrigation Pocket Book. The lower fall is a rectangular notch. It was desired to use one or the other of the falls as a meter.

The data of the two falls were analysed by Mr. G. A. D. Cochrane by using the North (Punjab type) fall, the formula for discharge per notch being

$$Q = 5.35 C H^3 (B + 0.04 nH)$$

where $C = 0.75$ for $Q > 300$ cusecs, and

$$0.70 \text{ for } Q < 300 \text{ cusecs,}$$

and where H is the head upstream over the sill

n = side slope and

B = width of sill (across the line of flow).

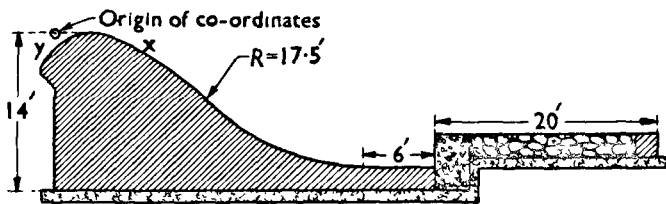
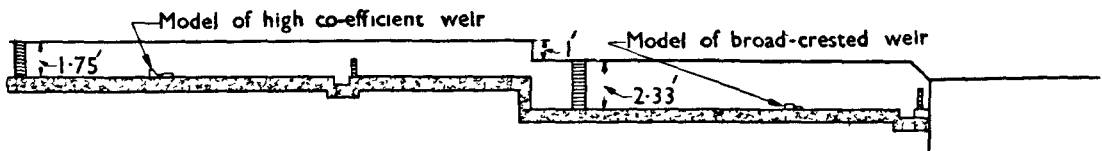
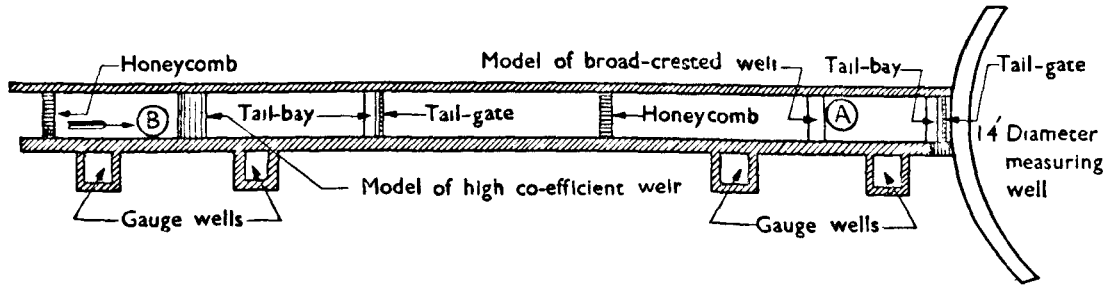
He worked out values of K_1 for the three notches of the fall at R. D. 2,783 for various depths upstream in the formula,

$$Q = K_1 B H^3 \text{ for the corresponding discharges according}$$

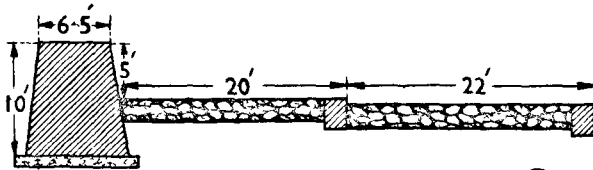
to the Punjab formula.

The rectangular notch at R. D. 2,803 has a sill width = 30.3 feet (across the line of flow) and length = 3.5 feet in line of flow. The sill is horizontal and the edges are not rounded. Using the discharges worked out above, K_2 was found for this fall in the formula $Q = K_2 B H^3$. It was found that $K_1 \geq 3.75$ and $K_2 \geq 3.7$. This value of K_2 is much higher than one would expect from such "bastard" type notch.

(2) Central Waterways, Irrigation and Navigation Research Station, Poona, Annual Report Technical, 1947, pages 23-25.



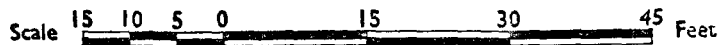
| Co-ordinates for the Ogee curve | |
|---------------------------------|--------|
| x | y |
| 0.0 | 1.134 |
| 0.9 | 0.324 |
| 1.8 | 0.063 |
| 2.7 | 0.000 |
| 3.6 | 0.063 |
| 5.4 | 0.567 |
| 7.2 | 1.377 |
| 9.0 | 2.403 |
| 10.8 | 3.690 |
| 12.6 | 5.310 |
| 15.3 | 8.280 |
| 18.0 | 11.790 |
| 22.5 | 18.900 |



| Co-ordinates for the lip | |
|--------------------------|------|
| x | y |
| 0.00 | 1.20 |
| -0.85 | 2.20 |
| -1.20 | 2.70 |
| -1.40 | 3.20 |
| -1.30 | 3.70 |
| -0.90 | 4.20 |
| 0.00 | 5.20 |

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Figure 3A.4:- Showing layout of models to determine co-efficient of discharge over anicuts



A comprehensive series of experiments with weir of $B=0.48$ to 16.30 feet and H up to four feet was done at the Cornell University and results are given in Gibson's Hydraulics (page 172, 4th edition). Gibson's analysis showed that results were correct within three per cent. so long as the length of the weir in line of flow was greater than twice the head and that the relative error increased as the relative depth increased.

In the case of the rectangular notch under reference, only one case satisfied the above condition and hence it was not surprising that the co-efficient were greater than the value of 3.09 for a broad-crested weir. Every weir with its individual approach conditions would have a different value of C . In this case it is, therefore, better either to estimate 'C' by current meter observations or model tests, rather than estimating the discharges from the Punjab notch formula which was perhaps never verified by accurate model tests but obtained only from rough discharge measurements with floats, since it was obtained years before the use of models and current meters was generally accepted. Besides, the effect of piers being considerable the co-efficient for three notches of the the first fall will be appreciably lower than that of a single notch, which itself appears, *prima facie*, high and needs experimental corroboration.

(3) CO-EFFICIENT OF DISCHARGE OVER ANICUTS—SHIRIYA ANICUT (2)

ABSTRACT

Experiment were carried out on models of the proposed Shiriya anicut to find out (1) the afflux for various discharges over a broad crested weir and over a "high co-efficient" weir for free over fall conditions and (2) the effect of submergence on the co-efficient of discharge. The studies though made on a particular set of models are generally applicable to all structures designed on the lines adopted in the present case.

MODEL

The two designs tested are shown Figure 3A.4. The profile (b) is based on the underside of a nappe of nine feet overflow. Models to scale $1/48$ of the se were made in teakwood and fitted up within parallel walled flume two feet wide. The models were laid out one following the other as shown in Figure 3A.4 so that the same water could be passed over both of them and the afflux at each separately measured. Necessary stilling arrangements were provided with a view to ensuring identical approach conditions to both models. The discharge was volume trically measured in the gauging well at the end of the flume.

EXPERIMENTS

First series—The crest levels of both the models were carefully recorded by admitting some water in the beginning till they remained just at the crest. Subsequently the supply was gradually increased in stages and for each discharge when steady, the depth of overflow at each model was separately noted and the corresponding discharge measured in the well. The results so obtained are furnished in Table 3A. III, and plotted in Figure 3A.5.

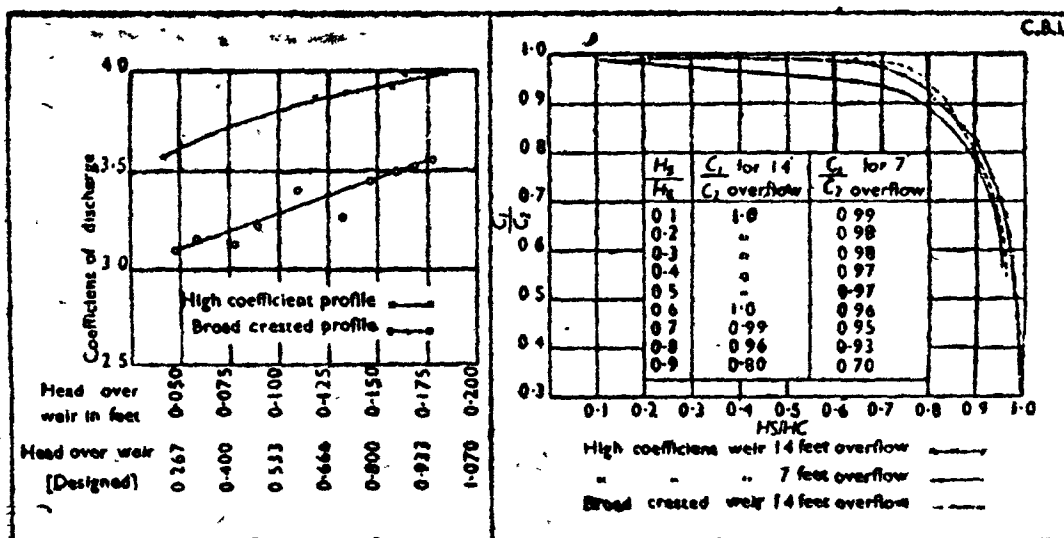


Figure 3A.5 : Left showing relations between co-efficient of discharge and head over weir.

Figure 3A.6 : Right showing Functional relationship between $\frac{H_s}{H_c}$ and $\frac{C_1}{C_s}$

SECOND SERIES

In this series two sets of experiments were carried out, one with overflow corresponding to seven feet (prototype depth over high coefficient weir) and the other with overflow corresponding to 14 feet. In each of these the discharge was maintained constant and was measured in the well. Starting from the overfall condition, the tail water was gradually raised in stages and its effect on upstream water level noted. The results are furnished in Table 3A.IV and plotted in Figure 3A.6.

DISCUSSION OF RESULTS

I. Series of experiments—(a) From the observations taken the value of co-efficient of discharge was calculated making use of the equation.

$$Q = C_d I (h_c + h_a)^{3/2}$$

where Q = discharge per foot width in cusecs.

TABLE 3A. III

| Item No. | ' h_c ' Headover weir in feet | ' q ' Dis- charge in cusecs per foot width | ' h_a ' Head due to velocity of approach | $(h_c + h_a)^{3/2}$ | $C_d = \frac{q}{(h_c + h_a)^{3/2}}$ | Remarks. |
|----------|---------------------------------------|---|---|---------------------|-------------------------------------|---|
| 1 | 0.061 | 0.0542 | 0.00047 | 0.01524 | 3.556 | Computations for the High co-efficient weir. |
| 2 | 0.071 | 0.0695 | 0.00073 | 0.01922 | 3.617 | |
| 3 | 0.081 | 0.0854 | 0.00104 | 0.02350 | 3.634 | |
| 4 | 0.123 | 0.1668 | 0.00313 | 0.04478 | 3.725 | |
| 5 | 0.140 | 0.2117 | 0.00461 | 0.05499 | 3.850 | |
| 6 | 0.155 | 0.2509 | 0.00600 | 0.06460 | 3.886 | |
| 7 | 0.167 | 0.2838 | 0.00724 | 0.07269 | 3.904 | |
| 8 | 0.177 | 0.3133 | 0.00841 | 0.07984 | 3.924 | |
| 9 | 0.185 | 0.3431 | 0.00972 | 0.08592 | 3.993 | |
| 1 | 0.067 | 0.0542 | 0.00060 | 0.01758 | 3.084 | Computations for the broad crested weir. |
| 2 | 0.078 | 0.0695 | 0.00091 | 0.02217 | 3.135 | |
| 3 | 0.089 | 0.0854 | 0.00127 | 0.02712 | 3.148 | |
| 4 | 0.111 | 0.1218 | 0.00225 | 0.03814 | 3.195 | |
| 5 | 0.131 | 0.1668 | 0.00374 | 0.04944 | 3.374 | |
| 6 | 0.168 | 0.2509 | 0.00689 | 0.07313 | 3.432 | |
| 7 | 0.180 | 0.2838 | 0.00827 | 0.08174 | 3.472 | |
| 8 | 0.190 | 0.3133 | 0.00959 | 0.08919 | 3.514 | |
| 9 | 0.200 | 0.3431 | 0.01094 | 0.09683 | 3.543 | |

TABLE 3A. IV

| h_s | h_c | $\frac{h_s}{h_a}$ | h_a | $\left\{ \begin{array}{l} (h_c + h_a)^{\frac{3}{2}} \\ - (h_a)^{\frac{3}{2}} \end{array} \right\}$ | $\frac{C_1}{C_2}$ | Remarks. |
|-------|-------|-------------------|-------|--|-------------------|---|
| 0.480 | 7.000 | 0.069 | 0.195 | 19.234 | 1.000 | Computations for the high co-efficient weir for 7 feet overflow condition. |
| 0.768 | 7.050 | 0.109 | 0.195 | 19.414 | 0.991 | |
| 1.728 | 7.100 | 0.243 | 0.194 | 19.615 | 0.980 | |
| 2.784 | 7.144 | 0.390 | 0.193 | 19.735 | 0.972 | |
| 4.272 | 7.192 | 0.594 | 0.192 | 19.976 | 0.962 | |
| 5.328 | 7.240 | 0.736 | 0.191 | 20.176 | 0.953 | |
| 6.192 | 7.336 | 0.844 | 0.189 | 20.568 | 0.935 | |
| 6.672 | 7.816 | 0.854 | 0.181 | 22.533 | 0.854 | |
| 7.392 | 8.296 | 0.891 | 0.173 | 24.578 | 0.782 | |
| 8.208 | 8.920 | 0.920 | 0.164 | 27.314 | 0.704 | |
| 8.02 | 13.11 | 0.612 | 0.934 | 51.70 | 1.000 | Computations for the high co-efficient weir for 14 feet overflow condition. |
| 8.98 | 13.21 | 0.680 | 0.927 | 52.27 | 0.989 | |
| 10.13 | 13.49 | 0.751 | 0.908 | 53.79 | 0.961 | |
| 11.91 | 14.02 | 0.850 | 0.874 | 56.66 | 0.912 | |
| 12.82 | 14.50 | 0.884 | 0.845 | 59.37 | 0.871 | |
| 14.07 | 15.46 | 0.910 | 0.791 | 64.79 | 0.798 | |
| 14.59 | 15.89 | 0.918 | 0.769 | 67.34 | 0.768 | |
| 15.31 | 16.51 | 0.927 | 0.738 | 71.25 | 0.726 | |
| 16.51 | 17.47 | 0.945 | 0.693 | 76.81 | 0.673 | |
| 19.06 | 19.87 | 0.959 | 0.598 | 92.16 | 0.561 | |
| 23.23 | 23.76 | 0.978 | 0.482 | 118.97 | 0.435 | Computations for the broad crested weir 14 feet overflow. |
| 25.30 | 25.73 | 0.983 | 0.433 | 113.52 | 0.387 | |
| 27.75 | 28.13 | 0.987 | 0.387 | 152.06 | 0.340 | |
| 8.79 | 12.78 | 0.688 | 0.809 | 49.363 | 1.000 | |
| 9.42 | 12.82 | 0.735 | 0.806 | 49.627 | 0.995 | |
| 9.80 | 13.02 | 0.753 | 0.792 | 50.625 | 0.975 | |
| 10.23 | 13.11 | 0.780 | 0.786 | 51.164 | 0.965 | |
| 10.62 | 13.16 | 0.807 | 0.782 | 51.368 | 0.961 | |
| 11.05 | 13.35 | 0.828 | 0.771 | 52.384 | 0.942 | |
| 11.72 | 14.05 | 0.835 | 0.725 | 56.172 | 0.879 | |
| 12.20 | 14.26 | 0.856 | 0.713 | 57.338 | 0.861 | |
| 12.49 | 14.46 | 0.862 | 0.701 | 58.433 | 0.845 | |
| 13.11 | 14.84 | 0.883 | 0.681 | 60.568 | 0.815 | |
| 13.64 | 15.22 | 0.904 | 0.660 | 62.624 | 0.794 | |
| 14.41 | 15.75 | 0.912 | 0.633 | 65.776 | 0.750 | |
| 14.79 | 16.08 | 0.920 | 0.617 | 67.736 | 0.729 | |
| 15.41 | 16.66 | 0.925 | 0.590 | 71.177 | 0.693 | |
| 16.90 | 17.81 | 0.949 | 0.543 | 78.160 | 0.631 | |

$l=1$ foot.

C =co-efficient of discharge.

h =head over the crest.

h_a = head due to velocity of approach.

$$= \frac{V_a^2}{2g} \text{ where } V_a = \text{velocity of approach.}$$

The exact equation however is

$$Q = Cl \left[(h + h_a)^{\frac{3}{2}} - h_a^{\frac{3}{2}} \right]$$

But the error in assuming the simpler form is not considerable and for the purpose of study it has the benefit $(h + h_a)$ can be taken as H = effective head without velocity of approach and in this form the results will have general significance. The values of C for different values of H are plotted as shown in Figure 3A.5 for both the broad crested weir and the high co-efficient profile. The values of $\frac{H}{\text{designed head}}$ are also shown along the x -axis so as to draw inferences of general application from the foregoing studies. It will be clear from this figure that the broad crested weir has the smallest value of C_d for any particular depth of overflow. The maximum value attained in the experiments was 4.05. Since the value of C_d is very much influenced by the shape of the lip it is difficult to ascertain the exact value in the absence of model experiments. Moreover there are limitations for drawing inference of the value of C_d of the prototype from model experiments in this type of studies. However the curve of Figure 3A.5 will be useful in choosing an appropriate value depending on the ratio of depth of overflow to designed head.

II. Series of experiments.—(b) in these experiments the basis for the computations was the equation for the discharge over a free overfall weir with velocity of approach.

$$Q = C_1 \sqrt{2g} l (hc + ha)^{\frac{3}{2}} - ha^{\frac{3}{2}}]$$

Where Q =discharge in cusecs.

C_1 =co-efficient of discharge.

l =length of weir in feet.

hc =head over the crest in feet.

h_a = head due to velocity of approach.

$$\frac{V_a^2}{2g}$$

where V_a = velocity of approach

$$= \frac{q}{(hc+p)}$$

q being discharge per foot width and p = height of weir in feet.

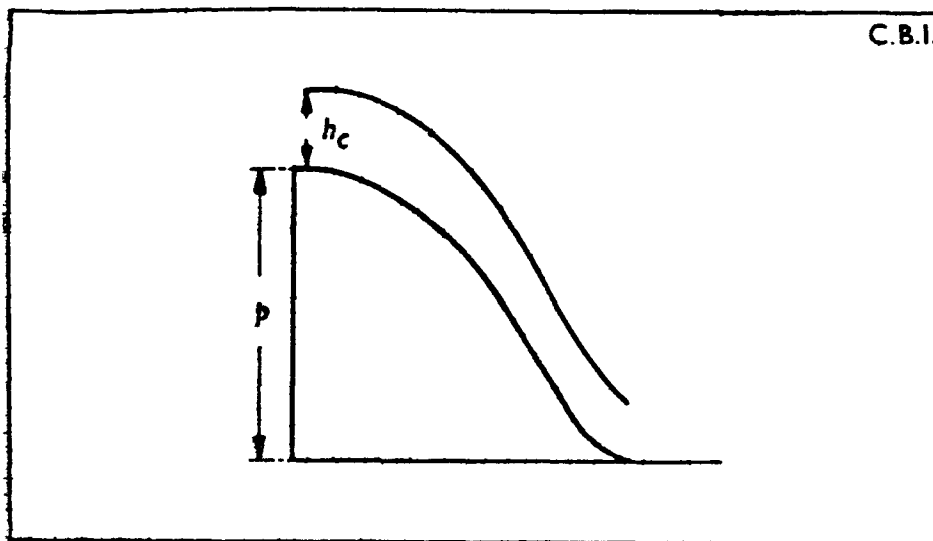


Figure 3A.7

When the weir gets submerged, that is when the downstream level rises above the crest level of the anicut the usual method of computing discharge is to treat the total discharge as a sum of two discharges: that through the submerged portion which is treated as a submerged orifice and that through the weir with a clear overfall.

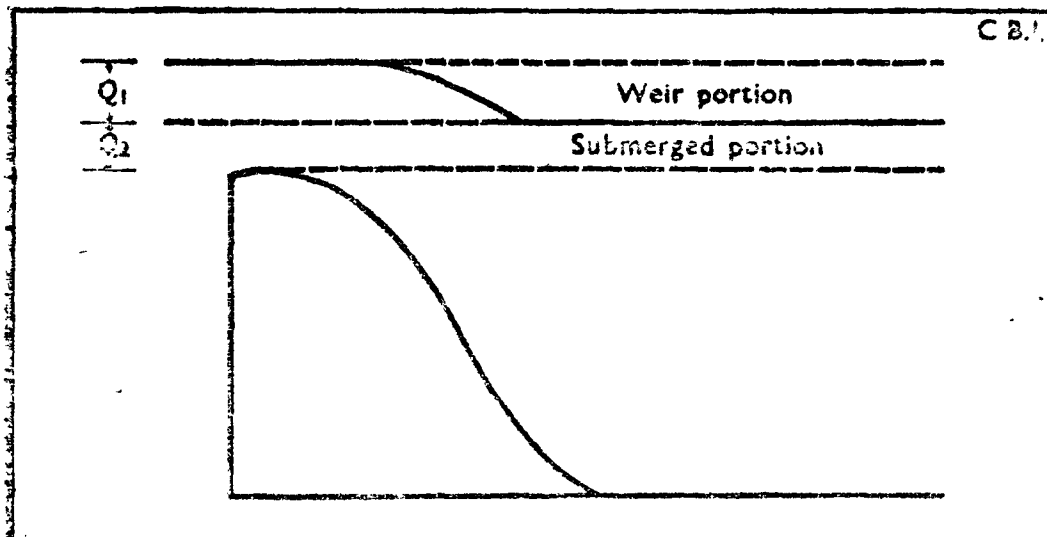
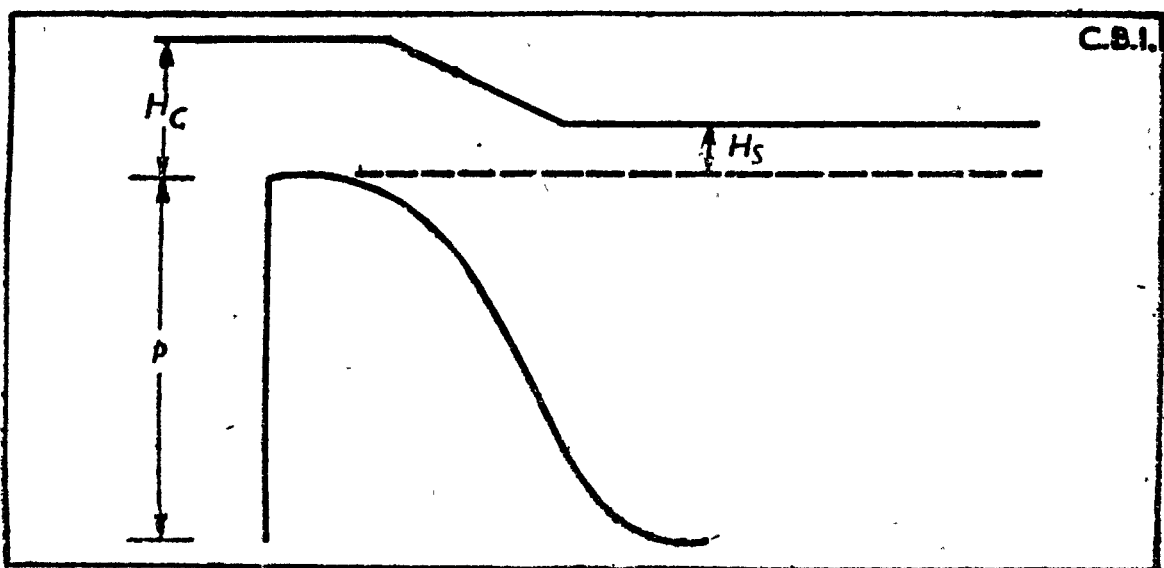


Figure 3A.8

For the purpose of the present analysis a new approach is made by computing the discharge in the submerged condition also precisely in the same way as in the free overfall condition, neglecting the tail water effect, but the co-efficient of discharge will of course have a different value, Figure 3A.8. The discharge remaining constant, as the submergence increases, the upstream depth over the crest correspondingly increases and therefore effects a diminution of the co-efficient of discharge. If the co-efficient of discharge in the submerged condition

is denoted by C the ratio $\frac{C}{C_1}$ is a measure of the effect of submergence $\frac{P}{H_0}$,

Figure 3A.9.



We have

$$Q = \frac{2}{3} C_1 \sqrt{2g} l \left\{ (h_c + h_a)^{\frac{3}{2}} - h_a^{\frac{3}{2}} \right\} \dots \dots \dots (3A.1)$$

C_1 = co-efficient of discharge in the free overfall condition.

h_a = head over crest in free overfall condition.

h_a = head due to velocity of approach.

$$\text{Again } Q = \frac{2}{3} C_2 \sqrt{2g} \cdot l \left\{ (H_c + H_a)^{\frac{3}{2}} - (H_a)^{\frac{3}{2}} \right\} \dots \dots \dots (3A.2)$$

Where Q is the same discharge in both the cases.

H_c = head due to velocity of approach, in the submerged condition.

$$= \frac{(V)^2}{2g} V_a = \frac{Q}{H_c + P} \quad \text{as shown in Figure 3A. 9. From Equations (3A.1) and (3A.2) we have}$$

$$\frac{C_1}{C_2} = \frac{(H_c + H_a)^{\frac{3}{2}} - (H_a)^{\frac{3}{2}}}{(h_c + h_a)^{\frac{3}{2}} - (h_a)^{\frac{3}{2}}} \dots\dots\dots (3A^3)$$

Thus all quantities for computing $\frac{C_1}{C_2}$ are known. These ratios are tabulated against corresponding values of $\frac{H_s}{H_c}$ in Table 3A.IV. For convenience all observations were converted to prototype values.

The functional relationship between $\frac{H_s}{H_c}$ and $\frac{C_1}{C_2}$ is shown graphically in Figure 3A.6 for the case of 14 feet and 7 feet overflow depths. Considering the curve for the 14 feet overflow depth it might be noted that the graph consists of three characteristic regions. Till $\frac{H_s}{H_c}$ is > 0.6 the value of $\frac{C_1}{C_2}$ is constant and the graph runs horizontal. In the region $\frac{H_s}{H_c}$ (0.6 to 0.9) the values of $\frac{C_1}{C_2}$ falls off from 1.0 to 0.85. Beyond $\frac{H_s}{H_c} > 0.9$ the values of $\frac{C_1}{C_2}$ falls off very rapidly.

The values are also plotted in an abridged tabular form suitable for reference in Figure 3A.6. It is seen from the table that even when the submergence was as great as 0.8 the value of co-efficient of discharge was not diminished by more than four per cent.

In Figure 3A.6 a curve is also plotted for the observations made on the broad-crested weir for 14 feet overflow. But the data were subject to much intransigence and it was not possible to draw any conclusions from them with any pretence to generalization.

The adoption of an ogee profile in places of a broad-crested weir results in considerable reduction of afflux. The co-efficient of discharge over an ogee weir increases with head and takes a value of about 4.0 (in the formula $Q = CLH^{\frac{3}{2}}$) for the head designed. This co-efficient remains unaffected for small ratios of submergence or in other words, a high degree of modularity continues even for submergence to a considerable extent. The curve in Figure 3A.5 will serve as a guide in estimating the value of Cd in submerged condition.

(4) DESIGN OF A STANDING WAVE FLUME FOR MEASURING DISCHARGE IN THE 24TH MILE DISTRIBUTARY OF THE IRWIN CANAL (4)

ABSTRACT

The discharge in the 24th mile distributary of Irwin Canal is now being measured by reading a gauge which has been calibrated by current meter gaugings. Due to non-availability of a proper site, the calibration does not seem to be correct. It may be denoting excessive discharge. The reason for this belief is due to the fact that while the discharge formula $Q=5A\sqrt{h}$ holds good to discharges through almost all other sluice vents, the discharge through this vent is connoted by the equation $Q=7A\sqrt{h}$ with similar conditions of upstream and downstream levels.

It was therefore considered desirable to note correctly the discharge of this channel as, although large quantities, are being lead on, there are still persistent complaints of scarcity of supply. If correct discharges are known it will not only facilitate to allow adequate quantities but will also accurately record any improvements that may be made to enhance the duty of this channel.

The standing wave flume has been designed to measure discharge with a bulk proportionality from two third to full supply discharge. The head after recovery has been maintained at the present at the full supply level.

DATA

| | | |
|------------------|---|--------------------------------|
| Bed width | = | 12 feet |
| Side slope | = | 1 to 1 |
| Fall | = | 3 feet per mile |
| Kutter's n | = | 0.0225 |
| Area | = | $(12+3) 3=45$ sq. feet |
| Wetted perimeter | = | $12+2\times 3\sqrt{2}$ feet |
| | = | $12+6\times 1.414=20.484$ feet |

45

$$r = \frac{45}{20.48} = 2.223 \text{ feet}$$

$$41.65 + \frac{0.00281}{3} + \frac{1.811}{0.0225}$$

0

$$= \frac{1 + 0.0225}{2.2} (41.65) + \frac{0.00281}{3}$$

$$= \frac{41.65 + 4.95 + 80.50}{0.0225} = \frac{127.1}{1.71} = 74.3$$

$$1 + \frac{0.0225}{1.48} (41.65 + 4.95)$$

(4) Hydraulic Research Station, Krishnarajasagar, Annual Report, 1947, pages 86—90.

$$v = C\sqrt{rs} = 74.3\sqrt{\frac{2.2 \times 3}{5280}}$$

$$= 74.3 \times 1.48 / 41.95 = 2.612 \text{ ft. per sec.}$$

$$Q_1 = a.v. = 45 \times 2.612 = 117.5 \text{ cusecs ;}$$

If $d = 4$ feet.

$$\text{Area} = (12 + 4) \times 4 = 64 \text{ sq. feet.}$$

$$\begin{aligned} \text{Wetted Perimeter} &= 12 + 2 \times 4\sqrt{2} \\ &= 12 + 8 \times 1.414 = 23.28 \text{ feet} \end{aligned}$$

$$r = 2.74 \text{ feet}$$

$$C = \frac{41.65 + 4.95 + 80.50}{1 + \frac{0.0225}{2.74} (46.6)} = \frac{127.1}{1 + \frac{1.048}{1.66}} = 78$$

$$v = \frac{78 \sqrt{2.74 \times 3}}{5280} = \frac{78 \times 1.66}{41.95} = 3.07 \text{ feet per second}$$

$$Q_2 = 64 \times 3.07 = 196.5 \text{ cusecs.}$$

$$117.5 = C_1 3^n \text{ and } 196.5 = C_1 4^n$$

$$\text{So } 117.5 \times 4^n = 196.5 + 3^n$$

$$\log 117.5 + n \log 4 = \log 196.5 + n \log 3$$

$$2.07004 + n \times 0.60206 = 2.29336 + n \times 0.47712$$

$$\text{i.e., } 0.12494 n = 0.22332. \text{ Therefore } n = 1.8$$

We see that the discharge in the channel Q varies generally as $C. d^{1.8}$.

For a bulk proportionality of $\frac{2}{3}$ to full supply discharge height of hump required is 0.15 as given by the equation:—

$$\text{Height of hump } d_2 - D_2 = d_1 m^n \left(1 - \frac{1 - \frac{1}{m^{\frac{1}{n}}}}{\frac{1}{m^{\frac{1}{n}}} - 1} \right)$$

where d_2 = Depth of water at the toe with free flow.

m = Any fraction of full supply discharge.

D_2 = Depth of water above the hump.

d_1 = Mean depth of water in the channel upstream.

n = Exponential of D_1

Value of the lump is taken from the graph printed on page 45 of the Poona Research Station Report for 1944, Figure 3A10.

DESIGN

Approach channel.—Its section may be secured by having revetment pitching to sides for a short length of 15 feet and then the channel lined both upstream and downstream to the required section for a length of 15 feet.

In this case $B = 12$ ft.

Bell-mouth Entrance: Length of bell-mouth entrance L_1 , from Figure 3A.11

$$CE = 12\frac{1}{2} \text{ ft.}$$

$$CD = 25/2 \sin 60^\circ = 12.5 \times 0.866$$

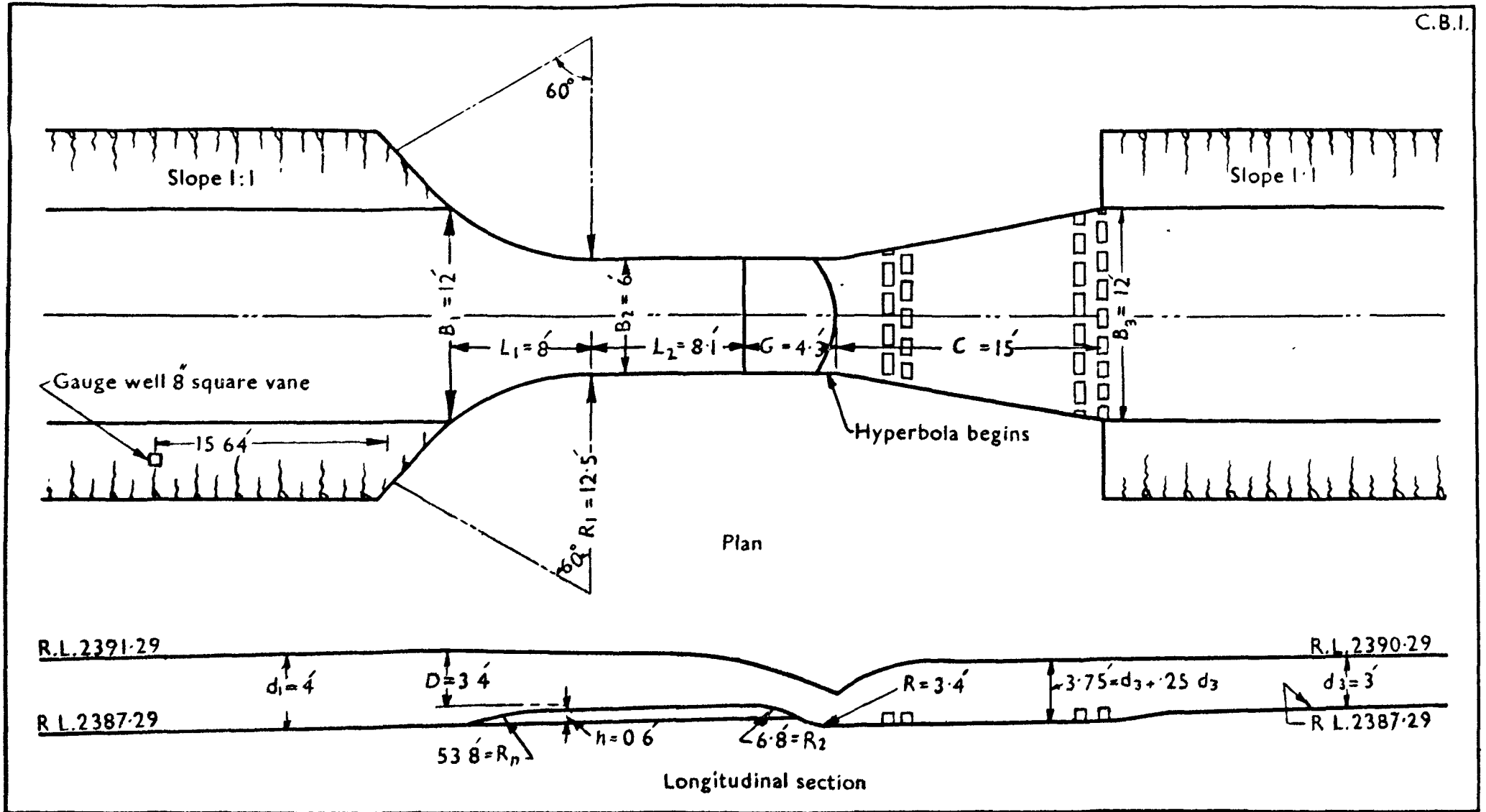


Figure 3A.10:- Showing standing wave flume for 24th Mile Distributary on Irwin Canal

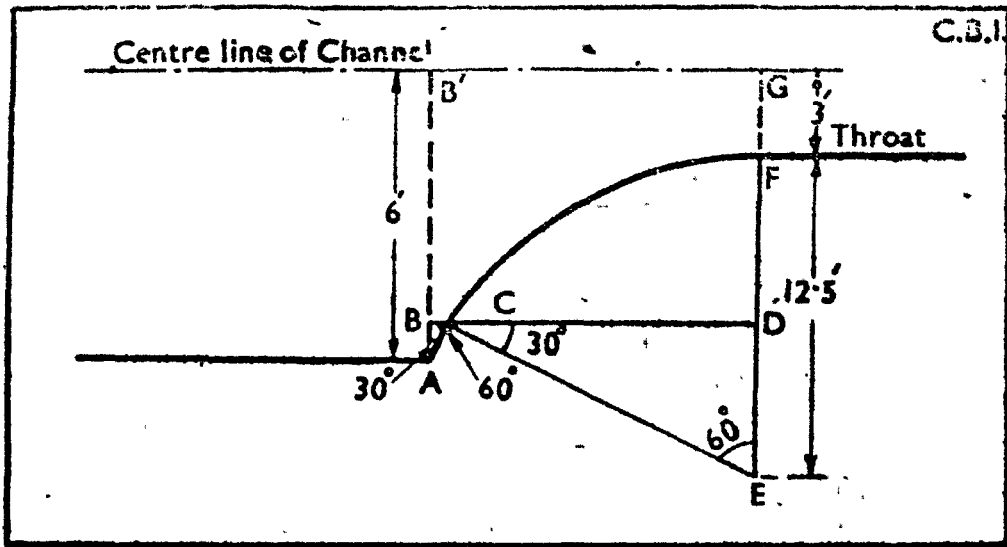


Figure 3A. 11

$$L_1 = 10.82 - 2.82 = 8 \text{ feet}$$

$$\text{and } D E = 12.5 \cos 60^\circ = 6.25 \text{ feet}$$

$$\text{or } F D = D E = 6.25 \text{ feet}$$

R_1 the radius of the side walls (side contractions)

$$= 2D^{1.5} = 2 \times 3.4^{1.5} = 12.5 \text{ feet.}$$

$$\text{Height of the hump} = 0.15 \times d = 0.15 \times 4 = 0.6 \text{ feet}$$

$$\text{or } D_1 - D = 4.0 - 3.4 = 0.6 \text{ feet}$$

$$\text{Throat width} = 6 \text{ feet } R_s = \frac{L_1^2 + h^2}{2h} = \frac{(8)^2 + (0.6)^2}{1.2}$$

$$\frac{64 + 0.6}{1.2} = \frac{64.6}{1.2} = 53.8 \text{ feet}$$

And $R = 6.8$ feet

The gauging well should be situated $2.5 D^{1.5}$ feet upstream of bell-mouth entrance $= 2.5 \times 3.4^{1.5} = 15.64$ square feet.

$$Q = 3.06 \times 6 \times (3.4)^{\frac{3}{2}} = 115 \text{ cusecs measured by the standing wave flume.}$$

DESIGN OF DOWNSTREAM PORTION

Glacis: Bed radius of curve $= 2D = 2 \times 3.4 = 6.8$ feet tangential to the sill and to a 2 to 1 downstream glacis. Similar bed curve of $R = D = 3.4$ feet, tangential to 2 : 1 glacis and bed at toe. And length of glacis is $0.69D + 2 F =$

$$0.69 \times 3.4 + 2 \times 1 = 4.3 \left(F = \frac{B_1}{B_2} = \frac{12}{12} = 1 \right)$$

The parallel sides should extend to the toe of the glacis.

$$\text{Equation of a rectangular hyperbola is a } B_x = \frac{B_0 B_3 L}{L B_3 - (B_3 - B_0) X}$$

Where L Length of cistern = 15 feet

B_0 Overfall throat width = 6 feet

B_3 Bed width of channel downstream = 12 feet

B_x Width of expanding flume at any distance X from the beginning of Expansion. Value of X varies from 0 to 15 feet

$$B_z = \frac{6 \times 12 \times 15}{15 \times 12 - (12 - 6) X}$$

$$= \frac{1080}{180 - 6 X}$$

Cistern: Length = $5 \times d_3 = 5 \times 3 = 15$ feet

The depth: Same as bed level of channel downstream at the sides and "bowed" at the centre = $3 + \frac{3}{4} = 3\frac{3}{4}$ ft. at the centre and 3 ft. at sides.

Control blocks: Two rows of staggered blocks should be spaced close together longitudinally at the distance = 3 feet from the toe of the glacis, the height of each block = $\frac{\text{Depth of water in the cistern midstream}}{9}$

$$\text{or } h = \frac{3.75}{9} = 0.42 \text{ feet}$$

Length of each block $2h = 0.42 \times 2 = 0.84$ feet

and thickness = $\frac{2}{3}h = \frac{2}{3} \times 0.42 = 0.3$ feet

Deflector: At the downstream end of the cistern the deflector should be fixed-

$$\text{Height of deflector} = \frac{\text{Depth of water in the cistern midstream}}{12}$$

$$= \frac{3.75}{12} = 0.31 \text{ feet}$$

Deflector should have gaps = the height of deflector = 0.31 foot, at intervals of 1.5 feet. Thickness of deflector should be = 0.25 feet.

DISCUSSION BY THE RESEARCH COMMITTEE

DR. N. K. BOSE introduced item (1) and said that the site at which these observations were taken was extremely inaccessible, about 50 miles from any railway head and 15 miles from any motor head. The site was so unapproachable that it was not possible to equip it properly. An attempt was made to take discharge observations by chemical method but as no proper equipment was available, this had to be abandoned. The bed of the river consists of boulders and the depth of water varied between six inches and a foot. DR. BOSE further said that a word about the factor to be applied to the surface velocity to getting the average velocity would not be out of place. In the Punjab, the usual practice was to apply a constant factor of 0.89 to the surface velocity to get the average velocity. The flow under the present circumstances was fairly turbulent. The whole depth of water acted more or less like a turbulent boundary layer and a factor of 0.75 appeared to be suitable for such cases. Opinion on this point from different workers was requested.

MR. G. SINHA said that the statistical analysis regarding item (1) was divided into three parts :—(i) Studying the effect of introducing more cross sections for the calculation of sectional area and discharge. The reach available for velocity observation was a length of 100 feet. This was divided into eight small reaches of $12\frac{1}{2}$ feet length by means of nine cross section lines. The velocity was observed by floats from the first to the fifth section lines and also from the fifth to the ninth section lines, which were called the front to mid reach and mid to rear reach, both of 50 feet length. The discharges were calculated by taking the area of waterway to be the average of the first and last section of each reach and also by taking the average of all the five sections in the reach. It was found that the discharge value based on five cross sections was systematically and significantly less than the discharge figure calculated on two cross sections; that is, the average area for five sections was less than the average area for the two sections. (ii) Weekly observations were also taken of velocities simultaneously in each of the eight small reaches of $12\frac{1}{2}$ feet. It was found that there was a significant variation amongst simultaneous observations in different reaches which was something more than the sampling fluctuation. (iii) To get the minimum flow cubic parabolas were fitted to the discharge figures separately for the two reaches as also a fifth degree curve to the whole set of discharge values. The minimum discharge obtained was about 265 cusecs.

MR. S. T. GHOTANKAR introduced item (2) and concluded that it was better either to estimate 'C' by current meter observations or by model tests instead of estimating the discharges from the Punjab notch formula which was perhaps never verified by accurate model tests but obtained only from rough discharge measurements with floats, since it was obtained years before the use of models and current meters were generally accepted.

MR. T. P. KUTTIAMMU in introducing item (3) said that the experiment described were carried out on models of weirs for determining their co-efficients of discharge. There was only one important aspect of these studies which he wanted to point out viz. the variation of the co-efficient with the degree of submersion of the weir.

The formula used for calculating the discharge over weirs in its simplest form was $Q=C.L.H^{\frac{3}{2}}$. For weirs with high co-efficient profiles, the value of C could be as high as 4.0 or 4.5 or even more. That was for free overfall conditions. When the weir was submerged, the same formula could still be used, but obviously, the co-efficient might not remain the same. These studies

showed that for submersion ratios below 0.6 there was no change in the coefficient ; for submersion ratios from 0.6 to 0.9, the fall in coefficient was less than 15 per cent. and for higher submersion ratios the fall was very considerable.

Similar results were not obtained on a broad-crested weir. The values were erratic and no dependable data could be obtained.

These results showed one advantage of the high co-efficient profile over the broad crested trapezoidal type. Another advantage was the economy and efficiency of downstream protective works possible with ogee profile weirs. The present practice in Madras was to prefer this type of design for surplus weirs of tanks and for anicuts across streams.

MR. N. S. GOVINDA RAO introduced item (4) and said that he only wanted to point out that the design which closely followed the instructions given in the Annual Report of the C. W. I. N. R. Station proved to be very costly and some other device had to be thought of.

RAO BAHADUR D. V. JOGLEKAR referring to item (4) said that if the accuracy was to be high, it should be possible to spend more on such a design than having a structure with lower accuracy.

MR. N. S. GOVINDA RAO referred to item (1) and said that the discharge observations were so conducted as to get as accurate a result as possible, in a very difficult situation. Further accuracy could have been obtained if instead of dividing the width of the waterway into five equal spans, it had been divided in such a manner as to get regions of uniform flow. The presence of rocky boulders just immediately after the rear section must have induced ponding up of the flow in the river in which case it should have been difficult to determine the reduction co-efficient to be adopted for multiplying the surface velocity to get the average velocity. The co-efficient of 0.75 adopted seems to be reasonable in view of the ponding effect referred to.

Probably if the observations were confined only to the distance between the front and mid section it might have given more accurate results.

MR. S. L. MALHOTRA said that for a churning section the co-efficient should be taken as 0.8 or even higher.

DR. N. K. BOSE pointed out that the selection of the co-efficient depended upon one's judgment.

MR. S. L. MALHOTRA said that the velocity at the top was always more uniform than at the bottom.

MR. R. D. SONDHI said that in turbulent flow the surface flow was so irregular that no reliable measurement of linear velocity was possible. So long violent turbulence was not there, it was possible to find some correlation between the surface velocity and the mean velocity.

MR. N. S. GOVINDA RAO said that as the turbulence was only on the surface Dr. Bose was quite right in taking the co-efficient as 0.75.

DR. N. K. BOSE said that he took 0.75 as the co-efficient from the velocity in the boundary layer.

RAO BAHADUR D. V. JOGLEKAR described the progress made by the sub-committee—to draft instructions on (a) standard methods of rating meters and (b) discharge measurements and said that Mr. Framji was going to rewrite the draft when he was transferred. The sub-committee had gone through the draft and Mr. Govinda Rao had undertaken to revise the same.

MR. S. L. MALHOTRA said that it seemed that in the South a boat was never used for discharge measurements.

MR. T. S. VENKATARAMA IYER said that boats were being used in Madras.

RAI BAHADUR M. C. BIJAWAT said that discharges observed by means of cradles were more accurate than those observed from boats.

MR. S. L. MALHOTRA said that cradles could be used only for rivers with smaller widths and not for rivers which were miles wide as the Punjab rivers.

He also suggested that before taking up the writing of the draft Mr. Govinda Rao should visit discharge sites in the North and Mr. Sondhi should visit discharge sites in the South.

THE PRESIDENT agreed with Mr. S. L. Malhotra's suggestion.

MR. S. L. MALHOTRA enquired the difference between methods of velocity observation in rigid and non-rigid channels.

MR. R. D. SONDHI said that the equipments differed in North and in South and that methods should be standardised.

It was decided to keep the subject on the Agenda.

DISCUSSION BY THE BOARD

THE SECRETARY described the work done at the Research Committee meeting and said that the cost of the current meter evolved by Mr. Govinda Rao was about Rs. 350. A request had been made to the Chief Engineers of East Punjab, Madras, West Punjab and Central Waterways, Irrigation and Navigation Research Station to obtain the instrument and see if it required further improvement. The Chief Engineers of Bombay, Bihar and Orissa also expressed a desire to obtain the instrument from Mr. Govinda Rao and to try it in their provinces.

RAI BAHADUR C. L. HANDA intimated that they had developed an organisation for repairs to current meters and they could assist other provinces in this respect. Also they were perfecting a new method of taking discharge, observation from one bank of a river. He hoped to show photographs *etc.* at the next meeting. It would not be difficult to manufacture this instrument in India.

THE SECRETARY intimated that a sub-Committee appointed by the Board was working on compiling a draft to draw standards for (a) calibration methods for current meters, and (b) discharge observations and equipment. At the Research Committee meeting it was suggested that as practice differed in the North and in the South, it would be advantageous that Mr. Govinda Rao should visit discharge sites in the North and Mr. R. D. Sondhi in the South before they finalised the draft. Their respective Chief Engineers were addressed accordingly and they had accorded sanction for the visits by their respective officers.

4A. Sampling of Bed and Suspended Load

PRELIMINARY NOTE

This subject came on the agenda as a separate item in 1942.

At the 1946 informal winter meeting of the Research Committee a sub-committee comprising Mr. K. K. Framji, Mr. K. M. Bhatia and Rai Bahadur B. K. Kapoor was formed to draft standard instructions on the determination of detritus load in rivers and canals. The sub-committee has since completed its work and the draft of the publication has been circulated to all research organizations, and some individuals. The sub-committee as it now stands comprises Mr. K. K. Framji, Dr. N. K. Bose and Shri S. L. Malhotra. The committee will meet just before the forthcoming annual meeting of the Research Committee to consider the comments received from various officers and to bring the publication into its final form.

The following items were discussed at the 1947 Research Committee meeting.

- (1) Suspended and bed load characteristics of the river Brahmaputra at the railway bridge site near Jogigopa.
- (2) Experiments on measurement of suspended load.
- (3) Experiments on measurement of bed load.
- (4) Silt surveys.
- (5) Determination of detritus load in rivers and canals. (Draft of Central Board of Irrigation Publication).

cent Literature

(1) GRIFFITH, W. M.—Further notes on silt transportation. Journal of Institution of Civil Engineers. November 1946.

(2) AUDEN, J. B.—Siltation on the Damodar Basin and Sand—stowing. Geological Survey of India, November 1946.

(3) ALGER—BAGNOLD, B. R.—Sand movement by waves, some small scale experiments with sand of very low density. Journal of Institution of Civil Engineers, No. 4, February 1947.

(4) DENEL P., Director des Recherches Neyrpic, Grenoble. —Suspension. The second meeting of the International Association for Hydraulic Structures Research, Stockholm, 1948, Paper No. 30.

THE YEAR'S WORK

The following items were discussed at the 1948 meeting of the Research Committee :—

- (1) Silt behaviour and silt analysis of the Damodar river and the Mor river.
- (2) Comparative analysis of sand by Puri Sand Meter and Air Sand Meter.
- (3) Silt load in flood water samples.
- (4) Investigations of the suspended sediment load of the Mahanadi and the Kosi rivers.

(1) SILT BEHAVIOUR AND SILT ANALYSIS OF THE DAMODAR AND MOR RIVERS ⁽¹⁾

This year silt analysis was carried out on the sites as usual and in addition some other observations were also undertaken.

(1) Efforts were made to find the silt distribution at different depths. Experiment on this line was carried out at Barakar (Asansol), Ramgarh and Barakar (Giridih). There were difficulties in taking sampling at different depths. These are being gradually overcome.

(2) Water samples were also collected from different spans of the bridge to find if there is any difference between them. These experiments were conducted at Ramgarh, Barakar (Asansol) and Barakar (Giridih).

(3) In the Mor Valley analysis were extended to find the percentage of silt within the range below 0.05 mm., between 0.05 mm. to 0.6 mm., and above.

The maximum silt intensity observed during the year at the different sites in the Damodar Valley are given on Table 4A I. Table 4A II gives the average, maximum and minimum silt intensities for each of the monsoon months (June to October) for these sites.

Tables 4A III and 4A IV give the corresponding data for the sites on the Mor, Dwarka and Brahmani rivers.

TABLE 4A. I

Maximum silt intensities at different sites at the Damodar Valley for the year 1947.

| Site | Date | Time | Maximum silt in gms./litre | Silt above 0.6 mm. in diameter |
|-----------------------|----------------------|-----------|----------------------------|--------------------------------|
| Barakar-Giridih.. .. | August 1, 1947 .. | 3-30 p.m. | 14.08 | 0.693 |
| Usri | June 8, 1947 | 4 p.m. | 13.08 | 0.512 |
| Barakar-Asansol | August 1, 1947 | .. | 9.81 | 0.074 |
| Barhi | June 9, 1947 | 9 a.m. | 6.05 | 0.178 |
| Ramgarh | September 3, 1947 .. | 4 p.m. | 5.33 | 0.198 |
| Sudamdih | August 9, 1947 | .. | 4.56 | 0.12 |
| Chas Road | July 17, 1947 | .. | 7.65 | 0.11 |
| Bokharo-Danea | June 24, 1947 | 6 p.m. | 8.31 | 0.014 |

(1) River Research Institute, West Bengal, Annual Report 1947, pages 51—53,

TABLE 4A. II

Average maximum and minimum silt intensities at Damodar sites.

| Site | June | | | July | | | August | | | September | | | October | | |
|--------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|-----------|---------|---------|---------|---------|---------|
| | Average | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum |
| Barakar-Giridih .. | 1.147 | 8.31 | 0.017 | 1.869 | 10.55 | 0.066 | 2.127 | 14.08 | 0.07 | 0.971 | 5.03 | 0.02 | 0.954 | 3.37 | .. |
| Ussi .. | 2.595 | 13.08 | .. | 2.093 | 11.58 | 0.02 | 1.142 | 5.36 | 0.04 | 0.851 | 5.11 | 0.42 | 0.616 | 5.38 | 0.001 |
| Brakar-Asansol .. | 1.86 | 6.09 | 0.41 | 1.56 | 6.60 | 0.08 | 1.15 | 9.31 | 0.07 | 0.81 | 3.53 | 0.019 | 0.13 | 2.48 | 0.008 |
| Chas Road .. | 0.79 | .. | .. | 1.00 | 7.65 | 0.11 | 1.30 | 6.51 | 0.06 | 0.55 | 1.92 | 0.013 | 0.44 | 1.79 | 0.022 |
| Sudamdih .. | 0.99 | .. | .. | 1.00 | 3.51 | 0.17 | 1.29 | 4.56 | 0.12 | 0.71 | 3.69 | 0.100 | 0.62 | 1.18 | 0.0015 |
| Ramgarh .. | 0.657 | .. | .. | 1.436 | .. | .. | 1.46 | .. | .. | 1.085 | .. | .. | 0.949 | .. | .. |
| Bokharo .. | 1.160 | .. | .. | 0.357 | .. | .. | 0.570 | .. | .. | 0.325 | .. | .. | 0.131 | .. | .. |
| Barhi .. | 0.99 | 0.05 | .. | 0.57 | 2.55 | 0.09 | 0.506 | 2.99 | 0.05 | 0.318 | 2.28 | 0.006 | 0.270 | 3.57 | 0.002 |

SAMPLING OF BED AND SUSPENDED LOAD

TABLE 4A. III

Maximum silt intensities at different sites in the Mor Valley for the year 1947.

| Site | Date | Time | Maximum silt in gms./litre | Silt above 0.6 mm. in diameter in gms./litre |
|------------------|---------------------|-----------|----------------------------|--|
| Messenjore | July 22, 1947 | 12 noon | 5.0313 | 0.001 |
| Sainthia | July 21, 1947 | 6-30 p.m. | 3.1313 | 0.010 |
| Dwarka | July 31, 1947 | 5 p.m. | 5.2714 | 3.25 |
| Brahmani | June 18, 1947 | 4 p.m. | 4.7813 | 0.0009 |

TABLE 4A. IV

Average maximum and minimum silt intensities (in gms. litre) at Mor Sites.

| Site | June | | | July | | | August | | | September | | | October | | |
|------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|-----------|---------|---------|---------|---------|---------|
| | Average | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum |
| Messenjore | .. | .. | .. | 0.85 | 5.03 | 0.09 | 0.59 | 2.05 | 0.09 | 0.46 | 2.53 | 0.22 | 4.60 | 6.24 | 6.005 |
| Brahmani | 0.68 | 4.78 | .02 | 0.96 | 4.14 | 0.048 | 0.44 | 1.98 | 0.03 | 0.34 | 1.76 | 0.11 | 0.68 | 1.56 | 0.01 |
| Sainthia | .. | .. | .. | 0.54 | 3.13 | 0.008 | 0.25 | 1.005 | 0.04 | 0.49 | 0.53 | 0.01 | 0.18 | 1.65 | 0.003 |
| Dwarka | .. | .. | .. | 0.60 | 5.27 | 0.005 | 0.28 | 1.15 | 0.018 | 0.23 | 1.56 | 0.008 | 0.13 | 2.05 | 0.007 |

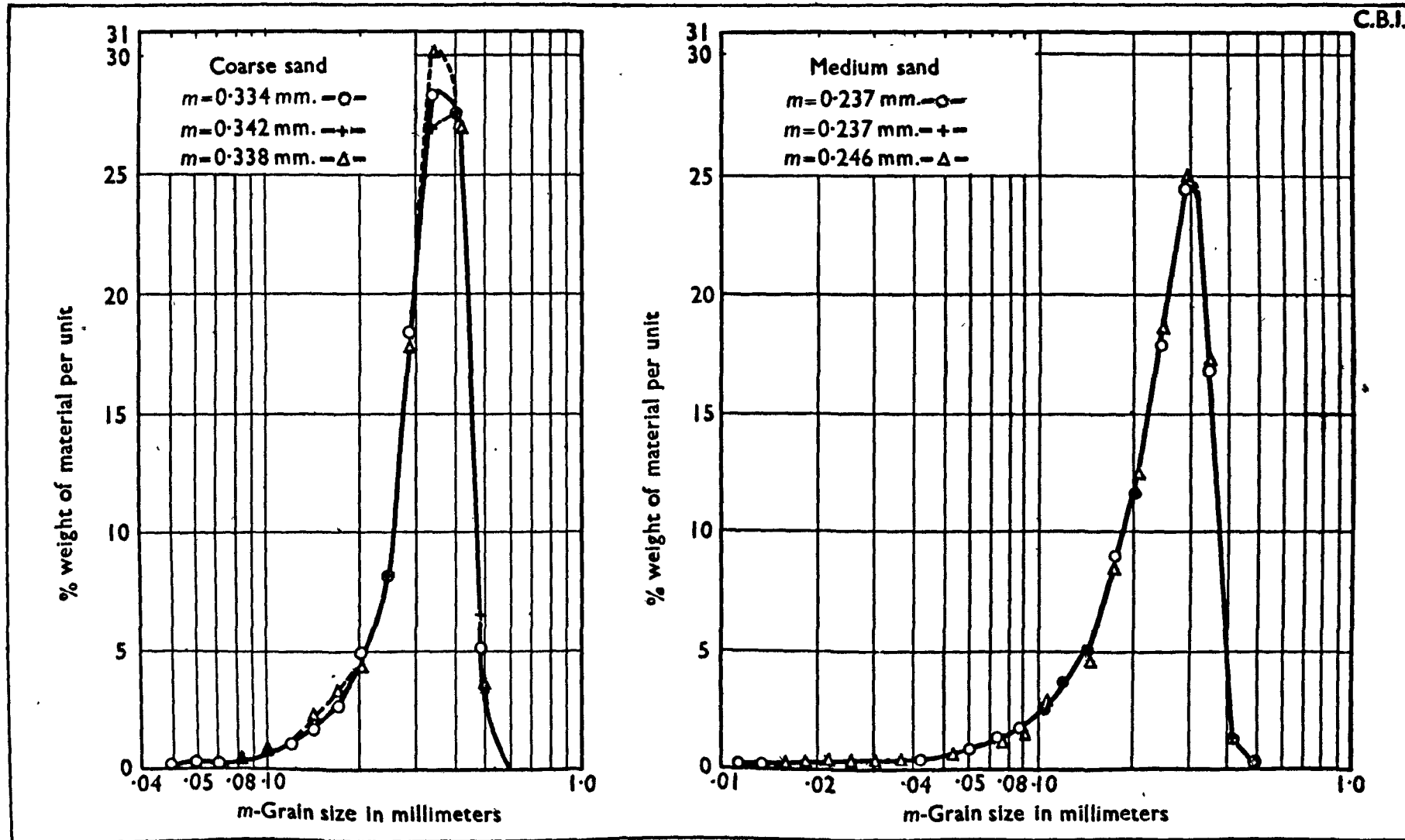


Figure 4A.1:- Showing size distribution curves of coarse & medium sands (By Puri sandmeter)

(2) COMPARATIVE ANALYSIS OF SAND BY PURI SAND-METER AND AIR SAND-METER⁽²⁾

ABSTRACT

Experiments described below were carried out to see if a similar distribution was obtained when the same sample was analysed by the two methods

EXPERIMENTS

Two samples of sands—one coarse and one medium, from the Indus at Sukkur and the Yamuna at Delhi respectively—were used for this analysis.

The coarse sand had a specific gravity 2.66 and the medium sand had a specific gravity 2.62. Each analysis was repeated three times with the same sand maintaining all the conditions of air sand-meter the same (*viz.*, velocity, and sand charge *etc.*). It was found that, even if the analysis was repeated several times, the air sand meter ⁽³⁾ gave almost exactly the same results.

The distribution curves of medium sand and coarse sand show that almost all points lie on the same curve and the results in Table 4A-V show that there is only a slight variation between the two results.

TABLE 4A. V.

Analysis by Air sand-meter.

| No. of observations | Air speed indicator at 31° | | Air speed indicator at 32° | |
|---------------------|--|--|-------------------------------------|-------------------------------------|
| | Sukkur coarse sand (Specific Gravity=2.66) Diameter in mm. | Yamuna medium sand (Specific Gravity=2.62) Diameter in mm. | Sukkur Coarse Sand. Diameter in mm. | Yamuna Medium Sand. Diameter in mm. |
| 1 | 0.352 | 0.252 | 0.341 | 0.243 |
| 2 | 0.353 | 0.256 | 0.343 | 0.246 |
| 3 | 0.348 | 0.253 | 0.340 | 0.245 |
| Mean of three .. | 0.351 | 0.254 | 0.341 | 0.245 |
| | ±0.0020 | ±0.0018 | ±0.002 | ±0.0013 |
| | Or ± 0.6 per cent. | ±0.7 per cent. | ±0.59 per cent. | ±0.53 per cent. |

A similar test with the Puri sand meter was also done with the same sand samples. Each analysis was again repeated three times with special care to eliminate personal error. It was found that in the case of coarse sand there was some variation between the results; but in the case of medium sand there was practically no difference between the first two observations.

The distribution curves in Figure 4A. I show that all the points overlap each other in the case of medium sand, while there is some variation in curves and also in 'm' value in the case of coarse sand.

⁽²⁾ Central Waterways, Irrigation and Navigation Research Station, Poona, Annual Report, Technical, 1947, pages 26-27.

⁽³⁾ Otto, Gauge H. and Rouse, Hunter. Wind tunnel classifier for sand and silt, Civil Engineering, July 1939, Vol. 9, No. 7, pages 414-415. Apparatus modified at Poona.

TABLE 4A. VI
Analysis by Puri sand meter.

| No. of observations | Sukkur coarse sand (Specific Gravity 2.66) minimum | Yamnua at Delhi medium sand (Specific Gravity 2.62) minimum |
|---------------------|--|---|
| 1 | 0.3340 | 0.2370 |
| 2 | 0.3420 | 0.2370 |
| 3 | 0.3280 | 0.2460 |
| Mean of three | 0.3350 | 0.2400 |
| | ± 0.0054 | ± 0.0042 |
| | or ± 1.6 per cent | or ± 1.75 per cent |

The summation curves of these two sands show the difference between the two observations. In case of the Puri sand meter we do not get the distribution curve directly; but by drawing a mean smooth summation curve we can get the distribution percentage of sand particles with the diameter interval of the multiple of (2)¹.

In the Air sand meter, there is little chance of any personal error and any variations in the distribution are due to air eddies which can be minimized, if not altogether eliminated.

Analysis by Puri sand meter is subject to the following sources of errors :—

- (1) The whole sample taken for analysis is dropped all together from the top with the result that there may be collision of particles and some coarse particles may drag along with them some fine particles lessening their velocity; but in the case of the Air sand meter, the particles on falling through a slit in the funnel (3 mm.) get separated by air and there is no chance of collision.
- (2) The time of interval of collection of particles in the troughs down to 0.24 mm. diameter is very small (< 4 seconds) so that some error is inevitable in bringing the collecting troughs below the vertical brass tube within such short intervals; on the other hand, the sand in the Air sand meter, when once dropped in the funnel is automatically graded in the various compartments.
- (3) The distribution percentage of the particles at a diameter interval of (2)¹ is obtained after drawing the mean summation curve, which may itself involve some personal bias; in the case of the Air sand meter, however, we get the distribution curves directly; thus, there is no personal bias, and much time is saved.

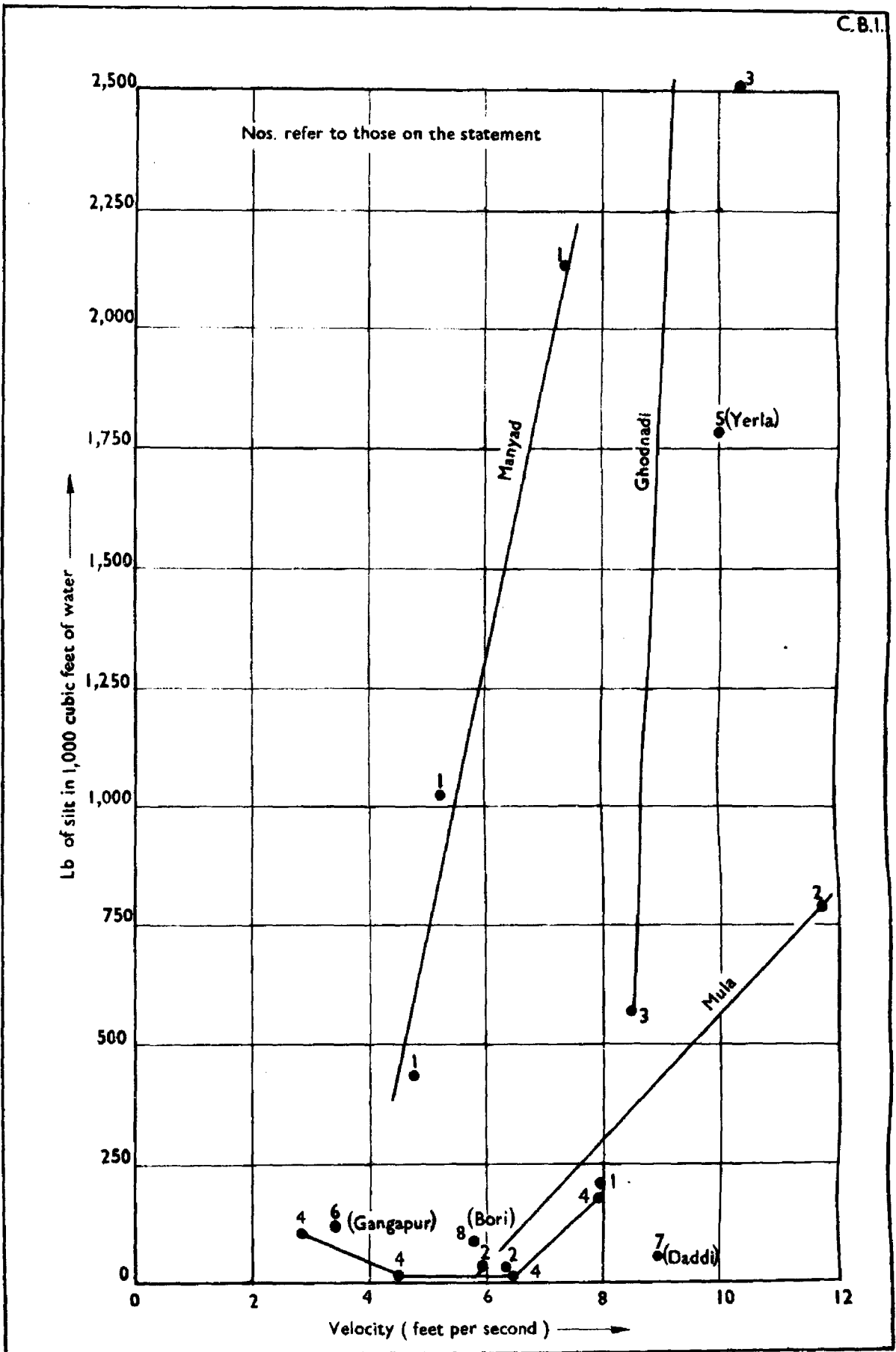


Figure 4 A.2:- Showing the relation of silt with velocity for some of the Deccan and Karnatak River

(3) SILT LOAD IN FLOOD WATER SAMPLES⁽⁴⁾**ABSTRACT**

Bombay Government have issued orders for collecting data regarding silting of tanks and reservoirs. Samples were received in the laboratory of this Division from the Poona River Gauging Sub-Division and the Executive Engineer, Sholapur Division, for estimating the amount of silt in flood water. The data have been considered in this note.

Table 4A. VII gives the results about gauges, velocity, discharge, silt and conductivity *etc.* Samples were received from the River Gauging Sub-Division on four occasions:—

- (i) In November, 1946, when there were floods in the Manyad, the Mula and the Ghodnadi,
- (ii) In August and September, 1947, from all the rivers when there were floods,
- (iii) In January and February, 1947, when there were no floods.

Provided there is a large amount of erodable silty material in the catchment of a river, silt is expected to vary directly with velocity. In Figure 4A. 2, silt (lbs. per 1,000 cft., of water) has been plotted against velocity. It shows that the amount of silt increases rapidly with velocity in the case of the Manyad and the Ghodnadi. It increased in the Mula River but at a very slow rate, and the water is mostly clear.

The Yerla is said to bring abruptly silt floods of short duration and the sample tested supports this view. The Krishna passing through rocky bed had little silt and the water was clear. Waters of the rest of the rivers *viz.*, the Godavari, the Ghataprabha, the Bori and the Tapti were clear even during floods.

Conductivity figures showing the amount of soluble salts in waters are interesting. The Ghataprabha and the Mula have sweet waters (conductivity 50 and 119 respectively; water upto 300 conductivity is considered sweet water). The water of the Yerla in the Satara District is saline (700 conductivity). The Manyad (East Khandesh,) and the Tapti (Surat District) give high conductivity occasionally (630 and 850 respectively).

Silt content in the flood waters of the Ekruk and the Hotgi tanks (in the Sholapur District) is negligible. The water has however a high conductivity (400).

⁽⁴⁾ Poona Irrigation and Research Division, Poona, Public Works Department Bombay, Annual Report, 1947, pages 6—10.

TABLE 4A. VII

Statement showing velocity, Discharge silt content etc., in river waters 1947.

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| Serial No. | River | Date | Gauge | Velocity in feet per second | Discharge in cusecs | Silt — load (weight in lb. of 1 cubic foot of silty water) | Weight of dry silt per 1,000 cubic feet of silty water | Conduc- tivity | Remarks |
|--------------------------|---|--------------------------|-------|--------------------------------------|---------------------------|--|---|-------------------|--|
| 1 | Manyad River at Saygaon (District : East Khandesh) | (a) November 19, 1946 | 7.25 | 8.00 | 10,068 | 62.601 | 201.450 | 250 | |
| | | (b) January 1, 1947 .. | 3.50 | 1.80 | 1,850 | 62.837 | 437.100 | 630 | |
| | | (c) September 23, 1947 | 4.05 | 5.26 | 2,632 | 63.416 | 1,016.120 | 340 | |
| | | (d) September 8, 1947 .. | 7.25 | 7.86 | 9,897 | 64.545 | 2,145.010 | 450 | |
| | Mula at Chas (District: Ahmedna- gar) | (a) November 19, 1946 | 9.75 | 5.98 | 8,484 | 62.426 | 26.980 | 155 | Maximum flood at 1 p. m. on 19-11-46 Gauge 23.4. |
| | | (b) August 24, 1947 .. | 8.85 | 5.91 | 7,551 | 62.436 | 36.130 | 100 | |
| | | (c) August 30, 1947 .. | 10.30 | 6.38 | 9,614 | 62.403 | 3.115 | 100 | |
| Mula at Chikalthan | (a) November 19, 1946 | 19.50 | 11.67 | 34,139 | 63.196 | 796.200 | 410 | H.F.L.-34' | |
| 3 | Ghod river at— Kalamb .. (Poona Distt.) | (a) July 17, 1947 .. | 18.45 | 10.39 | 33,590 | 66.713 | 4,313.690 | 410 | High flood. |
| | | (b) August 30, 1947 .. | 13.10 | 8.46 | 19,730 | 62.794 | 574.410 | | |

| | | | | | | | | | |
|-----------|--|------------------------|----------------|-------|--------|---------|-----------|--------|-----|
| 4 | Krishna river (Satara District) at Bhogaon | (i) November 18, 1946 | 6.15 | 4.47 | 1,630 | 62.408 | 8.185 | 230 | |
| | | (ii) July 17, 1947 | 12 | 7.88 | 8,917 | 62.574 | 174.440 | 170 | |
| | | (iii) August 17, 1947 | 3.43 | 2.82 | 424 | 62.509 | 109.026 | 275 | |
| | | (iv) August 23, 1947 | 8.15 | 6.54 | 3,886 | 62.408 | 8.099 | 110 | |
| At Kusnal | (i) October 30, 1946 | 3.60 | Not observed | .. | 62.538 | 137.990 | 300 | | |
| | (ii) November 22, 1946 | Hot weather | .. | .. | 62.728 | 377.820 | 430 | | |
| 5 | Yerla at Ambawade, (Satara District) | (i) November 8, 1946 | .. | .. | .. | 64.089 | 1,888.517 | 750 | |
| | | (ii) August 17, 1947 | 5.95 | 10.00 | 14,360 | 64.192 | 1,791.766 | 650 | |
| 6 | Godavari at Gangapur (Nasik District) | November 13, 1946 | 3.75 | 3.50 | 2,219 | 62.493 | 92.515 | 250 | |
| 7 | Ghatprabha at Daddi, (District: Belgaum) | July 16, 1947 | 11.3 | 9.00 | 33,630 | 62.451 | 51.086 | 50 | |
| 8 | Bori river at Purampada | August 19, 1947 | 7.40 | 5.84 | 5,790 | 62.464 | 63.671 | 200 | |
| 9 | Tapti at Tashkoda (Surat District) | (i) November 20, 1946 | .. | .. | 437 | 62.510 | 109.960 | 300 | |
| | | (ii) February 10, 1947 | .. | .. | 38,741 | 62.794 | 394.230 | 850 | |
| 10 | Ekruk tank (Sholapur District) | September 1947 | 1/8th distance | .. | .. | .. | 62.412 | 11.837 | 300 |
| | | | 1/4 distance | .. | .. | .. | 62.412 | 11.837 | 325 |
| | | | 5/8th distance | .. | .. | .. | 62.438 | 38.003 | 400 |
| | | | Mean | .. | .. | .. | 62.420 | 20.559 | |
| 11 | Hotgi tank (Sholapur District) | September 1947 | 1/8th distance | .. | .. | .. | 62.416 | 16.198 | 400 |
| | | | 1/4 distance | .. | .. | .. | 62.412 | 12.460 | 400 |
| | | | 5/8th distance | .. | .. | .. | 62.406 | 6.230 | 400 |
| | | | Mean | .. | .. | .. | 62.412 | 11.629 | |

Silt load data obtained previously for the Deccan rivers are given in Table 4A. VIII.

TABLE 4A. VIII

| Rivers | | | | | | | 1938-39 | 1939-40 |
|----------|----|----|----|----|----|----|---------|---------|
| Mutha | .. | .. | .. | .. | .. | .. | 62.5 | 62.3 |
| Nira | .. | .. | .. | .. | .. | .. | 62.95 | 62.4 |
| Karha | .. | .. | .. | .. | .. | .. | 63.76 | 62.5 |
| Pravara | .. | .. | .. | .. | .. | .. | .. | 62.3 |
| Godavari | .. | .. | .. | .. | .. | .. | 63.7 | 62.4 |

These figures have been exceeded by the data obtained this year in respect of the Manyad, the Mula (at Chikalthan) the Ghodnadi and the Yera Rivers.

(4) INVESTIGATIONS OF THE SUSPENDED SEDIMENT LOAD OF THE MAHANADI AND THE KOSI RIVERS

ABSTRACT

Information on the suspended sediment load of water of a river is very helpful in assessing the rate of silting up of the reservoir after the completion of the dam. On the basis of that information it also becomes possible to designate the extent of dead storage of the pond.

Investigations of the suspended sediment load *etc.* of the Mahanadi and Kosi rivers have, therefore, been carried out.

THE MAHANADI RIVER

(A) (i)—*Suspended Sediment Load*

Water samples were collected daily from the Mahanadi river at Sambalpur discharge site at 0.6 depth from a number of points along the cross section of the river. Sometime later similar work was also started at the Kaimandi discharge site (proposed Naraj Dam site) on the same river. The usual analysis of the suspended sediment load in the water samples ; *i.e.*, separating into three trades ; coarse (above 0.2 mm), medium (0.2 mm to 0.075 mm) and fine (below 0.075 mm) and separately estimating each fraction was carried after the samples were collected.

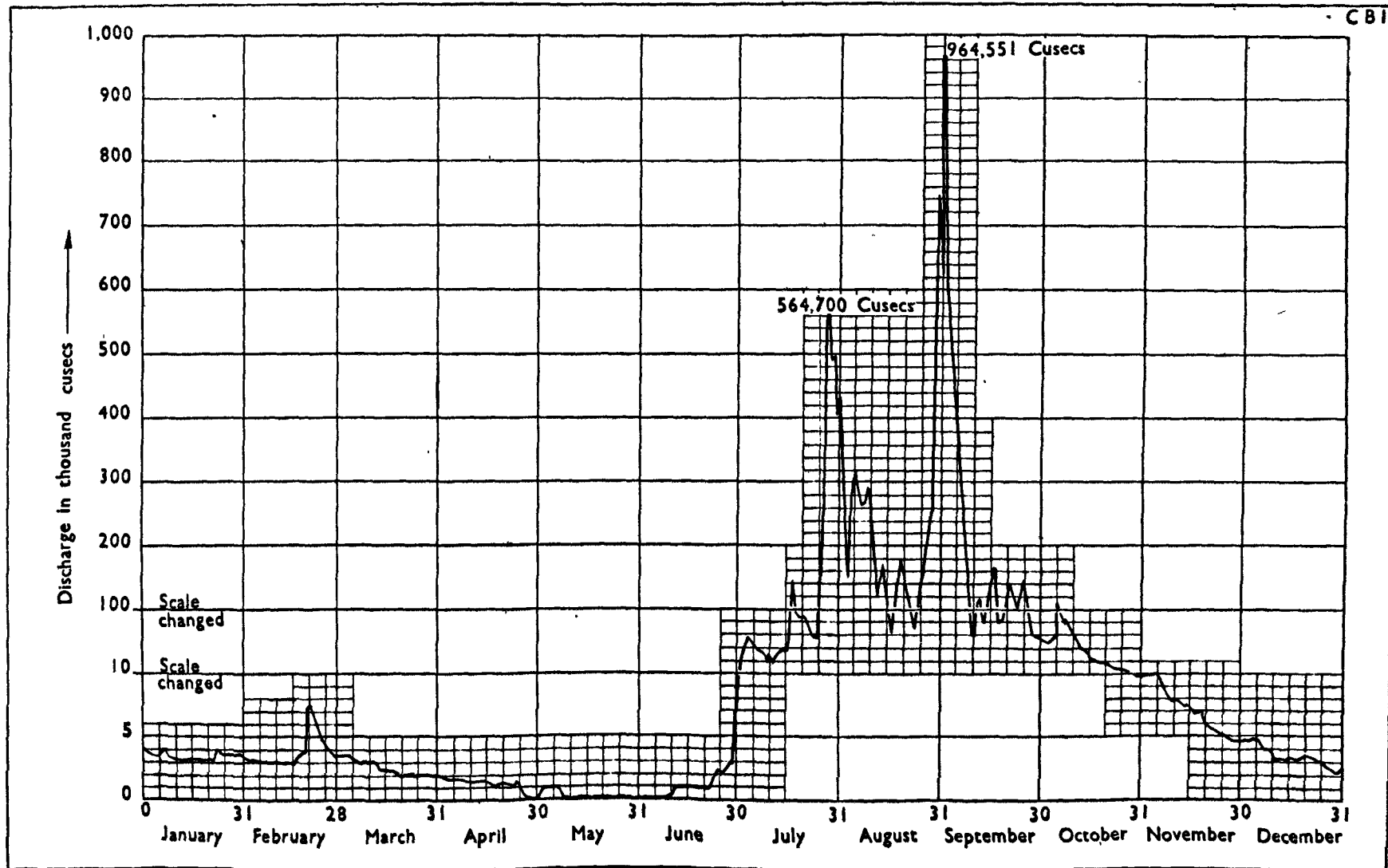


Figure 4A.3:- Showing daily discharge curve for the year 1947 [Mahanadi River]

Figure 4A.3 represents the curve based on the daily discharge figures of the Mahanadi river at Sambalpur during 1947. The estimated amounts of the sediment load of each category and the river discharge along with their respective cumulative totals for each month of the year are given in Table 4A.IX.

TABLE 4A. IX

| Month | Total discharge (cusecs) | Cumulative discharge (cusecs) | Sediment load for the whole month (acre feet) | | | | Cumulative |
|-----------------|--------------------------|-------------------------------|---|------------|-----------|-----------|------------|
| | | | Coarse | Medium | Fine | Total | |
| January | 106,020 | .. | <i>Nil</i> | <i>Nil</i> | 49.26 | 49.26 | |
| February | 106,102 | 212,122 | .. | 0.08 | 33.91 | 33.99 | 183.25 |
| March | 78,475 | 290,597 | .. | <i>Nil</i> | 19.26 | 19.26 | 102.51 |
| April | 40,241 | 330,838 | .. | .. | 6.16 | 6.16 | 108.67 |
| May | 15,385 | 346,223 | .. | .. | 0.75 | 0.75 | 109.42 |
| June | 34,674 | 380,897 | 0.09 | .. | 9.89 | 9.98 | 119.40 |
| July | 4,209,832 | 4,590,729 | 1,237.00 | 1,803.24 | 6,900.19 | 9,940.43 | 10,559.83 |
| August | 7,135,437 | 11,726,166 | 1,682.62 | 1,631.52 | 11,183.44 | 14,497.88 | 24,557.41 |
| September | 6,129,403 | 17,855,569 | 773.92 | 924.89 | 6,295.70 | 7,994.51 | 32,551.92 |
| October | 1,384,535 | 19,240,104 | 27.69 | 23.42 | 612.93 | 664.03 | 33,215.95 |
| November | 222,951 | 19,463,055 | <i>Nil</i> | 0.21 | 13.66 | 13.87 | 33,229.81 |
| December | 126,781 | 19,589,836 | <i>Nil</i> | 0.05 | 5.48 | 5.53 | 33,235.31 |
| | | | 3,721.23 | 4,383.50 | 25,130.63 | | |

The results given by the above Table are diagrammatically represented in Figures 4A.4 and 4A.5. Figure 4A.4 gives the cumulative figures of discharge in cusecs and the total sediment load and also those for each of the three sizes of sediment particles for each month of the year. Figure 4A.5 represents, on the other hand, the variation in the total monthly river discharge and the suspended sediment load from month to month in the year.

It was considered of interest to study the rate of variation of the sediment load with varying discharges of the river. Therefore, the value of (i) total sediment load (ii) coarse and medium sediment and (iii) fine sediment have been plotted against various discharge figures in Figures 4A.6—4A.11 respectively. For ease in plotting the sediment load carried by the river discharges upto and below 100 thousand cusecs and those for discharges above 100, thousand cusecs have been plotted separately, i.e., Figures, 4A.6, 4A.8 and 4A.10 represent the former and Figures 4A.7, 4A.9 and 4A.11 the latter.

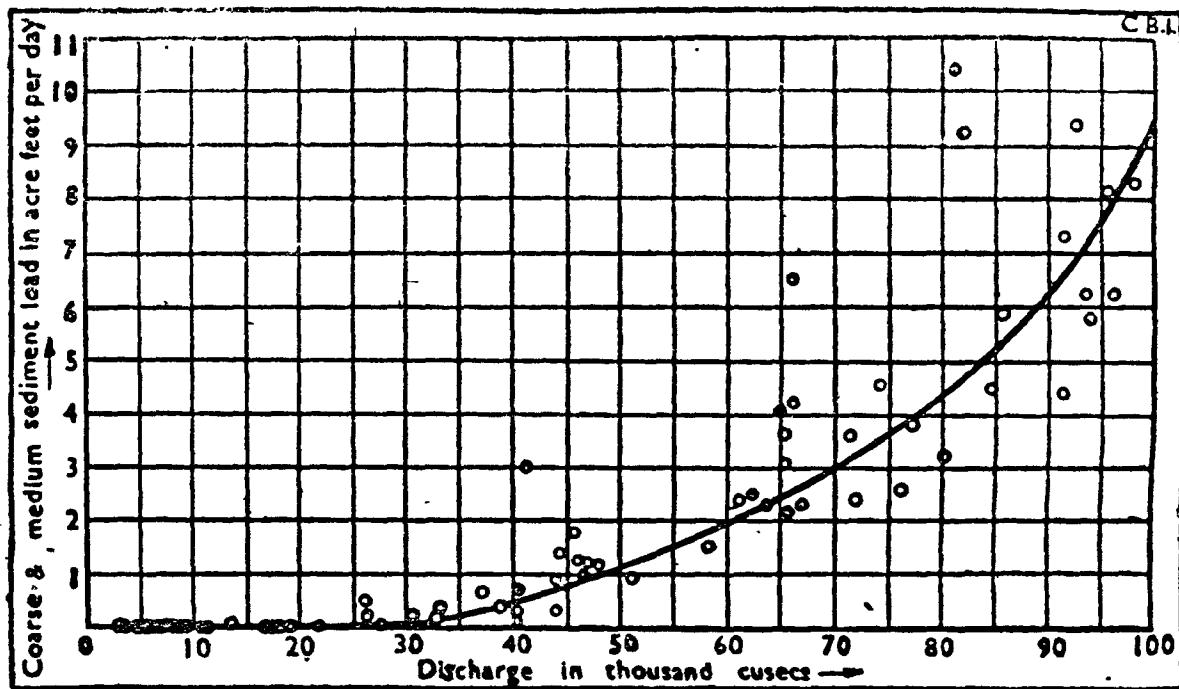


Figure 4A.8

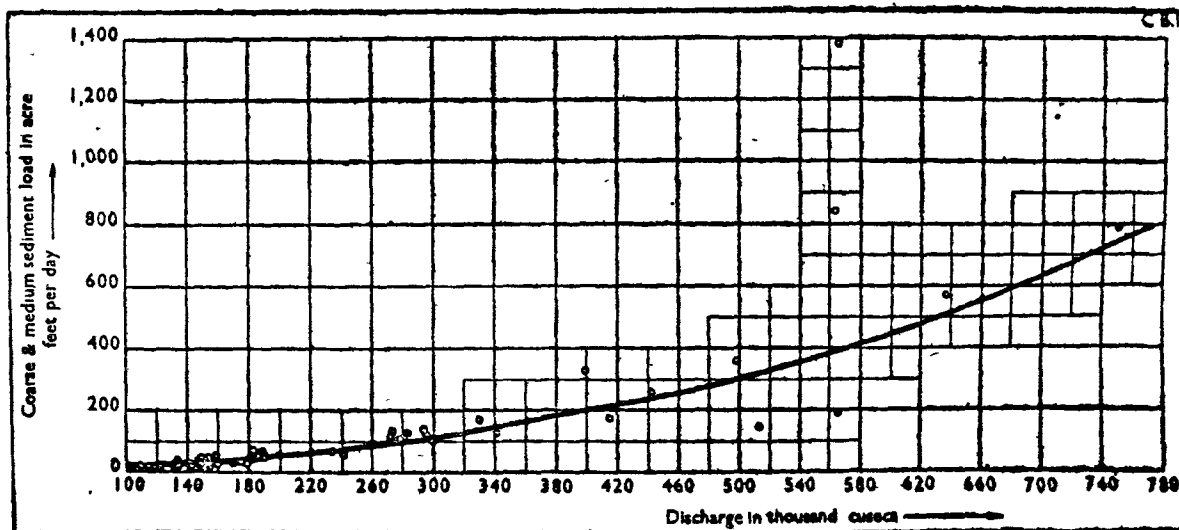


Figure 4A.9

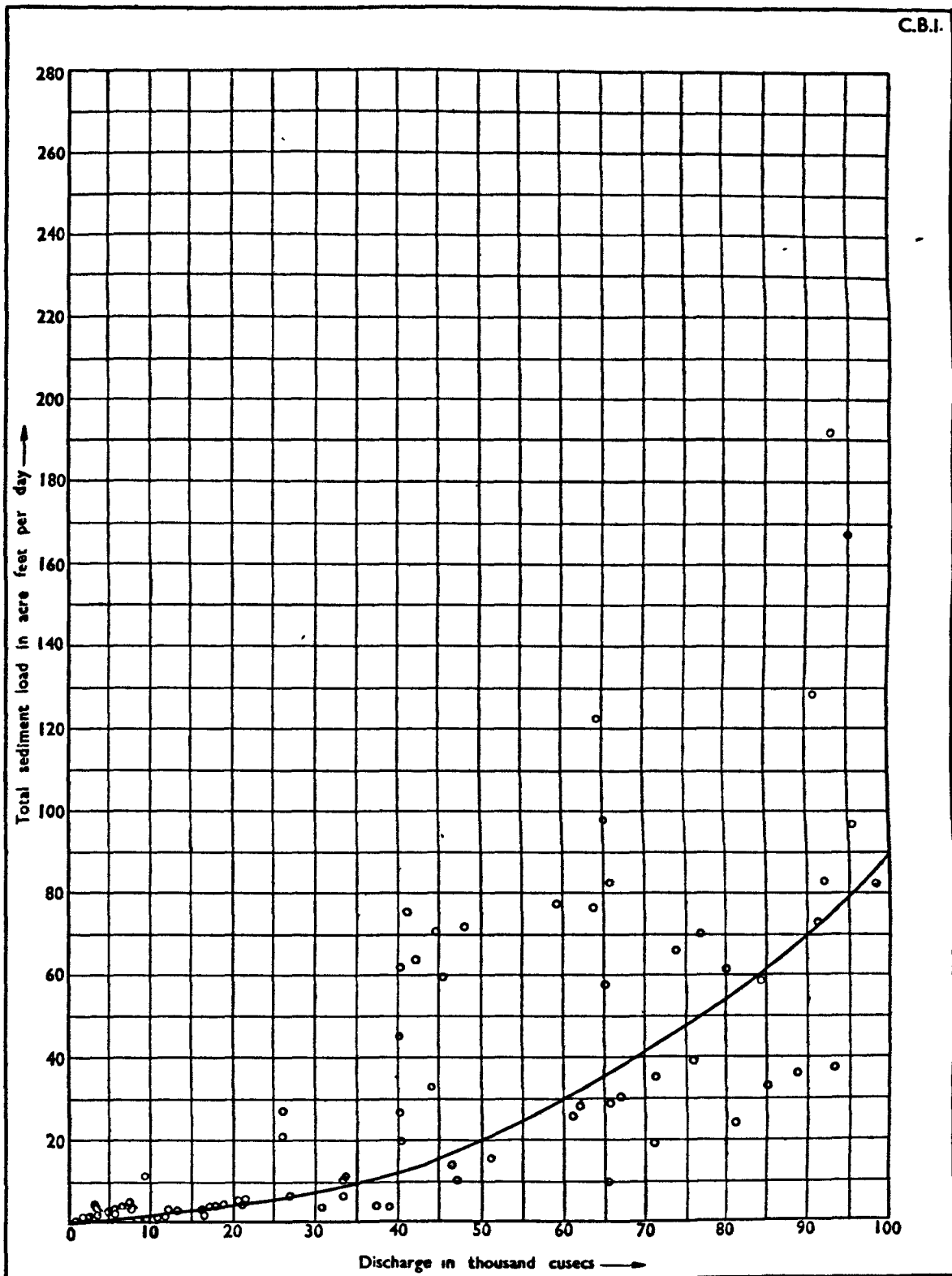
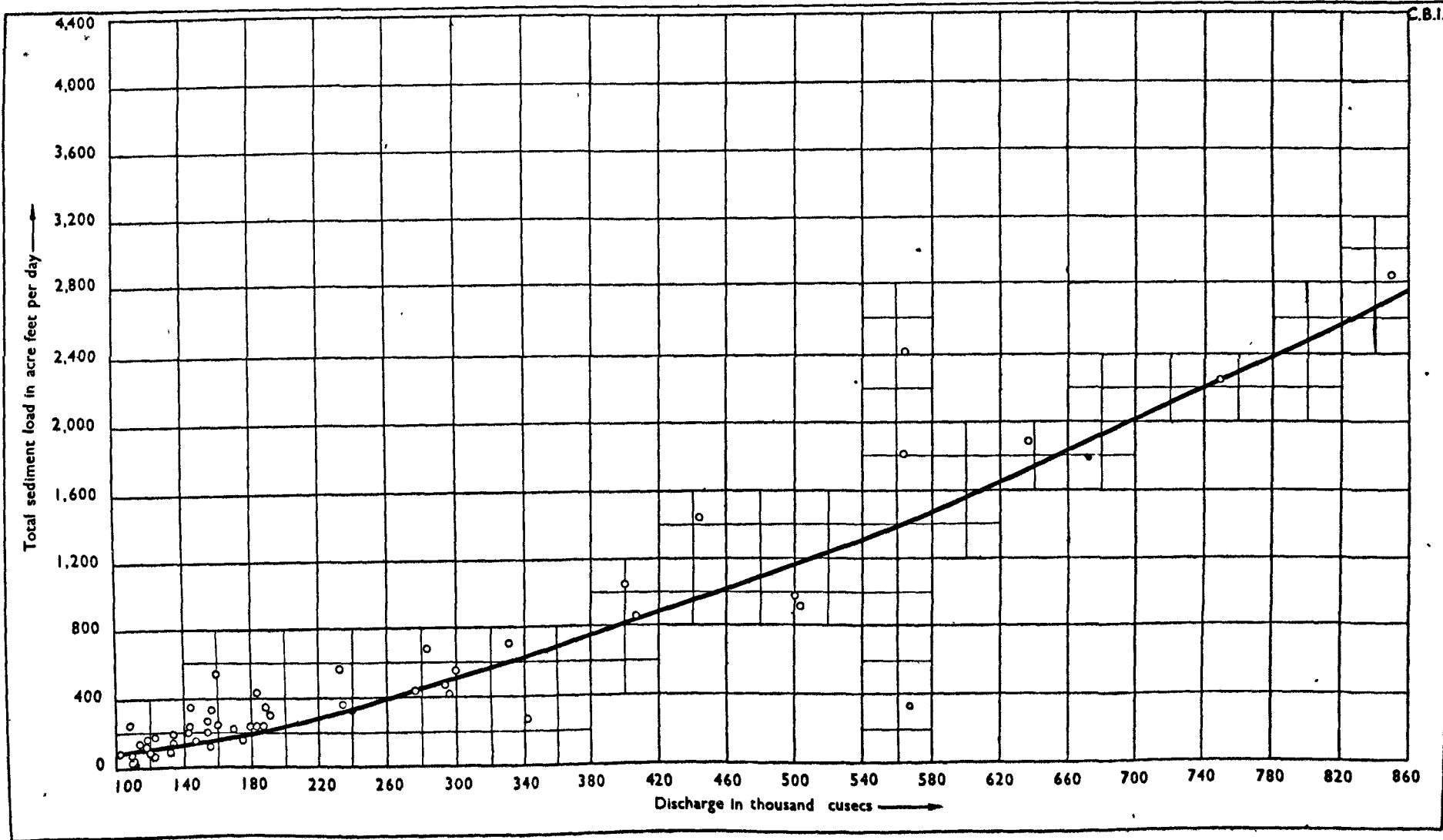
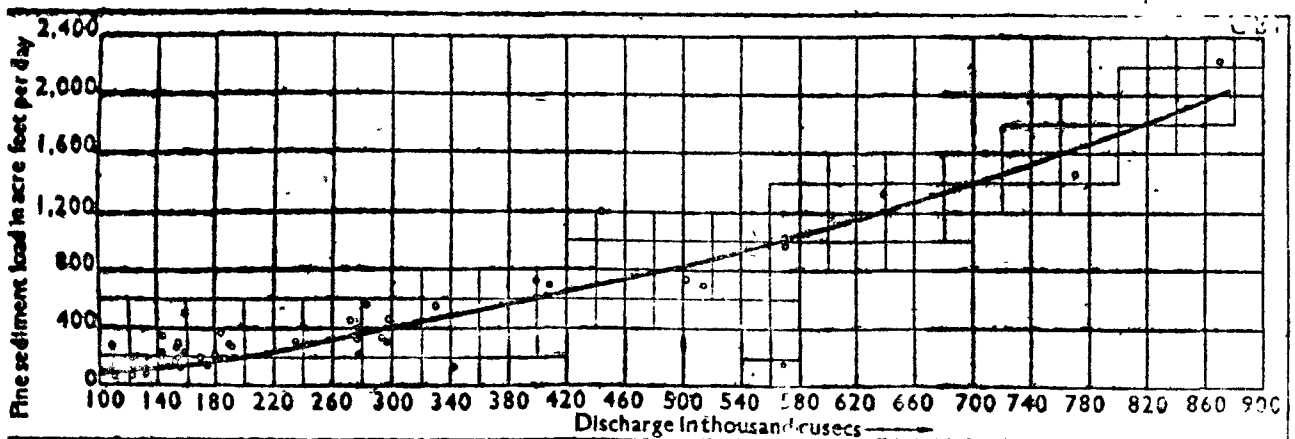
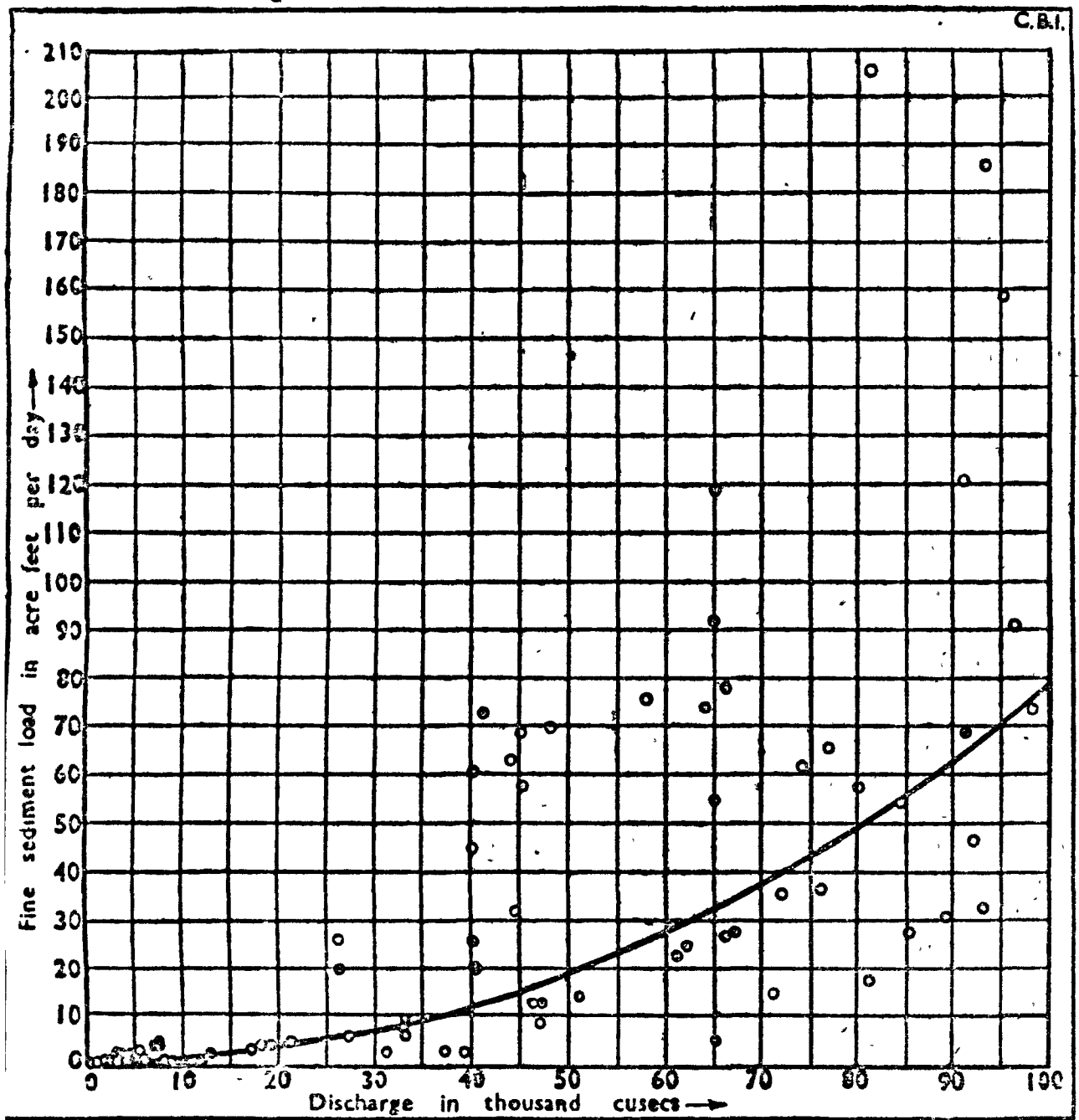


Figure 4A.6:- Showing relation between total sediment load and discharge
[Mahanadi silt investigation at Sambalpur site (1947)]



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Figure 4A.7:- Showing relation between total sediment load and discharge [Mahanadi silt investigation at sambalpur site 1947]



Figures 4A-10 (top) and 4A-11 (bottom)

(ii) General Conclusions

(a) As would appear from the above table, an approximate cumulative discharge of 19,589,336 cusecs and sediment load of 33,235.35 acre feet were obtained for the whole year for Sambalpur site.

(b) The fine sediment form the main bulk of total sediment recorded.

(c) The main feature of the sediment load in Mahanadi river has been that with an increase in the discharge due to occasional freshet or dood, there has occurred an increase in the suspended load of sediment of each category.

However, some very interesting exceptions were noticed to the above general behaviour. One reason for such discrepancies has probably been the variable sediment load brought down by the river Ib, a tributary of the Mahanadi. It is proposed to take observations on both the rivers, Mahanadi and Ib during the next flood season to throw some more light on the behaviour of sediment during flood period.

(B) Vertical Distribution of Silt

Experiments were carried out to study the variation in the general distribution of sediment load during the flood period of the year under review. On the days when the investigations were carried out the river discharges varied from 64525 to 638179 cusecs and the depth of river at experimental section from 8 to 20 feet. The water samples were collected at 0.1, 0.2, 0.3, 0.9D along the vertical section of the river. The results of the coarse and medium sediment in cc. per litre are plotted against the vertical section of the river at the experimental site in each case in Figure 4A.12. It has been brought out that, in general, the contents of the coarse and medium sediment increases from the top towards the bottom of the stream, the increase being more conspicuous in the case of the coarse sediment than for the medium sediment. As is clearly indicated by the various component diagrams in Figure 4A.12, the average contents of the coarse and medium sediment corresponded to the depth ranging between 0.45 to 0.68D (mean=0.55D) for the former and 0.4 to 0.7D (mean=0.58 D) for the latter. Those experiments corroborate that the collection of water samples for the sediment load at 0.6D afford a fair representation of the mean sediment load along the vertical.

THE KOSI RIVER

Suspended Sediment Load

The determination of the sediment load in the river Kosi was carried at the discharge site near the location of the proposed dam site from May 1947 onwards on lines similar to those adopted at the Mahanadi river. In Table 4A.X are given the figures for the river discharge from January to December, 1947, and for the sediment load from May to December respectively.

TABLE 4A. X

| Month | Total discharge (cusecs) | Cumulative discharge (cusecs) | Sediment load for the whole month (acre feet) | | | | |
|-----------------|--------------------------|-------------------------------|---|-----------|------------|-----------|------------|
| | | | Coarse | Medium | Fine | Total | Cumulative |
| January | 484,556 | 484,556 | | | | | |
| February | 353,632 | 838,188 | | | | | |
| March | 410,595 | 1,248,783 | | | | | |
| April | 503,316 | 1,752,099 | | | | | |
| May | 643,550 | 2,395,649 | 616.48 | 858.48 | 1,027.57 | 2,502.53 | 2,502.53 |
| June | 1,899,480 | 4,295,129 | 1,996.95 | 3,623.58 | 3,622.29 | 9,242.82 | 11,745.35 |
| July | 5,080,065 | 9,375,194 | 3,943.61 | 13,565.50 | 8,113.20 | 25,622.31 | 37,367.66 |
| August | 5,538,418 | 14,913,612 | 12,396.52 | 29,541.51 | 10,070.42 | 52,008.48 | 89,376.11 |
| September | 4,120,601 | 19,034,213 | 8,327.01 | 17,367.23 | 4,828.58 | 30,522.87 | 119,898.98 |
| October | 2,755,796 | 21,790,009 | 3,334.36 | 4,827.01 | 6,625.63 | 14,787.00 | 134,685.98 |
| November | 794,521 | 22,584,530 | 219.50 | 240.31 | Negligible | 459.81 | 135,145.79 |
| December | 572,446 | 23,156,976 | 107.05 | 40.66 | 56.63 | 204.34 | 135,350.13 |
| | | | 30,941.48 | 70,064.33 | 34,344.32 | | |

It is seen from the above table that an approximate discharge of 21,404,877 cusecs and a sediment load of 135,350 acre feet (May to December, 1947) was recorded.

It is interesting to note that unlike the Mahanadi which brings larger quantities of fine silt, the Kosi water brings down a lot of medium size silt.

A systematic work on the sediment load on the main river (Sapt Kosi) and its three tributaries (Tamura, Arun and Sun Kosi) is being carried out

DISCUSSION BY THE RESEARCH COMMITTEE

MR. S. K. BANERJI introduced item (1) and said that sampling of water and analysis of suspended silt were carried out at eight different sites in the Damodar Valley and at four different places in the Mor Valley in connection with the Damodar and Mor Schemes respectively. At both these places the total weight of silt in grammes per litre was first found out and thereafter the quantity of silt above and below 0.6 mm. was determined.

In addition to these investigations an attempt was made to find out the silt content at different depths and at different spans. This was being continued. In the Mor Valley there was another extra item of work and that was the determination of silt below 0.075 mm.

RAO BAHADUR D. V. JOGLEKAR introduced item (2) and said that experiments were carried out to see if a similar distribution was obtained when same sample was analysed by the two different instruments—Puri sand meter and Air sand meter.

MR. J. P. NAEGAMVALA introduced item (3).

DR. R. C. HOON introduced item (4) and said that information on the suspended sediment load of water of a river was very helpful in assessing the rate of silting of a reservoir after the completion of a dam. On the basis of that information it also becomes possible to estimate the extent of dead storage of the pond.

Water samples were collected daily from the Mahanadi river at Sambalpur discharge site at 0.6 depth from a number of points along the cross section of the river, similar work was also done at the Kaimnadi discharge site (proposed Naraj Dam site) on the same river. The usual analysis of the suspended sediment load in the water samples *i.e.*, separating into coarse (above 0.2 mm) medium (0.02 mm—0.75 mm) and below 0.075 and separately estimating each fraction was carried out after the samples were collected. The estimated amounts of the sediments load of each category and the river discharge along with their respectively cumulative totals for each month of the year were given in the note. An approximate cumulative discharge of 19,589,836 cusecs and a sediment load of 33,235 acre feet were obtained for the whole year for the Sambalpur site.

The main feature of the sediment load in Mahanadi river was that with an increase in the discharge due to occasional freshets, there occurred an increase in the suspended load of sediment of each category.

Unlike the Mahanadi which brings large quantities of fine silt, the Kosi water brings down a lot of medium sized silt.

MR. R. D. SONDHI said that the volume of the suspended load in the Sutlej at Bhakra could not be determined. He asked Dr. Hoon how the samples were obtained in the Mahanadi.

DR. R. C. HOON said that so far sampling was done with the help of bottle sampler at a number of verticles in the cross section of the river from a boat. At the Kosi river, which due to the very high velocity the boat could not be used in the river. Sampling was done from a boil as far away from the river bank as possible. An attempt was being made to design a water sampler for use at high velocity.

THE PRESIDENT said that a cradle was being fixed at the Kosi.

DR. N. K. BOSE asked if it was possible to use a boat on the Mahanadi.

DR. R. C. HOON replied that at the Mahanadi for a major part of the year sampling could be done with the help of one boat. During peak discharge period, however, two boats one at each bank were employed.

RAI BAHADUR S. D. KHANGAR asked at how many points samples were taken for each cross section.

DR. R. C. HOON replied that there were eight segments in the Mahanadi and five in the Kosi. Eight samples were taken from end to end at 0.6 depth.

DR. R. C. HOON in reply to Dr. Bose said that the width of the Mahanadi was 700 yards in lean period and about 1,600 yards at the peak flood period and that of the Kosi was about 330 feet.

MR. N. S. GOVINDA RAO pointed out that eight segments for 700 yards width were too small a number.

MR. S. L. MALHOTRA said that the classification of observations made on the Bhakra Dam showed that detritus below 0.005 was all clay.

DR. R. C. HOON asked how the analysis was carried out and the clay content determined. In his opinion it was not possible to do this sort of classification from day to day. This may be possible for some particular samples.

DR. C. L. DHAWAN said that samples were taken usually in the monsoon.

THE PRESIDENT said that this point regarding classification was an important one and, therefore, it was very necessary to standardise the classification also.

THE SECRETARY said that the sub-committee to draft standard instructions on the determination of detritus load in rivers and canals should deal with the standardisation of classification also.

RAI BAHADUR S. D. KHANGAR suggested that standard international classification should be followed.

DR. R. C. HOON said that a complete analysis into final fraction below 0.075 mm was fairly completed and could not be conveniently done for day samples. That sort of work could, however, be done with bulk silt sample collected occasionally.

DR. N. K. BOSE did not agree with Dr. Hoon that classification should not be done from day to day. The silt varied from day to day and even the texture varied from day to day. Hence day to day classification was essential.

DR. R. C. HOON referred to some practical difficulties.

DR. N. K. BOSE said that after all the standards of gradation had to be defined. It was better to have two or three groups. It was the 0.002 and 0.005 sizes that really mattered.

THE PRESIDENT said that it was advisable to go down to 0.007.

DR. N. K. BOSE said that experiments would have to be carried out to determine that.

MR. T. N. SESHADRI said that routine experiments were being made in Madras for the last three years, on water samples taken at 0.6 depth from the different canals of the Cauvery, the Kistna and the Godavari deltas. In these experiments the full cumulative curve of particle size distribution in the suspended load was drawn for each sample where the suspended load was found to be greater than one part in a thousand. Not much time need be taken for these experiments either. The Madras experience was that one assistant could easily do the experiments and draw the complete curves for about four samples per day.

DR. L. R. RAMDAS suggested the use of a centrifuge.

DR. V. I. VAIDHIANATHAN suggested the use of an elutriator from which all grades could be obtained.

DR. R. C. HOON said he had seen elutriators being used for mechanical analysis of soil where the finer fraction was obtained by difference.

DR. V. I. VAIDHIANATHAN said that elutriator was also used for this sort of job.

THE PRESIDENT thought that elutriator should be tried.

DR. H. L. UPPAL said that the sand meter was developed in the Punjab in 1939 independently of the Hunter Rouse classifier. The sand meter gave consistent results and also quick results.

DR. R. C. HOON said the speed of the motor would have to be regulated and the samples would have to be dried before being tested.

DR. H. L. UPPAL in reply to Dr. Hoon said that it takes just one minute for the test and five grammes of the samples was required.

DR. R. C. HOON said that such samples were convenient for fractionating coarser grades of silts but not for the finer material usually brought in suspension by the river water.

MR. S. L. MALHOTRA said that the technique of taking samples in high velocity currents had not yet been developed. He asked Dr. Hoon if he was trying some type of sampler for such conditions.

In reply to the query made by Mr. S. L. Malhotra, DR. R. C. HOON said that they were trying to evolve a type of weighted sampler for this type of work.

MR. T. N. SESHADRI said that weighted streamlined samplers might be tried for such conditions.

DR. N. K. BOSE said that he had used weights upto one maund and even then the sampler was dragged away.

RAI BAHADUR S. D. KHANGAR asked if any bed silt samplers too had been designed.

DR. H. L. UPPAL explained the use of an automatic sampler.

MR. R. D. SONDHI said that this sampler did not go down to the bed, it only floated.

RAO BAHADUR D. V. JOGLEKAR reported the progress made by the sub-committee to draft standard instructions on determination of detritus load in rivers and canals and said that the draft would be re-written.

DISCUSSION BY THE BOARD

THE SECRETARY said that four items were discussed under this subject head by the Research Committee. There was no resolution. A sub-committee was working on preparing a draft on the standard instructions for the determination of detritus load in rivers and canals. The sub-committee met at the time of the Research Committee meeting, and it was decided that the draft prepared previously required re-writing. Mr. S. L. Malhotra undertook to do the work but he had since left the Research Institute. The Secretary understood that Rai Bahadur C. L. Handa had taken the work in hand.

DR. R. C. HOON said that something should be done about the standardization of Classification of silt. At present different classification systems were being followed in different provinces. There ought to be some sort of standardization.

THE SECRETARY read out the relevant proceedings of the Research Committee meeting.

RAI BAHADUR C. L. HANDA suggested the appointment of a sub-committee to go into this matter. He furnished a note* on the practice in vogue in East Punjab.

*East Punjab Practice, printed on the next page.

A Sub-Committee comprising Mr. A. C. Mitra, Dr. N. K. Bose, R. B. C. L. Handa., Dr. R. C. Hoon, and Dr. C. L. Dhawan was formed to examine the question. It was decided that the conclusions of the Sub-Committee should be sent to Dewan Bahadur N. Govindaraja Ayyangar, and should be finalised after receiving his comments.

EAST PUNJAB PRACTICE

(1) The East Punjab Research station is determining the following silt-grades.

- (a) Particles less than 0.005 mm.
- (b) Particles greater than 0.005 mm. but less than 0.02 mm.
- (c) Particles greater than 0.02 mm. but less than 0.2 mm.
- (d) Particles greater than 0.2 mm.

The results are expressed in total silt-load in ounces per cubic foot of water, and are finally converted into acre feet.

(2) The overseers collecting the silt-water samples collect the following data

- (i) Name of the river
- (ii) Name of the site
- (iii) Date of sampling
- (iv) Time of sampling
- (v) Weather-conditions *i.e.*, rainfall *etc.*
- (vi) Temperature of the water
- (vii) Condition of water
- (viii) Width of the river
- (ix) Gauge
- (x) Mean-velocity
- (xi) Discharge
- (xii) Places and depths at which the samples are taken.

The advantage of having the classification in sizes given in para 1 above lies in the fact that more detailed information is available to the engineer while forecasting the rate of sedimentation of reservoirs. It also helps in suitable location of river outlet works. Exclusion, through overflow spillways and also with the help of density currents can also be properly visualised.

5 A. Regeneration and Losses

PRELIMINARY NOTE

This subject was introduced for the first time in 1947, to deal with (i) Seepage losses (ii) Evaporation losses and (iii) Regeneration. Sub-heads (i) and (iii) have already been on the agenda for several years. Sub-head (ii) is introduced for the first time.

(i) Seepage Losses

PRELIMINARY NOTE

In 1945 it was decided to issue a Board Publication on the subject of Stauching of Canals and a request was made to various research organisations to review the work done to date at their institutions in their annual reports for the year 1945.

In response to this request the Irrigation Research Division Sind, gave a summary of the work done on the subject. The Central Waterpower, Irrigation and Navigation Research Station Poona, Engineering Research Laboratories, Hyderabad and the River Research Institute, Bengal, reported that they had nothing to contribute.

A request was again made to the rest of the research organizations to include all the data available in their institutes in their reports for the year 1946 but there was no fresh contribution. It was decided that the compilation of the data (whatever existed) should be taken in hand immediately by all concerned but there was no contribution on the subject at the 1947 meeting of the Research Committee.

Recent Literature

(1) Killeen, A.B.—Head Race Canal Embankments. A seepage problem—investigation and treatment. Transaction, Institution of Civil Engineers, Ireland, Vol. 71, 1945.

THE YEAR'S WORK

The following items were discussed at the 1948 meeting of the Research Committee :—

(1) Data of seepage losses available in the East Punjab Irrigation Research Institute.

(2) Sweating from Krishnarajasagar Dam.

(1) DATA OF SEEPAGE LOSSES AVAILABLE IN THE EAST PUNJAB IRRIGATION RESEARCH INSTITUTE⁽¹⁾

This brief note is written to comply with the request contained in the Central Board of Irrigation circular No. 1503/J-194 dated 4-2-1948, to the effect that all the available data for seepage losses should be incorporated in the Annual Report of the Research institute for the year 1947.

The data obtained from *ad hoc* experiments by the Punjab Irrigation Research Institute, or transmitted to it for analysis by other officers are accordingly compiled. Where possible, references to earlier work are also given.

(2) SWEATING FROM KRISHNARAJASAGAR DAM⁽²⁾

The data gathered during the year is printed in Table 5A.I. There has not been any appreciable decrease or increase in the rate of sweating.

TABLE 5A. I

Observation on the sweating of the rear side of Krishnarajasagar Dam.

(Observations continued from last year)

| Reservoir Level Range in feet | Date | Sweating in cusecs per million square feet |
|-------------------------------|---------------------|--|
| 124 to 120 | September 20, 1947 | 0.105 |
| 120 to 115 | December 2, 1947.. | 0.020 |
| 115 to 110 | December 16, 1947 | 0.016 |
| | December 25, 1947 | 0.016 |
| | January 5, 1948 .. | 0.013 |
| 110 to 105 | January 26, 1948 .. | 0.014 |
| | February 10, 1948 | 0.007 |
| | February 24, 1948 | 0.0069 |
| | March 2, 1948 .. | 0.0062 |
| 105 to 100 | March 22, 1948 .. | 0.004 |

⁽¹⁾ East Punjab Irrigation Research Institute, Amritsar, Annual Report, 1947, pages 69-101.

⁽²⁾ Hydraulic Research Station Krishnarajasagar Annual Report 1947 page 7.

DISCUSSION BY THE RESEARCH COMMITTEE

THE SECRETARY said that in connection with the proposed Board Publication on "Staunching of Canals" so far contributions had been received only from Sind and East Punjab. If no other station had any note to send, the compilation of the Board Publication could be taken in hand.

MR. S. N. GUPTA promised to send a note on the subject.

THE PRESIDENT enquired if any body would volunteer to prepare the draft of the publication.

DR. J. K. MALHOTRA offered to take up the work.

Introducing item (1) MR. S. L. MALHOTRA said that this was in response to the request made by the Central Board of Irrigation.

DR. MALHOTRA briefly described the contents of the note.

MR. N. S. GOVINDA RAO introduced item (2) and said that the sweating showed a tendency to decrease.

It was decided that the subject should continue on the agenda.

DISCUSSION BY THE BOARD

THE SECRETARY said that two items were discussed at the Research Committee meeting and that there was no resolution.

DR. J. K. MALHOTRA said that at the Research Committee meeting the President had asked whether anybody would volunteer to prepare a draft of publication by the Central Board of Irrigation on this subject. At that time he offered to take up this work. He had since obtained a lot of books and help from the Central Board of Irrigation and he was getting on with the work.

References were made to the work done on the Bikaner canal for determining seepage losses.

PRELIMINARY NOTE**(ii) Evaporation Losses**

The subject was introduced for the first time in 1947. In 1946 Research Committee meeting the following resolution was passed under the subject Rainfall-Runoff concerning evaporation :—

" Systematic and extensive observations must be undertaken all over India. To start with, observations should be made of evaporation from free water surface at 50 per cent., of the regular observatories of the Meteorological Department.

" As regards evaporation from soil and transpiration losses, *etc.*, it is understood that this work is being taken up at the farm observatories (about 80 in number) recently established by the Agricultural Department in conjunction with the India Meteorological Department. The nature of the work undertaken at these places should be ascertained, together with their location, and proposals for the extension of the work, particularly to hilly areas, should be examined. This investigation can be made appropriately by the India Meteorological Department."

At the 1947 Research Committee meeting the following item was discussed :—

- (1) The estimation of evaporation losses.

Recent Literature

(1) Wilm, H. G. and Niederhof, C. H.—Effect of cutting mature lodgepole—pine stands on rainfall interception. *Journal of Forestry*, Vol. 41, No. 1, January 1943.

THE YEAR'S WORK

The following items were discussed at the 1948 meeting of the Research Committee :—

- (1) Evaporation measurements in India. A brief report of the present position " with suggestions for future organisation " by Dr. L. A. Ramdas, Director, Agricultural Meteorology, India Meteorological Department.
- (2) Investigations on evaporation losses.
- (3) Experiments conducted at Krishnarajasagar.

(1) EVAPORATION MEASUREMENTS IN INDIA

A BRIEF REPORT OF THE PRESENT POSITION WITH SUGGESTIONS OR FUTURE ORGANIZATION

by

Dr. L. A. Ramdas

Director of Agricultural Meteorology, Meteorological Office Poona.

ABSTRACT

A summary of the experimental researches on evaporation from water and soil surfaces and allied phenomena, being conducted at the Central Agricultural Meteorological Observatory at Poona was presented by the present writer in a " Report on Soil Moisture and Evaporation Investigations being conducted by the Agricultural Meteorology Section at Poona ", read before the meeting of the Research Committee of the Central Board of Irrigation, held at Simla in July 1947. Recently another report on " Evaporation from bare soil in relation to the depth of the water table or zone of saturation " was sent through the Central Board of Irrigation, for communication to the International Union of Hydrology which meets in August 1948 at Oslo, Norway.

On the present occasion a review of the present position regarding the estimation of ' evaporation in India ' is made and suggestions are offered for bringing into existence an adequate net work of stations in India for recording evaporation according to a common plan.

STATEMENT OF THE PROBLEM

There are two distinct problems, *viz.*,

A. *Study of the fate of rainfall : the Water Balance.*

The controlling factors are :—

- (i) evaporation from the soil surface
- (ii) surface drainage
- (iii) percolation through the soil
- (iv) retention by the soil and
- (v) underground drainage along the impervious layer of rock or other material on which the soil layer may be resting.

It may be mentioned here that the evaporation from the soil surface will be comparable to that from a free water surface so long as the soil surface is saturated with moisture. When the soil surface dries up, the evaporation will decrease, depending on the upward or capillary ascent from the water soil below. This supply diminishes as the distance between the soil surface and the zone of saturation increases ; ultimately, the soil surface will begin to exchange water vapour with the air layers above, yielding hygroscopic moisture to the air during part of the day and re-absorbing water vapour from the air during the rest of the day and during night.

The study of items A-(i) to (v) will need wholetime and intensive research with specially designed instruments. Such work is relevant to Hydrology so far as land surfaces are concerned.

B. *Study of the evaporating power of the air layers near the ground.*

The measurement of evaporation from a free water surface is a simpler matter. It is relevant to hydrology in so far as its measurements will give some idea of the evaporation from lakes, reservoirs *etc.* Actually such measurements as can be made indicate the "evaporating power of the air layers near the ground", but can be correlated with actual losses from lakes, large reservoirs, *etc.*, if necessary, if comparative observations are recorded for a few years.

The measurement of evaporation from a free water surface is also useful in estimating the possible evaporation E from a soil when the depth z of the water table or zone of saturation below the soil surface is known and α the characteristic constant of the particular soil has been determined previously from the measurements made with a series of soil evaporimeters. For, our work at Poona has shown that

$$E = E_0 \times 10^{-\alpha z}$$

CHARTS SHOWING THE VALUES OF EVAPORATION IN INDIA COMPUTED FROM THE METEOROLOGICAL FACTORS CONTROLLING IT

Early in 1933 the present writer found that we had practically no evaporation records in India. In order to obtain some idea of the probable evaporation in different parts of the country, the values were computed according to a modified form of Carl Rowler's formula (U. S. A. Department of Agriculture, Tech. Bull. No. 271, 1931), which is given below :—

$$E = (1.465 - 0.0186B)(0.44 + 0.118W) \left(\frac{100}{h} - 1\right)e$$

where E is the mean daily evaporation in inches corresponding to that measured with a U. S. A. type of evaporimeter,

B is the barometric pressure in inches at station level,

W is the mean wind velocity of the day at four feet above ground in miles per hour,

h is the mean relative humidity of the day and

e is the mean vapour pressure of the day in inches of mercury.

This calculation of evaporation was made for 80 representative stations in India for different months of the year.

A discussion of the results will be found in a paper entitled "Evaporation in India calculated from other meteorological factors" by Messrs. P. K. Raman and V. Satakopan (Ind. Met. Dept., Scientific Notes, Vol. VI, No. 61, 1935).

It may be mentioned that the series of 14 charts showing the mean monthly evaporation, the mean annual evaporation and the mean "Annual Rain *minus* Annual Evaporation" published in the above paper proved very useful indeed as a provisional basis for all discussions on the subject.

Actual measurements of evaporation made at a steadily increasing number of stations in India agree very *satisfactorily* with the charts of computed evaporation referred to above.

TYPES OF EVAPORIMETERS

The types of evaporimeters recommended for recording the evaporating power of the air layers near the ground are :—

- (1) The U. S. A. standard Evaporimeter with a reservoir four feet in diameter and a hook gauge (in stilling well).
- (2) The Athavle Open Pan Evaporimeter with a reservoir one foot in diameter and micrometer gauge and
- (3) The Piche Evaporimeter.

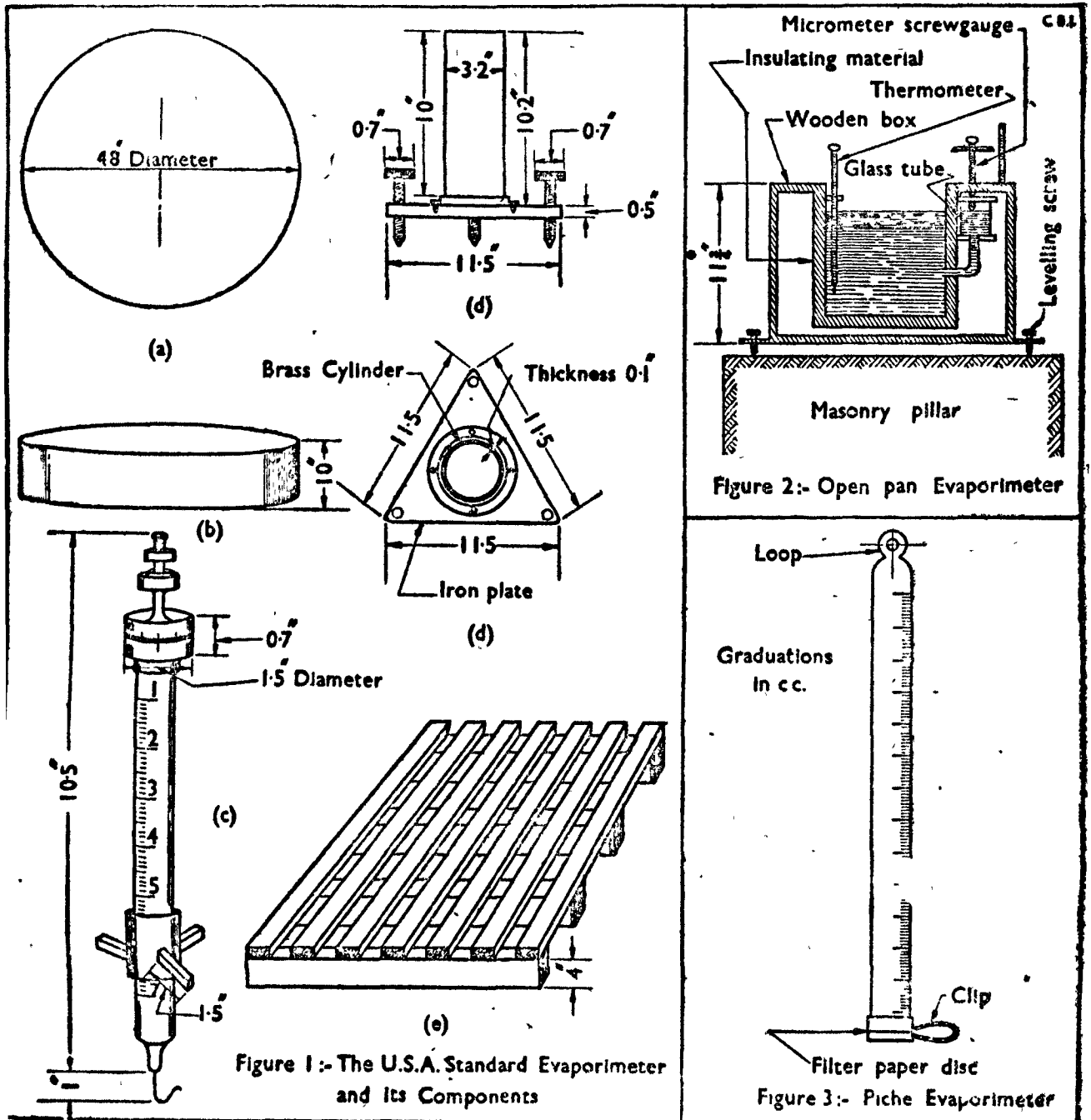


Figure 5A.1 : Left. Figure 5A.2 : Right top. Figure 5A.3 : Right bottom.

The above three types of instruments are shown in sketch in Figures 5A.1, 5A.2, and 5A.3 respectively. The U. S. A. Standard Evaporimeter is the most suitable for important stations where the necessary whole-time staff is available for maintaining the instrument and recording the observations. The Athavle Open Pan Evaporimeter is a less costly instrument but has not got the advantage of a large reservoir like the U. S. A. type. The Piche Evaporimeter is very cheap and handy and, when exposed inside the Standard Stevenson Screen, has the advantage of giving the evaporation data even on rainy days. The Piche Evaporimeter, however, requires very careful calibration before issue as well as periodically thereafter, to verify that changes in corrections are noted every time the quality and size of filter disc undergo any alteration. Each instrument has a correction factor by which the data have to be multiplied,

EXPERIMENTAL FARMS WHICH RECORD EVAPORATION DATA

In connection with the "Co-ordinated Crop-Weather Scheme" the Director of Agricultural Meteorology has persuaded the co-operating Provinces and Indian States to equip some of the selected *experimental farms* with evaporimeters. A list of the 40 and odd stations indicating the type of evaporimeter in use is given in Table 5A. II.

More and more of the experimental farms in India are likely to be equipped with evaporimeters in future years.

TABLE 5A. II

Selected Experimental farms and the type of evaporimeter in use.

| | Station | Type of evaporimeter in use | | Station | Type of evaporimeter in use |
|----|-------------------|--|----|------------------|-----------------------------|
| 1 | Dharwar .. | Piche | 21 | Delhi (I.A.R.I.) | Piche, U. S. A. |
| 2 | Sholapur | Piche, Open Pan | 22 | Muttra .. | Open, Pan |
| 3 | Jalgaon .. | Piche | 23 | Chinsurah .. | Piche |
| 4 | Karjat .. | Piche | 24 | Pusa | Piche, Open Pan |
| 5 | Niphad .. | Piche | 25 | Sabonr .. | Piche, Open Pan |
| 6 | Padegaon .. | Piche, Open Pan | 26 | Cuttack .. | Piche |
| 7 | Poona | Piche, Open Pan, U. S. A. Standard and a no. of other types all in use at the Central Agri-Met. Observatory. | 27 | Cawnpore .. | Piche, Open Pan |
| 8 | Raichur.. .. | Piche, Open Pan | 28 | Shahjahanpur .. | Piche |
| 9 | Parbhani .. | Piche, Open Pan | 29 | Muzaffarnagar .. | Piche, Open Pan |
| 10 | Rudrur .. | Piche, Open Pan | 30 | Indore .. | Piche, Open Pan |
| 11 | Shakarnagar | Piche | 31 | Irwin Canal Farm | Piche |
| 12 | Nagpur .. | Piche | 32 | Virajpet .. | Piche |
| 13 | Akola | Piche | 33 | Frazerpet | Piche |
| 14 | Raipur .. | Piche | 34 | Coimbatore .. | Piche, Open Pan |
| 15 | Powerkhera .. | Piche | 35 | Bijapur .. | Piche |
| 16 | Adhartal .. | Piche | 36 | Warangal | Piche |
| 17 | Sri Ganganagar .. | Piche | 37 | Nagina .. | Piche |
| 18 | Gurdaspur .. | Piche | 38 | Aduthurai .. | Piche |
| 19 | Jullundur ... | Piche | 39 | Hagari.. .. | Piche |
| 20 | Rohtak .. | Piche | 40 | Siruguppa .. | Piche |
| | | | 41 | Balehonnur .. | Piche |
| | | | 42 | Ollykkara .. | Piche |
| | | | 43 | Baroda .. | Piche |

SUGGESTIONS FOR SETTING UP AN ADEQUATE NET-WORK OF EVAPORATION RECORDING STATIONS IN INDIA

Now that, besides Agriculture, Hydrology too has entered into the picture, it is time to establish an adequate net-work of stations in India making evaporation measurements systematically, according to a common plan.

In the present report one shall confine attention to the existing major observatories of the India Meteorological Department which are manned by whole-time staff of the department.

Table 5A.III gives the names of such stations which may be equipped with (i) the standard U. S. A. type evaporimeter in the open and (ii) the Piche Evaporimeter inside the Stevenson Screen.

TABLE 5A. III

Meteorological Observatories of the India Meteorological Department which may be equipped with (i) the Standard U. S. A. type evaporimeter in the open and (ii) the Piche Evaporimeter inside the Stevenson Screen.

| | | | |
|----|------------|----|--------------|
| 1 | Srinagar | 22 | Nagpur |
| 2 | Ambala | 23 | Raipur |
| 3 | Delh | 24 | Jharsuguda |
| 4 | Bikaner | 25 | Jamshedpur |
| 5 | Bareilly | 26 | Calcutta |
| 6 | Jodhpur | 27 | Cuttack |
| 7 | Jaipur | 28 | Bombay |
| 8 | Gwalior | 29 | Poona |
| 9 | Udaipur | 30 | Begumpet |
| 10 | Allahabad | 31 | Jagdalpur |
| 11 | Gorakhpur | 32 | Vizagapatam |
| 12 | Gaya | 33 | Masulipatam |
| 13 | Saharsa | 34 | Gadag |
| 14 | Jalpaiguri | 35 | Anantpur |
| 15 | Tezpur | 36 | Mangalore |
| 16 | Bhuj | 37 | Bangalore |
| 17 | Veraval | 38 | Madras |
| 18 | Ahmedabad | 39 | Cochin |
| 19 | Malegaon | 40 | Kodaikanal |
| 20 | Bhopal | 41 | Trichinopoly |
| 21 | Jubbulpore | 42 | Nagercoil |

Table 5A. IV gives the names of those meteorological observatories which may be equipped with the Piche Evaporimeter alone in the Stevenson Screen. These stations have been selected in order to fill up the vacant spots on the map after plotting the stations of Tables 5A. II and 5A. III.

If the stations indicated in Tables 5A. III and 5A. IV are all equipped as suggested we shall have an excellent net-work of about 80 stations (in addition to the 40 and odd experimental farms) recording evaporation, with the help of the whole-time staff which exists already at these stations.

TABLE 5A. IV

Meteorological observatories of the India Meteorological Department which may be equipped with the Piche Evaporimeter alone in the Stevenson Screen.

| | | | |
|----|------------|----|------------|
| 1 | Roorkee | 20 | Amraoti |
| 2 | Hissar | 21 | Sutna |
| 3 | Agra | 22 | Chanda |
| 4 | Kotah | 23 | Daltonganj |
| 5 | Jhansi | 24 | Pendra |
| 6 | Bahraich | 25 | Kankar |
| 7 | Lucknow | 26 | Ratnagiri |
| 8 | Benares | 27 | Miraj |
| 9 | Patna | 28 | Belgaum |
| 10 | Dinajpur | 29 | Gulbarga |
| 11 | Dhubri | 30 | Nizamabad |
| 12 | Gauhati | 31 | Hanamkonda |
| 13 | Naya Dumka | 32 | Bellary |
| 14 | Bardwan | 33 | Chitaldrug |
| 15 | Dwarka | 34 | Vellore |
| 16 | Rajkot | 35 | Salem |
| 17 | Dohad | 36 | Cuddalore |
| 18 | Guna | 37 | Pamban |
| 19 | Khandwa | | |

N.B.—Attempts are being made by the Instruments Section at the Meteorological Office, Poona to construct self-recording evaporimeters which will record the hourly variation of evaporation. A few selected stations can be equipped with this in due course.

EVAPORATION MEASUREMENTS AT FIELD LABORATORIES AND OTHER RESEARCH STATIONS SET UP IN THE CATCHMENTS OF THE MAJOR RIVER SYSTEMS OF INDIA

These stations will be *in addition* to those indicated above. Here the whole programme will be solely devoted to Hydrology proper and besides the evaporation records, measurements of evaporation from soil surface (with soil evaporimeter sets) as well as seasonal variations of the depth of the water table, *etc., etc.*, should be made. The programme and equipment for such stations must be dealt with separately, and in greater detail than can be attempted in the present report.

MAINTENANCE AND COLLECTION OF DATA FROM STATIONS IN TABLES 5A. II, 5A. III AND 5A. IV REFERRED TO ABOVE

Issue of instructions for the maintenance and upkeep of these instruments, their periodical overhaul, *etc.*, is an important item of work. The daily readings should be received at fortnightly or monthly intervals, from the 80 stations directly under the India Meteorological Department and the 40 and odd experimental farms of the Agricultural Departments. After scrutiny, correcting and converting the readings to the "U. S. A. basis", the data should be made readily available to those concerned with Hydrology.

Staff will be required for the above purpose. One Professional Assistant and three Scientific Assistants may be adequate for attending to all the items of work enumerated above.

EQUIPMENT

The entire equipment can be obtained from Indian firms who are already manufacturing them. The U. S. A. Evaporimeters cost about Rs. 500 each and the Piche Evaporimeters about Rs. 15 each.

For giving effect to the proposals made in this report about 45 U. S. A. Evaporimeters and about 100 Piche Evaporimeters (making allowance for about 20 to replace breakages) will be required.

The cost of these will be of the order of Rs. 25,000.

(2) INVESTIGATIONS ON EVAPORATION LOSSES⁽¹⁾

ABSTRACT

(1) The experimental work on evaporation losses in this note comprises a study of the following aspects of this problem :—

- (i) The depth of the water table from which water could be drawn to the soil surface by evaporation and how far the quantity of water so drawn could meet the requirements of moisture needed for cultivation.
- (ii) The effect of evaporation on the movement of water table in initially saturated, stratified and unstratified, soil columns composed of various grades.
- (iii) The effect of particle size, depth and stratification of soil, on the intensity of evaporation from initially saturated soil columns.

The first investigation on this problem conducted in the field near Lahore Cantt., in the month of June 1934, related to the study of evaporation of water from a soil surface, with reference to the fluctuation of water table *etc.*

⁽¹⁾ East Punjab Irrigation Research Institute, Annual Report 1947 pp. 102—115.

The main object of this investigation was to ascertain

- (a) the depth of the water table from which water could be drawn to the soil surface
- (b) how far the quantity of water so drawn could meet the moisture requirements of cultivation, and,
- (c) if, as advocated by some previous investigators, the variation in barometric pressure was solely responsible for causing fluctuations in the water table.

The problem was studied by taking regular daily observations of the intensity of evaporation from the soil surface and of the corresponding positions of the water table. The moisture content of the soil sample taken at each foot of the soil strata, lying between the natural soil surface and the water table was also determined. From these observations it was concluded that

(a) Water was returning to the surface from a depth of 22 feet which was the depth of the water table in this particular case.

(b) The quantity of water drawn to the surface was 1.7×10^{-7} gm. per square cm. per second, on the average, for the month of June and was too small for cultivation purposes.

(c) The fluctuations of the water table were dependent not only upon atmospheric pressure, but also on surface evaporation. It may be pointed out here that, whereas other conclusions appear to be sound, the first one needs amendment. From some laboratory experiments done afterwards, the maximum depth, from which moisture in the liquid phase could be drawn up to the surface, was found to be about $7\frac{1}{2}$ feet in case of a sandy loam.

While attempting to trace the cause of the occurrence of the abnormal rise in the levels of wells, situated in areas of high watertable, after just a shower of rain, necessity was felt for determining the effect of size of the particles composing a soil stratum on the intensity of evaporation from the latter. This led to the study of another aspect of this problem. For this purpose china crucibles, 4 cm. in diameter and 5 cm. in height were taken, filled with water and packed with soils of different grades. The particle size of the soils covered a wide range, varying from 1.0 mm. to 0.10 mm. in mean diameter. To account for the varying atmospheric conditions, evaporation losses from the surface of water contained in a similar crucible were also noted. The crucibles were placed in an open place so that evaporation could take place under similar conditions, and their weights observed regularly after suitable intervals of time, till no further loss in moisture could be detected. The main conclusions drawn from these tests were :—

(1) When the moisture content was near the saturation value the intensity of evaporation, i.e. the loss in moisture per unit area per unit time was practically the same for all particle sizes and was equal to that occurring from a plane water surface.

(2) As the moisture content of the soil decreased by about 10 to 15 % the intensity of evaporation was still equal for all grades, but it was less than that from a plane water surface.

(3) Even when the soil columns got air dried, no discrepancy in the respective rates of evaporation could be detected. Of course, the evaporation was much less than from a plane water surface.

It is worth mentioning here that if the temperature of different soil columns does not remain constant, either due to variations in the colour of the container or of the soil, the intensity of evaporation would vary correspondingly. Moreover, during a storm blowing at a very high velocity, the rate of evaporation from a plane water surface was found to be substantially greater than that from a saturated soil column.

From the results of evaporation experiments conducted by Keen, a well-known soil physicist, at the Rothamsted Experimental Station in England for three years, it was deduced that by capillarity subsoil water can be drawn up from a depth not exceeding five feet. As the atmospheric conditions prevailing in the Punjab differ considerably from those in England, similar experiments were started at Lahore in order to verify if his conclusion was also applicable in our climatic conditions.

The dimensions of the experimental vessel used in the beginning were 4 feet \times 3 feet as its height and diameter respectively. A glass tube, one inch in diameter and having its lower end closed with a wire gauze, was embedded in the soil column. The vessel was filled with water and packed with a certain type of soil. To hasten its settling, water was passed down the soil column till the transmission constant showed no reduction in its value. Evaporation was then allowed to proceed from its surface and the position of the watertable, as given by the level of water in the glass tube, noted at suitable time intervals. On experiencing a difficulty in packing the soil uniformly throughout the length of the soil column.—a condition quite essential for obtaining replica results, an experimental vessel of smaller dimensions *viz.* 150 cm. \times 8 cm. was used. This necessitated a corresponding reduction in the manometric bore, as otherwise the manometer, acting as a source of water when water is removed from the soil column and a sink in the reverse case takes an unnecessarily long time to attain its position of equilibrium. The glass tube meant for recording the watertable was kept outside, for it was observed that so long the ratio between the diameter of the soil column and glass tube remained the same, the results were unaffected whether the tube was kept in the soil column or outside. A number of vessels containing different grades were placed in an open place, so that evaporation may occur from all of them under similar atmospheric conditions.

Though it was seen that the experiments were performed under as uniform conditions of evaporation as possible, yet as shown by the evaporimeter installed in the neighbourhood, the intensity of evaporation did not remain constant with lapse of time. Hence the time could not be supposed to serve as a correct basis for quantitative comparison. To account for the varying atmospheric elements the loss of moisture occurring from the surface of water contained in a similar vessel, placed beside other vessels, was also measured. This vessel was refilled to the same level daily. For each soil type a curve was drawn

between the evaporation losses from water surface as abscissa and the corresponding depression in the water table as ordinate. The main conclusions deducible from such curves were :—

(1) Starting with saturated soil columns, as evaporation proceeded, the water table would depress at an abrupt rate, which during the initial stages of evaporation was constant for a given soil type but varied for different grades, though the moisture lost from different soils during this period was practically the same for all of them. Generally, the finer the soil, the greater the rate of depression. After a few hours' evaporation the depressions caused in the watertable in case of very coarse sand, coarse silt and sand were 6 cm., 20 cm., and 80 cm. respectively, while for the plane water surface the depression was only 0.3 cms.

According to the usual method of computations the watertable in the soils should depress by 0.75 cm. assuming their pore space as 40%. Moreover the depression for an equal loss of moisture should be independent of the grade provided the pore space does not vary. This observation led to the conclusion that the records of spring level along, without a knowledge of capillary height and moisture content of the soil lying above the watertable could scarcely prove of much use in predicting the movements of the watertable especially when the latter lies at a depth less than the capillary height of the soil.

(2) After a few hours' evaporation, the respective rates of depression went on decreasing continuously, but still remained greater than that from a plane water surface. Finally, when the water-table had depressed by 11 cm., 40 cm., and 200 cm. in the respective cases, the rates became extremely slow being much less than that from a water surface. The finer the soil, the greater the time taken by it to attain the final stage.

The time interval, after which the rate of evaporation in the respective cases assumed a very low value, depended upon the particle size of the various soils. In case of very coarse, medium and very fine sand it amounted to a few days, one week and one and a half months respectively. It was proposed to continue these experiments for several years, but unluckily the rubber tubes connected to the manometers meant for recording the position of the water table cracked in case of fine, medium and coarse sand after two, three and eight months respectively and the observations had to be discontinued after these periods. The water table in case of the medium sand fell in the third month only by one centimeter while for very coarse sand the depression for a period of six months, *i.e.*, from the beginning of the third month to the end of the eighth month, was not more than four centimetres.

It may be pointed out that this method of determining the depth from which water could be drawn to the soil surface by capillarity is an indirect one. The evaporation occurs at the surface of an initially saturated unstratified soil column and the depth from which water is drawn up is ascertained from the magnitude of fall in the position of the watertable. By evaporation the water table can be affected, whether the moisture is lost from the soil column by capillarity or diffusion. No doubt, for a considerable duration of time, water

is drawn by the capillary forces to the surface, from where it gets lost by evaporation. During this period, most of the moisture is lost by this process. Again, for moisture to be lost mainly by capillaries must extend right up to the surface of the soil column. Whether the menisci of the capillaries still lie at the surface or have receded down can be tested as follows. A slight pressure applied at the surface, or a slight shower of water sprinkled at it, affects the water table, not only immediately, but also considerably, so long as some of the menisci lie at the surface. When however, they get below the surface the watertable remains almost unaffected by these factors. It was observed that when no capillaries reach the surface the rate of depression could become very slow. The watertable did fall even afterwards, but it was due to diffusion of water vapour. During this stage, water is not drawn to the surface. Applying the tests narrated above, water was drawn up by capillarity to the surface, from a depth of about 200 cms. in case of very fine sand, mean diameter 0.10 mm.

Again, if these experiments are conducted with a view to determining the moisture requirements of crops, it is not necessary that water be drawn up to the soil surface. It would reach the zone up to which the roots of the crops extend. From this stand point water can be drawn up even from greater depths.

As the above pipes used for recording watertable are generally fitted with strainers, it was desired to perform the experiment using a strainer instead of a blind pipe.

On repeating the experiment with a brass strainer, 2 mm., in diameter, embedded in an initially saturated soil column exactly similar results were obtained.

In order to explain the abrupt rate of fall of the water table and the dependence of this rate upon the particle size another set of investigations had to be undertaken. It was necessary to determine the weight of the loss in moisture, required to produce a given depression in the water table, by actually weighing the experimental vessel along with its contents. As it was not possible to detect slight variations in moisture from a heavy vessel, so experimental vessels, 4 cm. in diameter and 20 cm. in height were used instead. Packing two such tubes, fitted with manometers of one mm. bore, with saturated silts of different grades, the weight of the moisture lost due to evaporation and the corresponding depression in the water table were noted. Using the same vessel, experiments were also repeated with different bores of the manometer. The main conclusions drawn from these observations were :

(1) During the initial stages of evaporation the loss in moisture required to produce a certain depression in the watertable is just a fraction of the value usually expected. In the case of the fine silt it was about one hundredth of that value.

(2) Though the rate of loss in moisture was independent of the grade to begin with, yet the rate of watertable depression was a function of the particle size.

(3) The intensities of evaporation from different grades did not remain equal to each other after a few days. The finer the soil, the greater the evaporation losses.

The final conclusion stated above did not agree with the one deduced previously that intensity of evaporation is independent of the grade of the soil. As the previous experiments were done in china crucibles, 4 cm. × 5 cm. and the recent one with tubes, 4 cm. × 20 cm., the only cause of discrepancy could be the difference in the depth of the soil columns used.

For studying the effect of this factor three sets of experiments were performed. For different sets; metallic tubes, equal in bore, but varying in height viz 5 cm. × 15 cm. and 30 cm. were taken. In each set 12 tubes, equal in bore and height were used. Four different grades of silt, varying from 2.5 mm. to 0.10 mm. in mean diameter and one soil having its clay content about 7% were packed under water contained in these vessels. For verifying the accuracy of the observations, each soil was packed in two tubes. For eliminating the source of error due to the changing atmospheric conditions two tubes were filled with water only. They were daily refilled to the same level. All the tubes were kept in an open space so that evaporation may occur under similar atmospheric conditions. The weights of the tubes were regularly observed, till no reduction in their weights could be detected. The following conclusions were drawn from these observations :—

(1) During the initial stages of evaporation, the intensity of evaporation was practically the same in all the cases. It was independent of the grade, as well as of the depth of the soil column and was equal to that from a plane water surface.

(2) No difference in the respective rates of evaporation of the four finer grades could be detected, in case of 5 cm. deep soil columns, even when they get air dried. From the coarsest grade viz 2.5 mm. the intensity of evaporation at lower moisture contents became less than that from others.

(3) In case of 15 cm. deep soil columns the intensity of evaporation from the coarsest grade (2.5 mm.) became less than that from the finer ones after a few days. For all other grades the rates were equal, though somewhat less than that from a water surface. Later on 1.0 mm. grade began to show signs of lesser intensity of evaporation but from the other three grades the rates remained practically the same even up to the lowest moisture content.

(4) The effect of particle size upon the intensity of evaporation was much more pronounced for 30 cm. soil column. Here with lapse of time, three grades showed difference in the respective rates of evaporation, one after another. The finest grade of silt, viz 0.10 mm. and the soil did not show any difference in their intensities of evaporation, even up to the lowest moisture content.

These observations go to show that the intensity of evaporation, from a moist soil column, does depend upon the grade of the soil, provided appropriate depth of the soil column is taken.

As, in nature, the soil crust is generally stratified, the effect of heterogeneity on the intensity of evaporation from moist soil columns was studied next.

Two sets of experiments were performed. In one, the movements of the watertable, as evaporation proceeded from saturated soil columns composed of two different grades, was observed, while in the other the loss in moisture from similarly composed soil columns was noted.

Excepting one point, the same experimental technique and procedure as employed for homogeneous soil columns for studying the movement of the watertable, was used. The soil column was composed of two grades, the upper one being finer than the lower one. Four different thicknesses of the upper stratum were tried. The mean diameter of the silt of the upper stratum was 0.10 mm. while the mean diameter of the silt of the lower stratum was 2.0 mm. The main observations are given below :—

(1) As evaporation proceeded, there was an abrupt fall in the water table, its rate being characteristic of the upper grade only.

(2) After a few hours evaporation, the following watertable began to rise at a rate much more rapid than the rate of fall, though water was being lost from the soil column.

(3) The greater the thickness of the upper stratum, the greater the depth to which watertable would depress before it started rising up.

The time after which the reversal occurred was a function of the thickness of the upper stratum, the greater the thickness, the greater the time taken by it.

(4) The watertable underwent a series of reversals, till finally they subsided. For the smallest thickness *viz.* one cm. they lasted for a few days, while for 10 cm thickness the reversals continued for a few weeks.

(5) The final level assumed by the watertable, as reversals ceased, was a function of the grade of the lower stratum. In every case its depth below the surface of the lower stratum was the same *viz.* about 12 cms.

(6) After the subsidence of the reversals, the rate of depression was very very slow, being equal to about one cm. in one month.

From such observations it was deduced that ;

- (i) The behaviour of the watertable, when it moves in a heterogeneous medium becomes abnormal. It may show a rise even when moisture is being lost from the subsoil, or *vice versa*.
- (ii) It is the radii of curvature of the menisci lying at the top portion of the capillary fringe, which affect the movements of the watertable directly. So long as the menisci move within a non-stratified soil-crust, the watertable behaves in a normal way and its movements can be predicted, but as soon as they come across a different stratum, the capillary height of which varies from that of the first one, it may be from (a) one soil type to another (b) soil to air (c) soil to water ; it is very difficult to analyse its behaviour.

The stratification of the subsoil crust can be one of the factors that cause fluctuations in the watertable. The abnormal behaviour of wells may also be due to heterogeneity in the water-bearing strata.

Effect of perforated bore pipe on the movement of the watertable initially saturated stratified soil columns, the lower strata being coarser than the upper one, as evaporation proceeds from the latter.

In case of homogeneous or non stratified soil columns the effect of this factor was also examined and no difference in the results obtained with blind and perforated bore pipe could be detected. A similar experimental procedure was adopted, excepting one point. The soil column was composed of two strata, the upper stratum, about two inches thick, consisted of a fine silt having a mean diameter of 0.10 mm., while the lower stratum, about 58 inches thick, was composed of a coarse sand of mean diameter 1.0 mm. The perforated bore pipe was simulated by a brass strainer, 2 mm. in bore, which kept embedded in the soil column as before.

As evaporation started, the watertable began to fall abruptly, its rate of fall being characteristic of the upper grade. After the water table had depressed by a certain amount, viz. 16 cm. from the top of the upper stratum and 11 cm. from that of the lower stratum in this case, it would rise up, though only by a few mm. Again it would depress, but suffer a reversal at about 16 cm. depth once more. It would continue playing within the range for a considerable time. The depth at which the reversal occurred was a function of the lower grade. Whatever the thickness of the upper stratum, it would always recur at a depth of 11 cm. below the top of the lower stratum. This observation is in contrast to that for a blind pipe, in which case it was not a function of the lower grade, but of both the grade as well as the thicknesses of the upper stratum.

It is clear from this observation that if a bore pipe sunk in a stratified soil crust is fitted with a strainer, the watertable, as shown by the borepipe, would fluctuate to a much lesser extent than that indicated by a blind pipe. But it does not mean that the amount of water added to or deducted from the subsoil can be correctly evaluated from the watertable records taken from perforated bore-pipes alone, when the latter lies in a stratified soil crust.

THE EFFECT OF STRATIFICATION UPON THE INTENSITY OF EVAPORATION FROM SOIL COLUMNS NOT CONNECTED WITH ANY SOURCE OF FREE WATER

Two sets of experiments were performed. In one, the upper stratum was composed of the finer grade, while, in the other, the coarser grade was put at the top. Thus, different combinations of grades were tested. In each set different depths of the soil columns were also tried. For the sake of comparison, intensity of evaporation from homogeneous soil columns, composed of the grades, used in the stratified soil columns, was also determined.

In the first set, 36 tubes, 4 cm. in bore and 5 cm., 16 cm., and 30 cm. in height, were taken. 12 tubes of each subset were filled with a material as given below. In every case the sands were packed under water.

Height of the tube=5 cm.

Tubes No. 1 and 2 contained very coarse sand of mean diameter 2.0 mm.

Tubes No. 3 and 4 contained coarse sand of mean diameter 0.8 mm.

Tubes 5 and 6 contained very fine sand of mean diameter 0.10 mm.

Tubes 7 and 8 contained 2.5 mm. thick layer of very fine sand in the upper layer, and very coarse sand in the lower stratum.

Tubes No. 9 and 10 contained 2.5 cm. thick layer of very fine sand in the upper layer and coarse sand in the lower stratum.

Tubes No. 11 and 12 contained water only.

In the 15 cm. and 30 cm. high tubes similar stuff was filled.

The experimental procedure was similar to that employed for non-stratified soil columns. From the results thus obtained curves for 15 cm. and 30 cm. were drawn, taking the losses in moisture from the plain water surface and the soil columns as abscissae and ordinates respectively. The curves (a), (b) and (c) represent the losses from 15 cm. tubes for very coarse, coarse and very fine sand respectively, Figure 5A.4, while (d) and (e) are drawn for the stratified soil columns, in which very coarse sand and coarse sand form the lower stratum. Similar curves have been drawn for the 30 cm. tubes, Figure 5A.5.

As evaporation is believed to be a surface phenomenon, it was expected that evaporation losses would occur according to the structure of the upper stratum only. The grade of the lower stratum, be it very coarse or coarse sand, would not play any role, throughout the range of the moisture content. According to this view, the curves (d) and (e) would have coincided with (c), which represent the losses from the homogeneous soil column of very fine sand, throughout their ranges. It was, however, found to be only partly true. Up to the point Q, Figure 5A.4 the curves (c), (d) and (e) practically coincided. The intensity of evaporation up to this stage is, therefore, controlled by the grade composing the upper stratum. Beyond Q, the gradient of curve (d) undergoes an abrupt change. The flattening of this curve indicates that the influence of the upper stratum has ceased. The time interval, after which the rate of evaporation alters, suddenly, depends upon other factors remaining equal, the grade of the lower stratum.

The curves (c) and (e) coincide upto the point R, beyond which they also part ways. Beyond the stage corresponding to the point the influence of the upper stratum vanishes. Afterwards, the rate of evaporation becomes much less.

As the curves (d) and (e) are for stratified soil columns, having very coarse and coarse sand as the lower stratum, it follows that the finer the grade of the lower stratum, the longer the range over which these curves coincide with (c) i.e. the longer the duration of time, for which the influence of the upper stratum lasts.

The curves drawn for 30 cm. tubes are given in Figure 5.A5. The character of these curves is similar to that described above.

The main conclusions deducible from these observations are :

- (1) As evaporation proceeds from saturated, homogeneous and stratified soil columns, the upper stratum being composed of finer stuff the intensity of evaporation during the initial stages of evaporation is practically the same for all the cases.
- (2) After a few days' evaporation, the intensity of evaporation from homogeneous soil columns, composed of coarser grades turn by turn, becomes less than that from finer grades, but in case of stratified soil columns, it remains the same, irrespective of the grade composing the lower stratum, being equal to that from a homogeneous soil column composed of the grade forming the upper stratum in stratified soil columns.
- (3) During the later stages, the intensity of evaporation from the stratified soil columns also begin to vary.

The time interval, after which it decreases, is a function of the grade forming the lower stratum. The finer the soil, the greater the time taken. The decrease in the rate of evaporation occurs abruptly in every case.

In the second set of experiments the upper stratum was composed of coarser grade. The thickness of the upper layer was kept about 2.5 cms. in every case. Two depths of soil columns, viz. 5 cm. and 15 cm. were tried and 12 tubes were used for each depth. Each grade was packed in two tubes in order to have an idea of the accuracy of the experiments. For studying the effectiveness of stratification, the intensity of evaporation was also determined from the homogeneous soil columns, composed of the three grades tried in these experiments, viz. very coarse sand, coarse sand and medium sand having mean diameters of 2.0 mm, 0.8 mm and 0.45 mm. respectively. In the stratified soil columns, very coarse sand and coarse sand formed the upper stratum in the two cases, while the medium sand was used for the lower stratum for both of them. The contents of the 15 cm. tubes were similar to those used for 5 cm. tubes.

The experimental procedure was the same as adopted for the first set. The results are shown graphically in Figures 5A.6 and 5A.7. The curves (a), (b) and (c) represent the losses in moisture from homogeneous soil columns composed of very coarse, coarse and medium sand respectively, while (d) and (e) are drawn for the stratified soil columns, in which very coarse and coarse and form the upper stratum respectively.

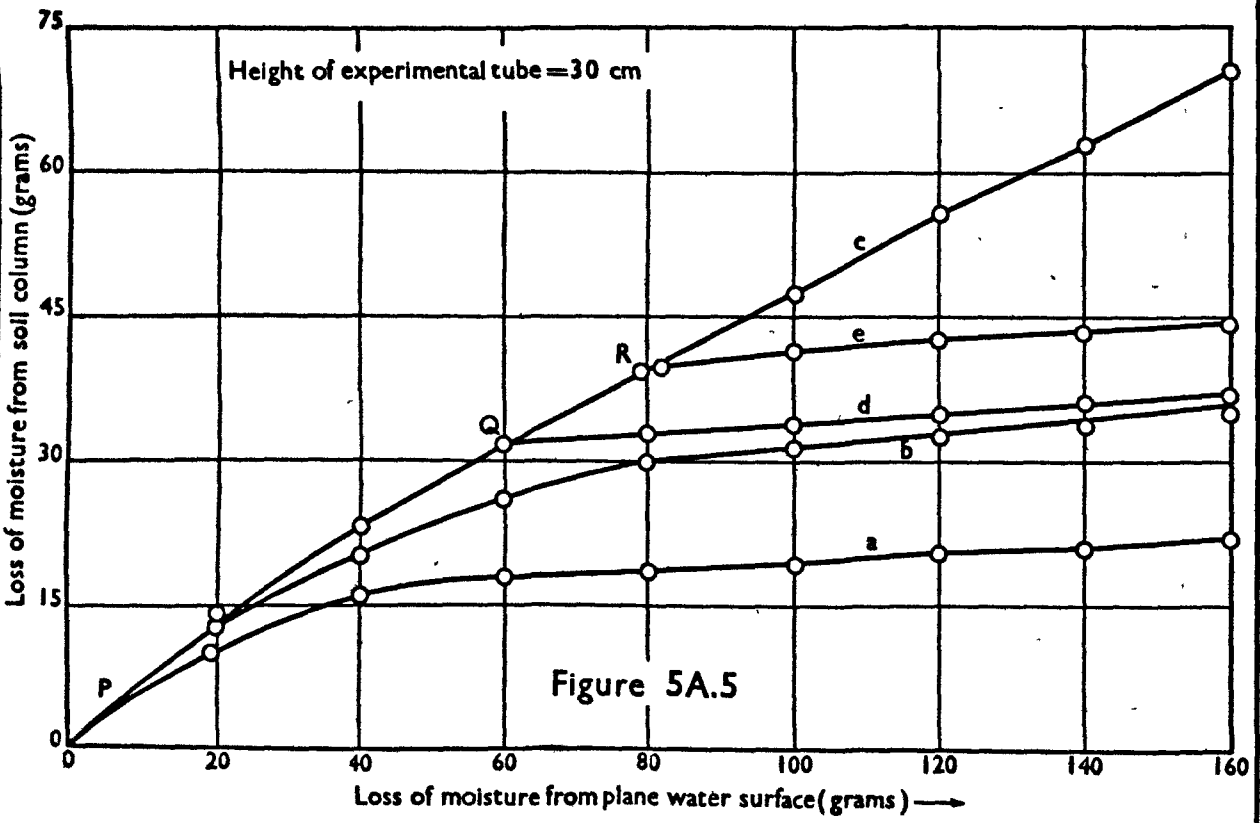
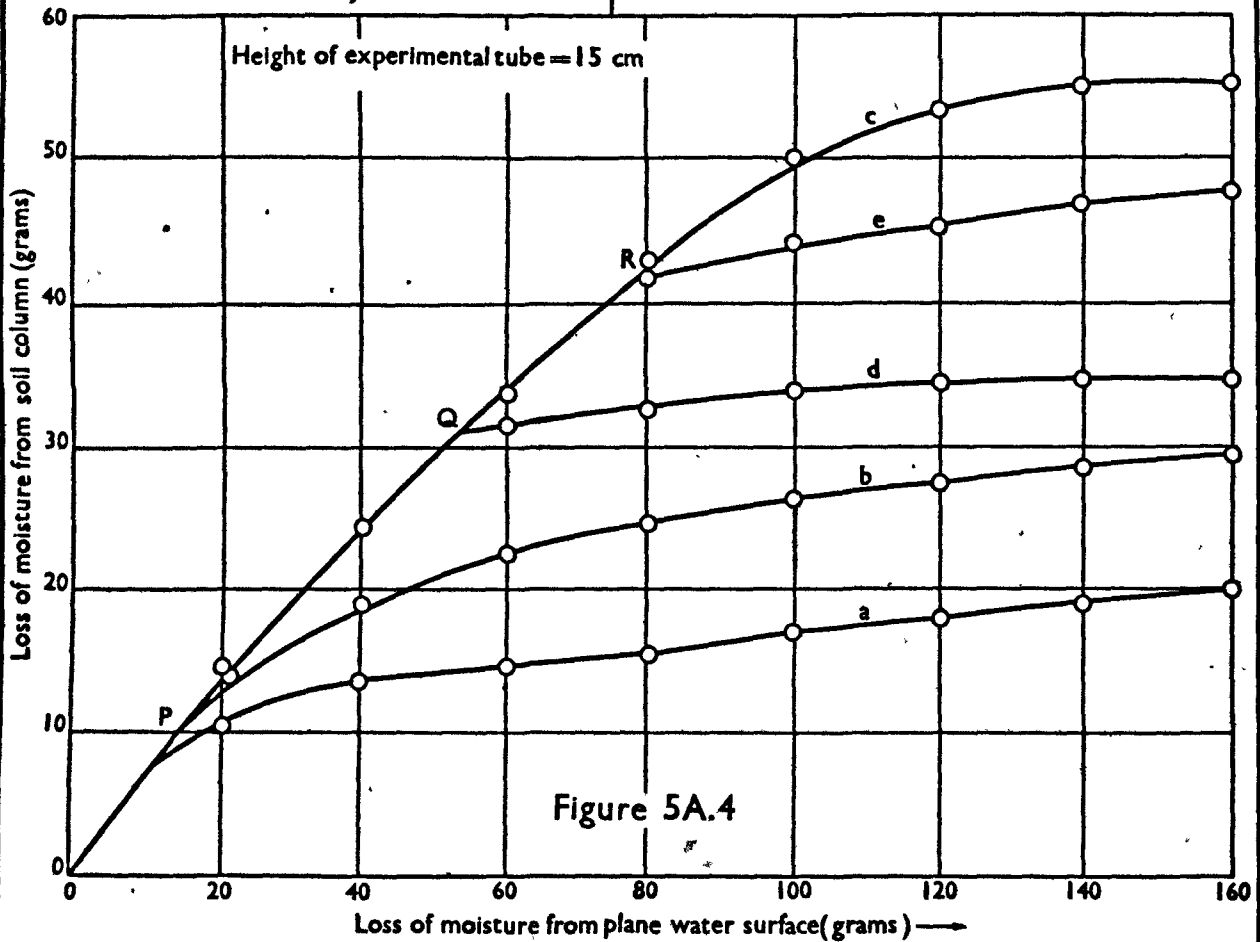
An inspection of the curve shows that, as evaporation proceeds the intensity of evaporation is practically the same for the stratified and the non-stratified soil columns. After a certain time corresponding to the point P, the intensity of evaporation from the stratified soil column, having very coarse sand

Curve a for very coarse sand
 Curve b for coarse sand
 Curve c for very fine sand

Unstratified soil column

References :-

Curve d for very fine sand at top, very coarse sand below
 Curve e for very fine sand at top, coarse sand below



Figures 5A.4 & 5A.5 :- Showing effect of stratification on evaporation losses

References

- Curve a for very coarse sand
 - Curve b for coarse sand
 - Curve c for medium sand
 - Curve d for very coarse sand at the top, medium sand below
 - Curve e for coarse sand at the top medium sand below
- } Unstratified soil column

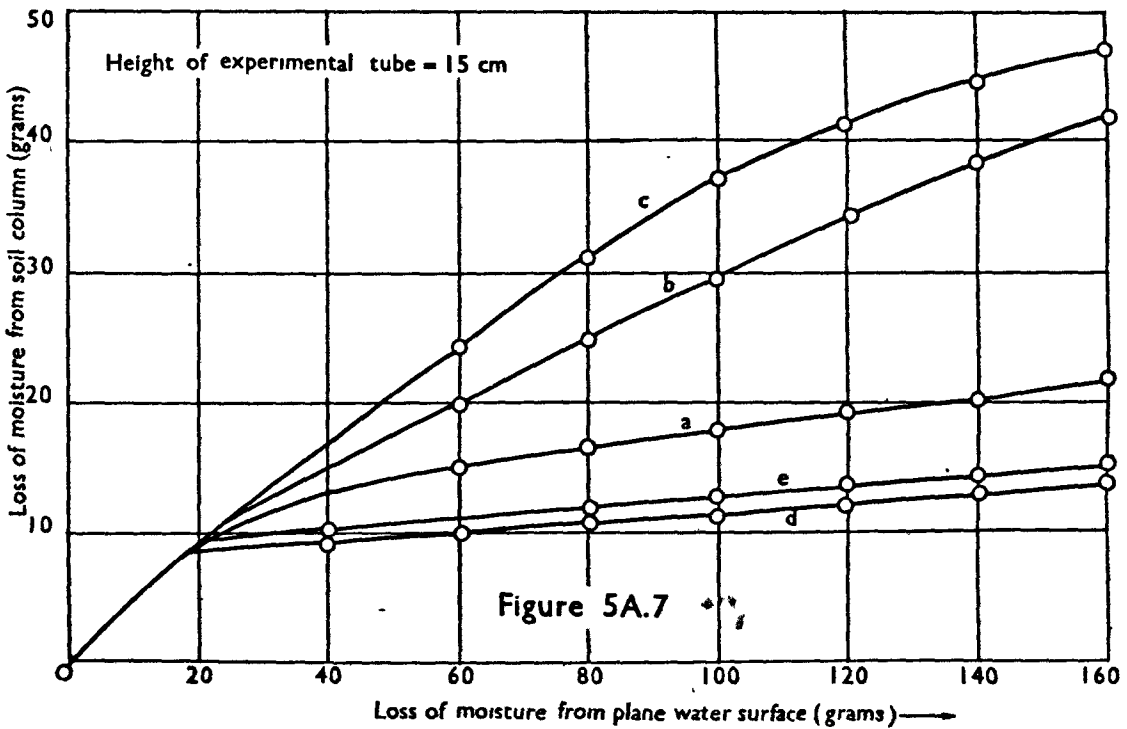
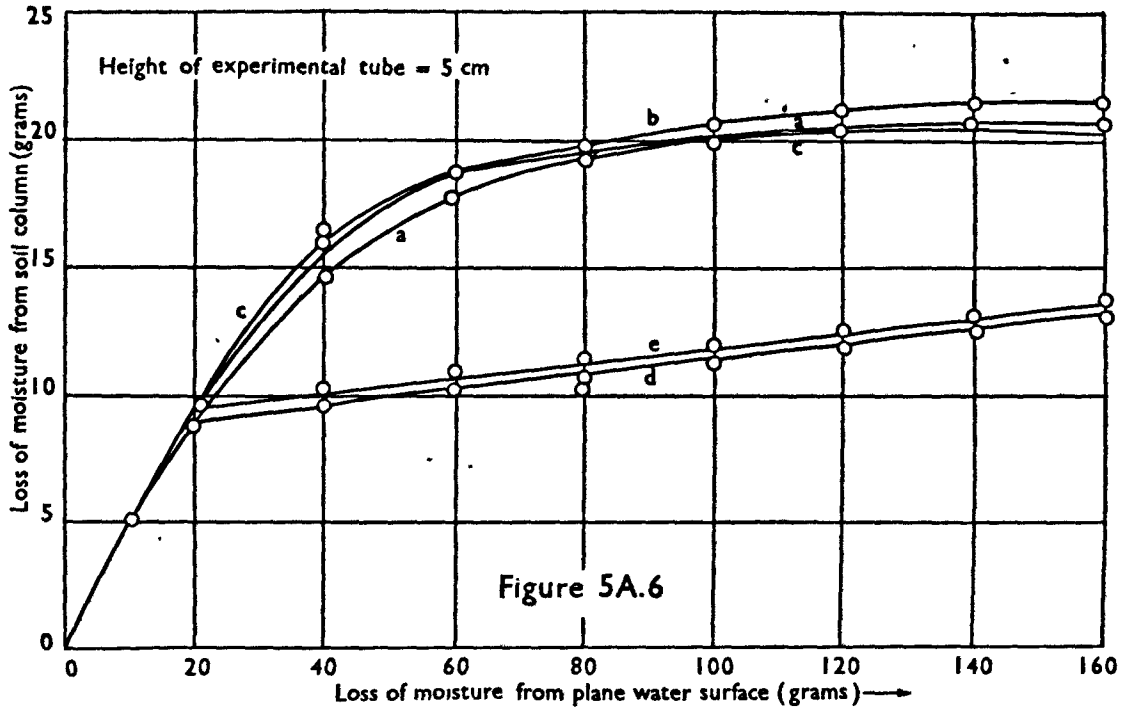


Figure 5A.6 & 5A.7:- Showing effect of stratification on evaporation losses

as its upper stratum, decreases abruptly. After some time corresponding to the point Q, the intensity of evaporation from the other stratified soil column also begins to diminish. The intensity of evaporation from homogenous soil columns remains greater than that from stratified ones for a considerable period. In case of 5 cm. soil columns the respective evaporation rates remained practically equal to one another even up to the lowest moisture content.

In case of 15 cm. soil columns, the intensity of evaporation from stratified soil columns was practically the same as for 5 cm. deep soil columns, though during the final stages of evaporation, the respective rates for homogeneous soil columns of the two depths, viz. 5 cm. and 15 cm. differ from each other.

In case of saturated, homogeneous, and stratified soil columns, having the upper stratum made up of coarser grade, the intensity of evaporation during the initial stages practically the same for all the cases. After a few days' evaporation, it decreased abruptly, in case of one stratified soil columns, though even for homogeneous soil columns of coarser grades, the rate of evaporation was fairly high. After another day, the losses from the other stratified soil column also underwent a sudden decrease. At this stage the coarser grade at the top becomes much less effective in drawing up water from the finer grade by the capillary forces. The greater the difference between the grades composing the upper and the lower strata, the more ineffective it becomes.

It may be mentioned here, that, in certain cases, the moisture which would have been lost by evaporation from a saturated soil column within days, took months to get lost, when that soil type was covered with a coarser stuff.

From the results of both the types of stratification it can be easily seen that the intensity of evaporation from a moist soil is highly influenced by the stratification of the column. For producing stratification it is not essential that two different grades be present in a soil column. It can also be brought about by compacting a soil type to different densities. As a slight stratification can produce a substantial difference in the vaporation losses, the importance of uniformity in packing of soil for such experiments cannot be over emphasised.

(3) EXPERIMENTS CONDUCTED AT KRISHNARAJASAGAR⁽²⁾

Krishnarajasagar is a reservoir having 47 square miles of waterspread area and a storage depth of 124 feet at its full reservoir level.

As the direct determination of the loss due to evaporation from the lake was not possible, observations were conducted jointly by Mysore and Madras Public Works Departments on pans filled with water and installed at the place. Studies were made to find

- (a) whether the evaporation from the lake was the same as that from a pan, and
- (b) whether the size and type of pan had any effect on the result.

⁽²⁾ Hydraulic Research Station, Krishnarajasagar, Annual Report, 1947, pages 2-6.

The apparatus used was a pan open at the top and an indicating mechanism at the centre. Two types of indicators were used, (1) by direct reading in which a needle would indicate the depth on a graduated arc, movement of which was actuated by a float at the centre and was known as the dial pan; (2) by having a needle fixed at the centre, known as the needle pan. In this type, the quantity of water lost at the end of each day by evaporation was determined by filling in the pan again to the level at the commencement with measured quantities of water. Knowing the area of section of the pan, the depth lost in evaporation was computed each day. Correction to rainfall was applied in these pans by noting the rainfall during the period.

At first, the needle pan used was of three feet diameter and dial pan was of six feet diameter. These were floated sufficiently far from the river bank to avoid radiation effects. They were secured by anchors.

Table 5A.V gives the losses as recorded from the two pan.

TABLE 5A.V

Showing the average monthly evaporation loss in inches.

| Month | 1919 | 1920 | 1921 | 1922 | 1923 | 1924 | 1925 | Average | 1922 | 1923 | 1924 | 1925 | Average |
|-----------|-----------------|-------|-------|-------|-------|-------|-------|-------------------|-------|-------|-------|-------|---------|
| | 6 feet dial pan | | | | | | | 3 feet needle pan | | | | | |
| June .. | 6.46 | 6.43 | 4.60 | 6.66 | 7.53 | 6.08 | 7.33 | 6.84 | 6.71 | 8.27 | 6.37* | 7.57 | 7.23 |
| July .. | 4.67 | 4.67 | 4.87 | 4.47 | 4.12 | 4.67 | 4.67 | 4.74 | 5.12 | 4.67 | 5.69 | 5.27 | 5.18 |
| August .. | 4.78 | 4.78 | 4.78 | 4.09 | 4.75 | 4.78 | 5.86 | 4.88 | 4.65 | 5.24 | 5.51 | 5.19 | 5.15 |
| September | 5.75 | 5.75 | 4.78 | 5.75 | 6.09 | 5.75 | 5.87 | 5.80 | 6.03 | 6.93 | 6.73 | 6.28 | 6.48 |
| October | 6.03 | 5.88 | 5.07 | 4.67 | 6.44 | 6.00 | 7.05 | 6.18 | 5.87 | 7.51 | 7.27 | 7.61 | 7.07 |
| November | 5.62 | 5.43 | 5.35 | 3.88 | 6.48 | 5.27 | 5.24 | 5.42 | 4.20 | 7.33 | 6.15 | 5.71 | 6.35 |
| December | 5.27 | 5.51 | 5.99 | 4.60 | 6.08 | 5.84 | 4.48 | 5.49 | 6.02 | 6.95 | 6.57 | 4.03 | 6.10 |
| January | 4.96 | 5.58 | 7.14 | 4.81 | 4.54 | 5.86 | 5.51 | 5.63 | 6.28 | 6.34 | 6.95 | 5.70 | 6.31 |
| Total .. | 43.74 | 44.03 | 42.58 | 39.93 | 46.03 | 44.45 | 46.01 | 44.98 | 44.88 | 53.22 | 51.23 | 47.36 | 49.87 |

As there was wide difference between the results of the two pans, to study, whether size of the pan has any effect on the amount of evaporation a pan of

six feet diameter of the needle type was floated along with the other two. Table 5A.VI gives the loss as noted on the six feet diameter needle pan.

TABLE 5A.VI

Six feet diameter needle pan.

| Month | 1925 | 1926 | Average |
|-------------------|-------|-------|---------|
| June | 6.96 | 8.09 | 7.52 |
| July | 5.58 | 5.30 | 5.44 |
| August | 4.95 | 4.95 | 4.95 |
| September | 4.98 | 6.06 | 5.52 |
| October | 7.27 | 6.37 | 6.82 |
| November | 5.14 | 6.25 | 5.65 |
| December | 4.47 | 4.48 | 4.47 |
| January | 5.83 | 5.35 | 5.59 |
| Total | 45.18 | 46.78 | 45.96 |

Table 5A.VII gives a comparative statement of average losses from the three pans

TABLE 5A. VII

| Month | Three feet needle pan | Six feet needle pan | Six feet dial pan |
|-------------------|-----------------------|---------------------|-------------------|
| June | 7.23 | 7.52 | 6.84 |
| July | 5.18 | 3.44 | 4.74 |
| August | 5.15 | 4.95 | 4.88 |
| September | 6.48 | 5.52 | 5.80 |
| October | 7.07 | 6.32 | 6.18 |
| November | 6.35 | 5.65 | 5.42 |
| December | 6.10 | 4.47 | 5.49 |
| January | 6.31 | 5.59 | 5.63 |
| Total | 49.87 | 45.96 | 44.98 |

The six feet diameter pans give results fairly in close agreement. Thus, it illustrates that the size of the pan has influence on the amount of loss and not the type of pan. According to the observations of the U.S. Department of Agriculture, the evaporation from a pan of two feet diameter is 75%, from a pan of

four feet diameter 50%, and from a pan of six feet diameter 38% greater than that from a big pond or lake. According to this calculation, a three feet diameter pan should give 65% in excess of the true value. The ratio of losses as recorded between six feet diameter and three feet diameter pans would be 13:16.5. The results as observed at Krishnarajasagar give 44.98:49.89 or ratio of 9:10.

It was settled that for calculation of evaporation from the reservoir a correction coefficient of 0.85 to the results obtained from pan experiments should be used. The figures in Table 5A.VIII give the loss due to evaporation in inches.

TABLE 5A.VIII

| Month | Total for the month (in inches) | Month | Total for the month (in inches) |
|-------------------|---------------------------------|------------------|---------------------------------|
| June | 5.950 | December | 4.675 |
| July | 4.675 | January | 4.675 |
| August | 4.675 | February | 4.000 |
| September | 4.675 | March | 5.000 |
| October | 5.950 | April | 7.000 |
| November | 4.675 | May | 8.000 |
| | | Total | 63.950 |

Table 5A. IX gives the losses at different places recorded by three feet diameter pan.

TABLE 5A. IX

| Month | Upper Anicut Altitude about 250 feet above sea level | Urachi Altitude about 250 feet above sea level | Dhanagere About 2,200 feet above sea level | K. R. Sagar About 2,400 feet above sea level | Madras Red hill lake |
|-------------------|--|--|--|--|----------------------|
| June | 8.17 | 7.37 | 5.67 | 7.32 | 6.69 |
| July | 7.10 | 5.40 | 4.70 | 5.85 | 5.73 |
| August | 7.22 | 5.25 | 4.84 | 5.59 | 6.50 |
| September | 6.81 | 5.40 | 5.40 | 6.83 | 5.66 |
| October | 4.98 | 5.87 | 6.26 | 7.49 | 4.79 |
| November | 4.26 | 4.95 | 5.69 | 6.54 | 3.97 |
| December | 5.16 | 5.78 | 5.82 | 6.21 | 4.27 |
| January | 5.49 | 5.69 | 6.57 | 6.24 | 4.66 |
| Total | 49.19 | 45.71 | 44.95 | 52.02 | 42.27 |

The temperature range of Krishnarajasagar is 55° F, wind velocity varies from 1.5 miles per hour to 11 miles per hour during a year and the elevation is 2,400 feet above sea level.

These results were further sought to be verified by actually calculating the quantity of water entering and leaving the reservoir. Taking into account the balance of storage at the beginning and end of each month also, it was possible to get at an idea of the quantities lost in evaporation and percolation. It was not possible to separately gauge these two losses in a reservoir, though in the experiments, the losses gauged were only those due to evaporation.

The results shown in Table 5A. X are not significant, due to errors in gauging the quantities received by local rainfall over the reservoir water spread which is 50 square miles in extent, to the varying rates of percolation losses depending on reservoir levels, and due to uncertain quantities of drainage water entering the reservoir from the wet fields of nearly 20,000 acres above it.

TABLE 5A. X

| Months | 1944 | | | 1945 | | | 1946 | | |
|--------------|---|--|---------------------------|---|--|---------------------------|---|--|---------------------------|
| | Evaporation loss in million cubic feet calculated on daily water levels | Evaporation loss as per behaviour of reservoir | Number of impounding days | Evaporation loss in million cubic feet calculated on daily water levels | Evaporation loss as per behaviour of reservoir | Number of impounding days | Evaporation loss in million cubic feet calculated on daily water levels | Evaporation loss as per behaviour of reservoir | Number of impounding days |
| January .. | 433 | 575 | 4 | 250 | 261 | 4 | 187 | 218 | 4 |
| February .. | 341 | 534 | 29 | 192 | 217 | 28 | 151 | 151 | 28 |
| March .. | 399 | 398 | 31 | 214 | 217 | 31 | 168 | 169 | 31 |
| April .. | 476 | 504 | 30 | 229 | 245 | 30 | 208 | 209 | 30 |
| May .. | 339 | 412 | 27 | 192 | 221 | 27 | 171 | 207 | 27 |
| June .. | 307 | 303 | .. | 127 | 139 | .. | 147 | 54 | 6 |
| July .. | 313 | 314 | 15½ | 367 | 428 | 10 | 346 | 417 | 15½ |
| August .. | 509 | 939 | 3½ | 457 | 509 | 2½ | 609 | 534 | 28½ |
| September .. | 366 | 389 | .. | 402 | 389 | Nil | 507 | 292 | 2 |
| October .. | 502 | 459 | 1½ | 410 | 381 | 2 | 505 | 811 | 5½ |
| November .. | 334 | 323 | .. | 280 | 282 | .. | 455 | 404 | 9 |
| December .. | 282 | 299 | ½ | 224 | 220 | .. | 462 | 673 | 12 |

DISCUSSION BY THE RESEARCH COMMITTEE

DR. L. A. RAMDAS introduced item (1) and said that in 1932 there were 3,000 rain gauge stations all over India but there were hardly any evaporimeter. Evaporation was calculated by using Rovers' formula. Highest evaporation was found to be near about Bombay Deccan. Table 5A.II of the report showed the present position and gave a list of stations which should have evaporimeters installed. Self recording evaporimeters were also being developed at Poona. DR. RAMDAS was of the opinion that it was not enough simply to instal evaporimeters. The recording of observations was the most important part.

DR. RAMDAS went on to say that it was necessary to have all types of evaporimeters under comparison by a Central Station like the Central Agricultural Meteorological Observatory at Poona.

If the evaporation per day from a surface of water was E_0 then, evaporation E from a soil surface with the water table or zone of saturation at any depth Z , was given by

$$E = E_0 \times 10^{-XZ}$$

It was easy to find X for different types of soils.

DR. J. K. MALHOTRA introduced item (2) and said that investigation had been carried out on different aspects of the problem. The work was still continuing.

MR. N. S. GOVINDA RAO introduced item (3) and said that the note explained the necessity of standardising evaporation experiments as observations from pans of different diameters gave different results.

MR. J. P. NAEGAMVALA and DR. D. G. KULKARNI described the work being done at the Poona Irrigation and Research Division.

MR. N. S. GOVINDA RAO referred to item (1) and said that evaporation observations had to be standardized. The evaporation observations made in small evaporimeters would be quite different from the evaporation obtained from the surface of a big reservoir surface. The two required to be correlated.

THE PRESIDENT advised Mr. Govinda Rao to refer to American literature. They used different sized pans.

RAI BAHADUR S. D. KHANGAR said that the standard pan was four feet diameter and smaller pans gave higher results.

DR. V. I. VAIDHIANATHAN said that in the Punjab small tubes were used and corrections applied.

MR. J. P. NAEGAMVALA said that he had obtained a significant correlation between evaporation and temperature. Correlation between evaporation and humidity was not significant.

MR. J. C. HARDIKAR in a written communication (read out to the Meeting by the Secretary) said that the scheme proposed by Dr. Ramdas was welcome, as it would supply very useful data to the Irrigation Engineers. The distribution and number of stations proposed compared favourably with the distribution of Weather Bureau stations in U. S. A. MR. HARDIKAR, however, wanted to make a few suggestions to be incorporated in the scheme as drawn up.

They were :—

1. Practically all the stations that are proposed to be provided with devices for measurements of evaporation losses (Tables 5A. III and 5A. IV) are of medium and low altitudes. As height is also an important factor in a study of evaporation losses it is suggested that evaporation measurement devices may with advantage be provided in a few high altitude stations as well where facilities for observations exist. Probably Simla, Mussorie and Darjeeling in the North and Mahabaleshwar and Wai in the South may answer the purpose. These may with advantage be included in Table 5A. III.

2. The experience of Hyderabad laboratories (where all the three types of evaporimeters are installed) is that the record of Piche's evaporimeter is not very accurate. During a period of six days two similarly placed Piche's evaporimeters, but with the filter disc in one being held tightly and in the other loosely were observed. It is found that the average difference in the readings obtained on the two evaporimeters in this period is $5\frac{1}{2}\%$. As it will not be possible to specify the pressure with which the filter disc should be gripped, it cannot, as it stands, be expected to give accurate results even though it may be periodically calibrated with respect to variations in thickness and quality of the filter disc. So for obtaining accurate scientific data I feel that much reliance cannot be placed on Piche's evaporimeter. Hence it is suggested that at all stations in Table 5A. IV, where Piche's evaporimeters alone are proposed to be provided, open pan evaporimeters, either of the U. S. A. or Athavle pattern may be introduced. In other words the stations coming under Table 5A. IV may be incorporated in Table 5A. III.

DR. L. A. RAMDAS in reply to the suggestions by Mr. Hardikar, the suggestion to include a few high level stations would be kept in mind and that the Piche's evaporimeter was quite easy to handle and to adjust. In reply to the President's query he said that Rs. 25,000 would be required to implement the scheme and the instruments would be of Indian manufacture.

THE PRESIDENT enquired if isotherms had ever been drawn. He asked Dr. Ramdas to draw the isotherms month by month and compare them with evaporation lines : the two should be inter-related.

DR. L. A. RAMDAS promised to do so.

MR. T. N. SESHADRI referred to the paper by Dr. Ramdas and said that practically the whole of India was shown as having negative value which was not believable.

THE PRESIDENT said that it was theoretical--if there was water it would be evaporated, if there was no water it could not be evaporated.

MR. T. N. SESHADRI asked the significance of this result.

THE PRESIDENT said that it was the potential evaporating power.

DR. V. K. GOKHALE suggested the investigation of wind velocity as well.

It was decided to recommend to the Board to request the Government of India to place a sum of Rs. 25,000 at the disposal of the India Meteorological Department to cover the cost of equipment required and to sanction the staff required for setting up and looking after the apparatus at about 100 stations and to collect and analyse the data. The results to be obtained from the proposed investigations would be of considerable help in the operation of the multi-purpose projects already constructed or proposed to be constructed and in the development of Agriculture.

DISCUSSION BY THE BOARD

THE SECRETARY described the work done at the Research Committee meeting, and read out the resolution adopted by the Research Committee.

DR. S. K. BANERJI said that many formulae had been worked out. He thought that Dr. Ramdas's formulae were only theoretical. Whether those were really supported by factual observations had yet to be determined.

DEWAN BAHADUR N. GOVINDARAJA AYYANGAR said that in a book which was supplied some 15 or 20 years back, the observations and the formulae fitted into them were given side by side. He thought that the actual figures had been compiled at one site only.

DR. S. K. BANERJI said that it was not easy for any department to set up an evaporimeter at a moment's notice. It should be understood that when a proposition of the kind referred to in the resolution was made, it has to be progressively developed in 3, 4 or 5 years.

DEWAN BAHADUR N. GOVINDARAJA AYYANGAR said such observations were being made in the Tungabhadra now.

THE CHAIRMAN (RAO BAHADUR A. R. VENKATACHARI) asked the house if they accepted the resolution of the Research Committee as it was.

The resolution was accepted.

(iii) Regeneration

PRELIMINARY NOTE

This subject has been on the agenda since 1945. A number of interesting papers have been discussed at various times but so far it has not been possible to lay down any general principles governing regeneration and absorption in channels.

The following items were discussed at the 1947 meeting of the Research Committee :—

1. Regeneration of the river Yamuna above Okhla.
2. Return flow by Seepage into the natural drainage in canal area.

THE YEAR'S WORK

The following item was discussed at the 1948 meeting of the Research Committee :—

(1) Regeneration on the Hindan river.

(1) REGENERATION ON THE HINDAN RIVER ⁽³⁾

As a result of detailed quantitative analysis of several Doabs, a case of overpumping was established in 1943, *vide* Annual Research Report for 1942-43, in the Doab between Krishna and Hindan and it was suggested that water table will continue to go down in the Doab unless the rate of pumping was reduced. The river Hindan passes through a tract which is subjected to intense tube-well pumping and it is considered likely that the regeneration in this river may be affected significantly as a result thereof.

It is evident that if the pumping in the interior is limited to annual recuperation due to rainfall—the regeneration which seems mostly dependent on bank storage as a result of local rainfall as against percolation due to monsoon floods borne out *vide* page 88, Technical Memorandum No. 17—would not be affected at all due to pumping. However as overpumping in the vicinity of Hindan was clearly indicated earlier and is now statistically established *vide* the note on "Effect of Pumping", a watch on the regeneration of Hindan and study is clearly indicated. A correlation analysis between regeneration and monsoon rainfall has been carried out accordingly for both pre-tubewell and tube-well periods.

Regeneration of the river Hindan was worked out for a length of about 100 miles from its source near Dehra Dun to the head of Hindan Cut near Delhi. The water escaped through Jani Escape, which is again taken off *via* Hindan Cut to feed the Agra Canal is also taken into consideration and deducted from the total supplies as gauged at the head of the Hindan Cut. The former is measured at the Tikri Fall at mile 5 of Jani Escape and the latter at the head of Hindan Cut. Table 5A. XI gives figures for average daily regeneration at the head of the Hindan Cut from year to year (separately for pre-tubewell period, 1935-36 to 1936-37 and tube-well period, 1936-37 to 1945-46) for the fair weather months of November to May. Monthly and annual mean regenerations have been given in the same statement. It may be seen that monthly mean regeneration is generally slightly higher during pre-tubewell period, mean annual regeneration per day being 558 cusecs for the latter as compared to 493 cusecs for the tubewell period.

³⁾ United Provinces Irrigation Research Station, Annual Report on Research Progress for 1947, pp 25—27.

TABLE 5A. XI

Statement showing average daily regeneration in the Hindan River between Jani escape at M.5 Tikri fall and head of Hindan Cut in cusecs.

| Years | November | December | January | February | March | April | May | Mean |
|-----------------------------|-----------------------------|----------|---------|----------|-------|-------|------|------|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| (a) For pre-tubewell period | | | | | | | | |
| 1916-17 | 382 | -184 | 756 | 1,613 | 1,315 | 969 | 958 | 830 |
| 1917-18 | Complete data not available | | | | | | | |
| 1918-19 | Ditto. | | | | | | | |
| 1919-20 | 547 | 1,166 | 1,435 | 1,303 | 1,322 | 407 | 193 | 910 |
| 1920-21 | 878 | 1,212 | 1,073 | 1,148 | 1,073 | 373 | -101 | 765 |
| 1921-22 | 156 | 744 | 570 | 462 | 42 | 88 | -49 | 288 |
| 1922-23 | -6 | 854 | 264 | 644 | -965 | 341 | 55 | 170 |
| 1923-24 | 623 | 1,225 | -456 | -428 | 458 | 682 | 329 | 347 |
| 1924-25 | 76 | 40 | 29 | 49 | 322 | 124 | 480 | 160 |
| 1925-26 | 413 | 673 | 1,529 | 554 | 667 | 566 | 547 | 707 |
| 1926-27 | 382 | 617 | 1,025 | 1,437 | 1,104 | 421 | 84 | 724 |
| 1927-28 | 542 | 1,182 | 875 | 1,115 | 599 | 149 | 117 | 654 |
| 1928-29 | -60 | 332 | 514 | 565 | 375 | 127 | 38 | 270 |
| 1929-30 | 137 | 528 | 213 | 70 | 489 | 244 | 70 | 250 |
| 1930-31 | Complete data not available | | | | | | | |
| 1931-32 | 638 | 751 | 517 | 679 | 489 | 630 | -12 | 527 |
| 1932-33 | 1,195 | 1,153 | 1,026 | 867 | 1,066 | 886 | 730 | 989 |
| 1933-34 | 88 | 746 | 972 | 977 | 785 | 785 | 390 | 678 |
| 1934-35 | 1,500 | 1,370 | 1,082 | -294 | 316 | 480 | 189 | 663 |
| 1935-36 | 679 | 719 | 603 | 599 | 492 | 357 | 430 | 554 |
| Mean | 463 | 772 | 707 | 668 | 585 | 449 | 262 | 558 |
| (b) For tubewell period | | | | | | | | |
| 1936-37 | 676 | 814 | 759 | 872 | 553 | 337 | 457 | 638 |
| 1937-38 | 629 | 601 | 809 | 717 | 571 | 228 | 399 | 565 |
| 1938-39 | 517 | 394 | 383 | 353 | 473 | 325 | 103 | 364 |
| 1939-40 | 353 | 335 | 405 | 622 | 272 | 341 | 97 | 346 |
| 1940-41 | 248 | 251 | 468 | 438 | 257 | 179 | 45 | 269 |
| 1941-42 | 343 | 255 | 456 | 469 | 440 | 251 | 114 | 334 |
| 1942-43 | 958 | 813 | 774 | 669 | 445 | 402 | 259 | 617 |
| 1943-44 | 759 | 659 | 773 | 846 | 336 | 573 | 423 | 624 |
| 1944-45 | 653 | 510 | 794 | 487 | 438 | 400 | 458 | 534 |
| 1945-46 | 567 | 873 | 775 | 665 | 671 | 464 | 452 | 638 |
| Mean | 570 | 551 | 640 | 614 | 446 | 350 | 281 | 493 |

For considering rainfall over the tract, six rainfall stations were considered *vide* Table 5A. XII. All the stations are marked in Figure 5A. 8.

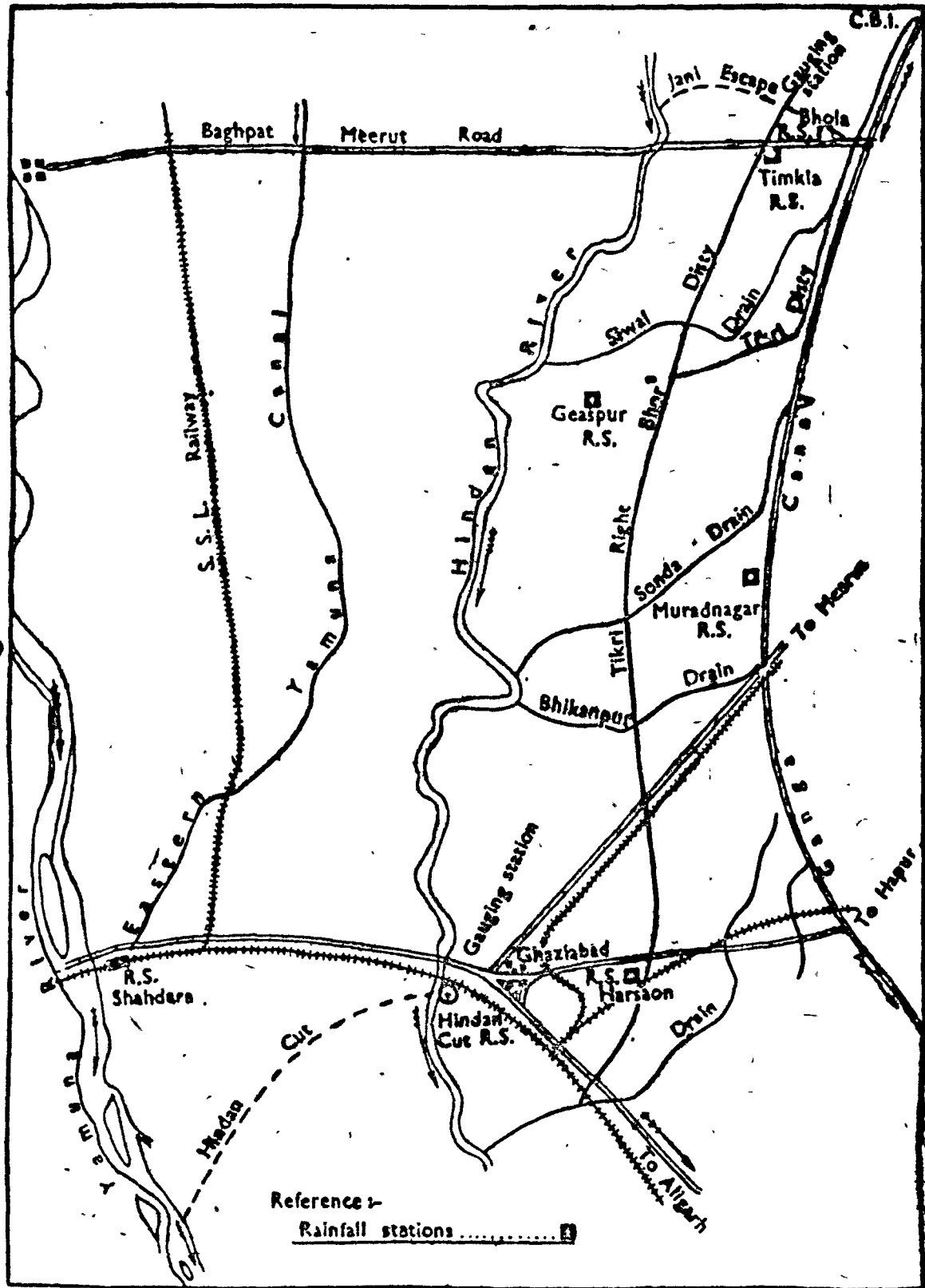


Figure 5A. 8 : Showing catchment area of Hindan river and canals between Jani escape and Hindan cut.

TABLE 5 A. XII

Statement showing monsoon rainfall in inches for rainfall stations situated on sides of the Hindan River, between Jani escape at M-5, Tikri fall and head of Hindan cut for (a) pre-tubewell period and (b) tubewell period.

| Serial No. | Name of rainfall station | (a) For pre-tubewell period | | | | | | | | | | | | | | | | General mean | (b) For tubewell period | | | | | | | | | | General mean | |
|------------|--------------------------|-----------------------------|------|-------|------|------|-------|-------|-------|-------|-------|------|------|-------|-------|-------|-------|--------------|-------------------------|-------|------|-------|------|-------|-------|-------|-------|-------|--------------|-------|
| | | 1916 | 1919 | 1920 | 1921 | 1922 | 1923 | 1924 | 1925 | 1926 | 1927 | 1928 | 1929 | 1931 | 1932 | 1933 | 1934 | | 1935 | 1936 | 1937 | 1938 | 1939 | 1940 | 1941 | 1942 | 1943 | 1944 | | 1945 |
| 1 | Bhola .. | 40.30 | 9.3 | 21.3 | 35.9 | 26.8 | 27.0 | 24.0 | 24.1 | 18.6 | 16.0 | 8.6 | 6.9 | 15.3 | 20.3 | 29.2 | 25.4 | 16.3 | 35.15 | 20.8 | 9.25 | 12.05 | 9.95 | 11.35 | 42.9 | 21.1 | 27.5 | 59.0 | | |
| 2 | Timakia .. | .. | .. | .. | .. | .. | .. | .. | .. | 24.5 | 13.9 | 8.8 | 7.5 | 15.6 | 19.3 | 37.8 | 19.0 | 18.9 | 22.6 | 23.4 | 6.45 | 9.2 | 10.3 | 6.6 | 29.9 | 12.9 | 20.1 | 24.8 | | |
| 3 | Geaspur .. | .. | .. | .. | .. | .. | .. | .. | 13.7 | 28.9 | 9.3 | 12.9 | 10.2 | 15.5 | 19.2 | 35.4 | 28.3 | 15.0 | 19.3 | 16.3 | 8.8 | 9.9 | 11.5 | 5.4 | 24.2 | 14.4 | 11.2 | 30.96 | | |
| 4 | Murad-nagar .. | .. | .. | .. | .. | .. | .. | .. | .. | 18.9 | 13.0 | 7.9 | 4.9 | 12.5 | 20.9 | 31.4 | 23.0 | 18.0 | 23.7 | 15.1 | 4.6 | 7.1 | 14.7 | 5.1 | 25.0 | 11.3 | 12.7 | 23.7 | | |
| 5 | Harason .. | .. | .. | .. | .. | .. | .. | .. | 13.0 | 19.8 | 16.0 | 7.6 | 9.4 | 16.1 | 13.9 | 47.3 | 20.0 | 14.1 | 27.6 | 15.7 | 7.1 | 11.0 | 18.2 | 5.7 | 40.28 | 22.1 | 12.3 | 18.8 | | |
| 6 | Hindan cut head | 31.30 | 9.9 | 9.85 | 18.3 | 27.4 | 11.7 | 16.25 | 30.0 | 23.55 | 18.7 | 3.0 | 15.1 | 17.2 | 13.3 | 54.27 | 26.57 | 17.5 | 23.7 | 16.1 | 5.8 | 9.7 | 8.25 | 7.55 | 26.35 | 19.4 | 22.4 | 24.3 | | |
| | Mean .. | 31.30 | 9.6 | 15.58 | 27.1 | 27.1 | 19.35 | 20.43 | 20.27 | 22.38 | 14.48 | 8.13 | 9.0 | 15.37 | 17.82 | 39.23 | 23.71 | 16.63 | 20.12 | 25.34 | 17.9 | 7.0 | 9.83 | 12.15 | 6.95 | 31.44 | 16.87 | 17.7 | 22.54 | 17.77 |

Note.—Monsoon rainfall is considered for the months of June to September.

Monthly mean regeneration figures were next plotted, showing the variation of regeneration from month to month, *vide* Figure 5A. 9. It is interesting to note that pre-tubewell period curve is above that for tubewell period except for November, showing thereby that the regeneration is slightly lower during tubewell period.

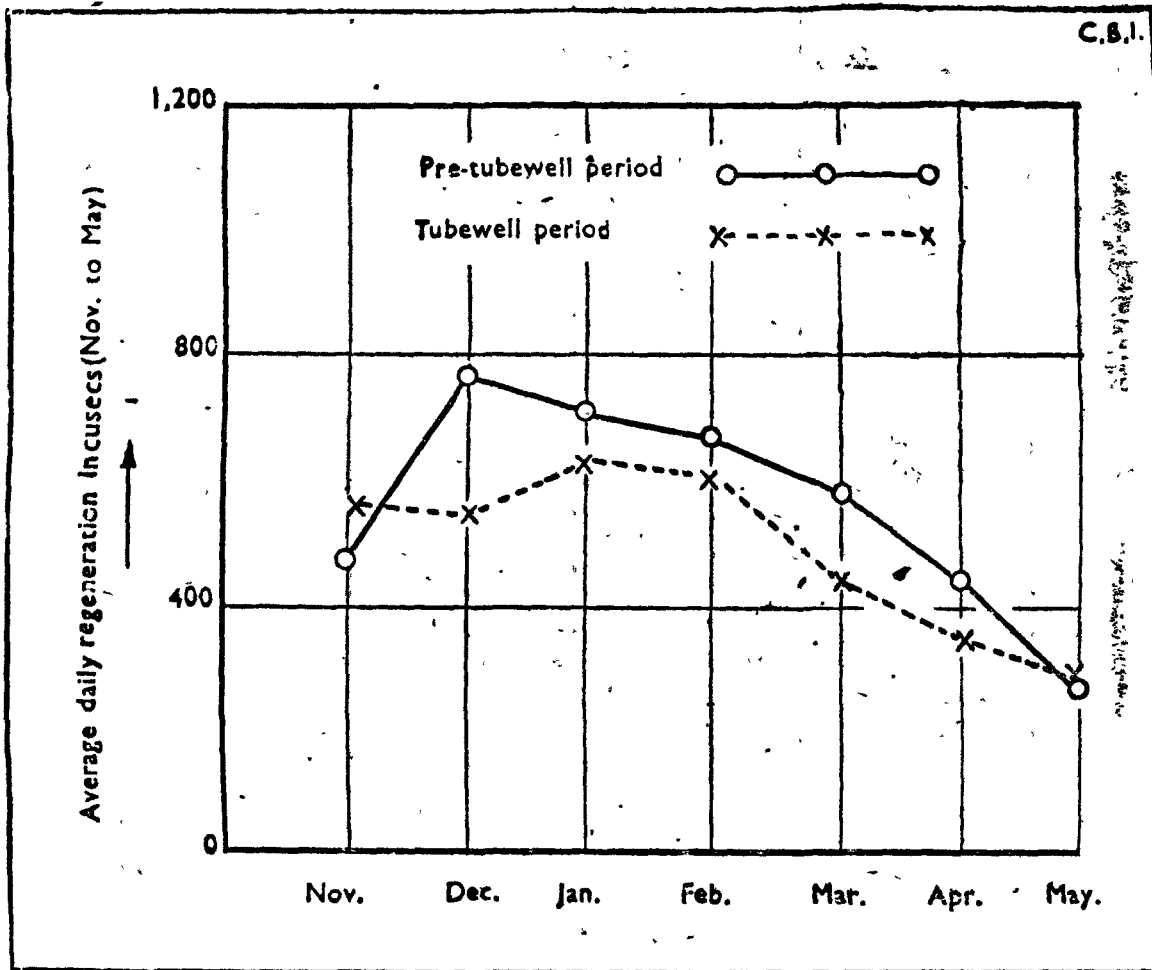


Figure 5A. 9 : Showing average monthly regeneration in Hindan river between Jāni escape at mile 5-0 and head of Hindan cut (a) for pre-tubewell period from 1915-16 to 1935-36 and (b) for tubewell period from 1936-37 to 1945-46.

Average monsoon rainfall over the tract was next plotted against regeneration from November to May in Figure 5A. 10. The two curves again bear out that for the same monsoon rainfall regeneration is somewhat less during tubewell period except for low rainfall figures.

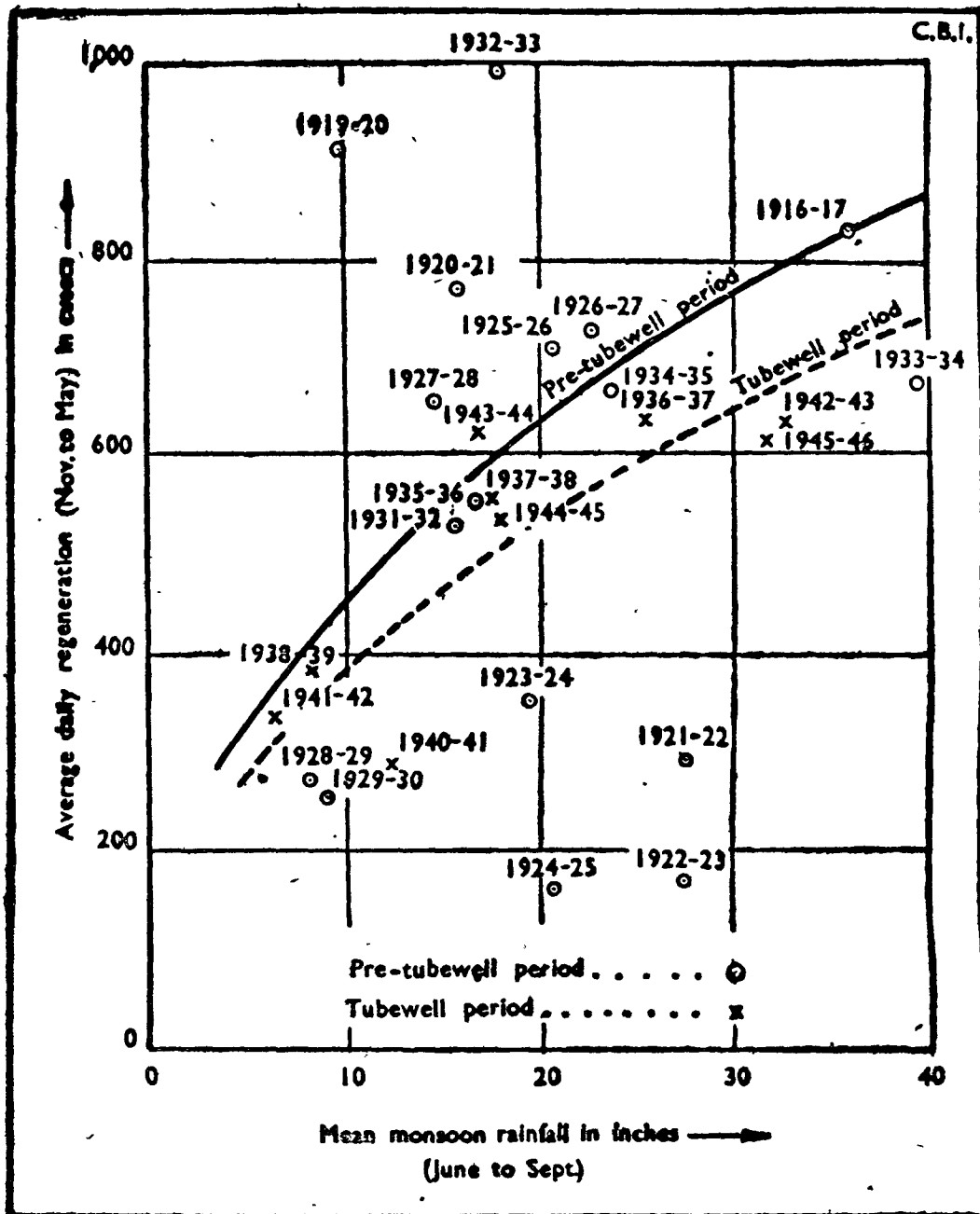


Figure 5A. 10 : Showing relation between monsoon rainfall in inches and average daily regeneration between Jani escape at mile 5-0 and head of Hindan cut (a) for pre-tubewell period from 1916-17 to 1935-36 and (b) for tubewell period from 1936-37 to 1945-46.

It was, however, necessary to confirm the above findings by rigorous statistical investigations. The correlation coefficients between regeneration and monsoon rainfall were found to be 0.2880 and 0.7848 for pre-tubewell and tubewell periods respectively.

Applying Fisher's z -test for transformed correlations, we find that the difference between the two samples does not exceed twice the standard error, and cannot, therefore, be judged significant. There is thus no sufficient evidence to conclude that the correlation between monsoon rainfall and regeneration is significantly different for the two periods, showing thereby that the regeneration is not affected significantly as a result of tubewell pumping.

A more direct approach to the problem has also been attempted by the application of t -test to the set of regeneration figures during pre-tubewell and tubewell periods. The value of t comes to be 0.7122.

From Fisher's tables, for $n=25$, the value of P is between 0.4 and 0.5 and cannot be regarded as significant. This test thus also brings out the fact that the regeneration during tubewell period is not significantly different from that during pre-tubewell period.

CONCLUSIONS

There are some indications regarding a slight decrease in regeneration figures during tubewell period, but the data is not yet sufficient to establish significantly that the regeneration is being affected by tubewell pumping in the vicinity of river Hindan.

DISCUSSION BY THE RESEARCH COMMITTEE

MR. A. P. BHATTACHARYA introduced item (1) and said that the river Hindan passes through a tract in the district of Meerut which is subjected to intense tube-well pumping whose effect on the regeneration of the river was studied to see particularly if it had been significantly affected as a result of tubewell pumping.

Regeneration figures were studied separately for both pre-tubewell period (dating from 1946-47 to 1935-36) and tubewell period from 1936-37 to 1945-46. No statistical evidence could be adduced in support of the hypothesis that regeneration was going down significantly as a result of tubewell pumping, although there were some indications regarding a slight decrease in regeneration figures during tubewell period.

It was decided to keep the subject on the agenda.

DISCUSSION BY THE BOARD

There was no discussion.

6A. Soil Denudation as an Adverse Factor on River Supplies and Agriculture

PRELIMINARY NOTE

At the 1945 meeting of the Board it was decided to keep this subject on the agenda till the Land Utilization Board was established, and it was known exactly what data they required.

At the 1946 meeting of the Board it was unanimously agreed to make recommendations to the Government of India that the Central Board of Irrigation should be represented on the Central Land Utilization Board and also the Policy Committee, which would deal with the report of the Land Utilization Sub-Committee. The Government of India replied that the proposed Land Utilization Board had not yet been formed and that the representation of the Central Board of Irrigation on the said Board was under the consideration of the Policy Committee.

The following resolution was passed by the Board at its 1947 meeting :—

“Whereas soil conservation work is being undertaken in different parts of this country and includes :

- (1) Control of grazing and scraping of grass in, and afforestation waste lands
- (2) Terracing of unirrigated fields
- (3) Reclamation of badly gullied lands
- (4) Torrent training and canalization of smaller streams
- (5) Fixation of shifting sands and
- (6) Application of soil-moving machinery to all these troubles.

“And whereas it is the considered opinion of the Board that this work should be correlated with the activities of other departments engaged in land and water development work, the Central as well as Provincial and State Governments be requested to create, at an early date, suitable coordinating bodies for this purpose.”

The United Provinces Government have formed a Land Management Board consisting of nineteen members to deal with the various problems relating to land utilization under the Post-War Land Management Scheme.

There was no contribution at the 1947 meeting of the Research Committee.

Recent Literature

- (1) Tamhane, R. V.—Crumb Structure as an important factor in soil erosion. *Indian Farming*, Vol. VIII, No. 2, February 1947.
- (2) Downes, R.G.—Tunnelling erosion in North Eastern Victoria. *Journal of Council for Scientific and Industrial Research*, Vol. 19, No. 3, August 1946.
- (3) Shepard, W.—Food or famine—the challenge of erosion. The Macmillan Company, New York, 1946.
- (4) Chhibber, H.L.—The Reclamation of the ravine lands of the Yamuna, United Provinces. *Science and Culture*, Vol. XII, No. 6, December 1946.

(5) Holmes, J. M.—Soil erosion in Australia and Newzealand. Angus and Robertson Ltd., London, 1946.

(6) Protecting soils in the U.S.S.R.—S.S. Sobolay—Soil Conservation, Vol. 13, No. 1, August 1947.

(7) Ellison, W.D.—Soil erosion studies—soil erosion, soil loss and some effects of soil erosion. Agricultural Engineering, Vol. 28, No. 7, July 1947.

(8) Act to make better provision for the combating and prevention of soil erosion and for the conservation, protection and improvement of the field, the soil, the surface of the land, the vegetation and the sources and resources of water supplies in the Union, to amend the Forest Act, 1941 ; and to provide for other matter incidental thereto. Union of South Africa, No. 45, 1946.

THE YEAR'S WORK

DISCUSSION BY THE RESEARCH COMMITTEE

There was no contribution and hence no discussion took place under this subject head at the 1948 meeting of the Research Committee.

DISCUSSION BY THE BOARD

THE SECRETARY said there was no contribution and no discussion on this subject head at the Research Committee meeting. The Central Land Utilisation Board had not been formed by the Government of India so far. It was, however, intimated by the Ministry of Agriculture that five soil scientists sent by the Government of India to U. S. A. had since returned and the best method of utilising their services, was under consideration.

DR. N. K. BOSE wanted to know exactly what was the scope of this subject head.

THE SECRETARY said that this subject was under the main head ' Hydrology ' and should include discussions of the effect of soil denudation on the river supplies. Soil conservation practice as such should be discussed under a separate head.

DR. J. K. MALHOTRA asked if it was possible to demonstrate the effect of the various factors that were enumerated in the resolution adopted last year. He said that Dr. Uppal had proposed a model.

THE SECRETARY asked Dr. Malhotra if he could describe the nature of the model.

DR. J. K. MALHOTRA said that the model would cover something like 200/150 feet, and should yield important results.

RAO BAHADUR A. R. VENKATACHARI said that the Madras Government had recently issued a booklet on Soil Erosion.

DR. J. K. MALHOTRA remarked that similar books had been issued in the Punjab long ago. Dr. R. MacLagan Gorrie, I. F. S. of the Punjab Forest Department, had published a report on " The use and misuse of land " in 1935 and a full fledged volume on " Soil and water conservation in the Punjab " in 1946 while yet another book entitled " Erosion in the Punjab, its causes and cure " by Sir Harold Glover, I.F.S., Chief Conservator of Forests had appeared in 1944.

7A. Sub-Terranean Waters

PRELIMINARY NOTE

This is a new subject head introduced in 1947. The following sub-heads previously falling under "Tubewells" have been brought under the above subject head: (i) Yield (ii) Effects of pumping, (iii) Recharging the underground basin and (iv) Evaporation and transpiration losses.

(i) Yield

PRELIMINARY NOTE

The following item was discussed at the 1947 Research Committee Meeting:—

(1) Transmission co-efficient of sand samples taken between ground level and 12 feet depth from three test borings and its verification with transmission co-efficient obtained from yield tests results in the Damodar river at Sindri.

Recent Literature

(1) Cady, R. C. and Scherer, O. J.—Geology and ground water resources of Box Butte County, Nebraska.—United States Department of the Interior, Geological Survey, Water Supply Paper 969, 1946.

(2) Auden, J. B.—Suggestions for future studies on ground water in India—Geological Survey of India, March 1946.

(3) Gulhati, N. D.—Note for the third meeting of the Planning Committee for Geophysics Institutions in India—The Central Board of Irrigation, Simla, 1946.

(4) Auden, J. B.—Report on ground water conditions in the Quetta Basin—Geological Survey of India.

(5) The ground water resources of the glacial deposits in the vicinity of Canton, Ohio, State of Ohio, Ohio Water Resources Board—Department of Public Works, Bulletin No. 3, Columbus, Ohio, June 1946.

(6) Boswell, P. G. H.—Some aspects of the geology of water supply—Science Progress, Vol. 34, No. 135, July 1946.

(7) Youngquist, C. V.—Ohio's Water Resources—Ohio State University Studies, Engineering Series, Engineering Experiment Station, Circular 48, Vol. XV, No. 1, May 1946.

(8) The Water Resources of Tuscarawas County, Ohio. Department of Public Works, State of Ohio, Ohio Water Resources Board, Bulletin No. 6, May 1947.

(9) Geology and ground water resources of the Wellton—Mohawk Area Yuma Country, Arizona, April 15, 1947.

(10) Krul, W. F. J. M. and Lieftrinck, F. A. Research in Holland—recent ground water investigations in the Netherlands. Elsevier Publishing Co., Inc., New York, 1946.

(11) Bernhagen, R. J.—Ground water in Ohio—Reprinted from the Ohio State University, Engineering Experiment Station News, Vol. 19, No. 2, April 1947.

(12) Sitz, M.—On the flow of ground waters—International Conference on Soil Mechanics and Foundation Engineering, Rotterdam, 1948, Vol. II.

THE YEAR'S WORK

DISCUSSION BY THE RESEARCH COMMITTEE

There was no contribution and hence no discussion took place under this sub-head at the 1948 meeting of the Research Committee.

DISCUSSION BY THE BOARD

DR. S. K. BANERJI said that all available information on sub-terranean waters was being collected together and published by the India Meteorological Department. He wanted to know if any other organisation too was collecting the information:

THE SECRETARY said that the Central Ground Water Organisation was doing this work.

(ii) EFFECTS OF PUMPING

PRELIMINARY NOTE

There was no contribution under this head at the 1947 Research Committee Meeting.

Recent Literature

(1) Summary of ground water conditions in Ohio, State of Ohio, Department of Public Works, Water Resources Board, Bulletin No. 5, March 1947.

(2) Glossop, R. and Collingridge V. H.—Notes on Ground Water lowering by means of filter wells. International Conference on Soil Mechanics and Foundation Engineering, Rotterdam, 1948, Vol. II.

THE YEAR'S WORK

The following items were discussed at the 1948 meeting of the Research Committee.

- (1) A statistical study of the behaviour of water table in *Doabs* 1 and 2 of the Meerut Tubewell Division.
- (2) Cone of depression in deep soil areas.

(1) A STATISTICAL STUDY OF THE BEHAVIOUR OF WATER TABLE IN DOABS 1 AND 2 OF THE MEERUT TUBEWELL DIVISION ⁽¹⁾

ABSTRACT

An analysis had been carried out in 1942-43 for *doabs* of Tube-well Division, Meerut, with a view to investigating the effects of tube-well pumping on the sub-soil water table, *vide* Annual Research Report for 1942-43. It was found quantitatively that overpumping was being done in *Doab* No. 2, where further development was liable to permanently lower the water table. Because of the meagreness of the data no statistically significant evidence of overpumping could, however, be adduced at that time. It so happened that the years 1937-38 to 1940-41 immediately prior to the period which was taken into consideration for the previous analysis were consecutive ones of drought—a rather abnormal phenomenon. The subsequent years have, however, witnessed quite normal and above normal rainfall, and pumping has also been further developed since then. It

⁽¹⁾ United Provinces Irrigation Research Station, Report on Research Progress during 1947, Pages 3--37.

was, therefore, thought interesting to study the behaviour of the water table statistically in the same area in the light of the latest available data, confining our attention to *Doabs* No. 1 and 2, where the most intense tube-well irrigation was being done.

Records of rainfall and readings of spring levels were available from the year 1920-21 and of volume of water pumped from tube-wells from 1935-36 or *Doab* No. 1 and from 1936-37 for *Doab* No. 2.

No weights were given to the figures for rainfall for the different stations in the *doab* in calculating mean rainfall, as the latter was found to be fairly uniform in the statistical sense of the term. Readings of spring levels were obtained from registers and the rise (or fall which was taken to be negative) δd , from May to the following May was found for every well. Mean value of δd was next calculated for every line of observation wells, from which the weighted mean value of δd for the *Doab* was found. The volume of water pumped was calculated from the registers for tube-wells which gave figures for the discharge of every tubewell and the number of hours of pumping. Figures for the above may be seen from the consolidated statement in Table 7A. I which is for tube-well period only.

TABLE 7A. I

Statement showing rainfall, fluctuation of water table and volume of water pumped for Doabs west of the Ganges Rivers.

| DOAB No. 1 (Hindan and Eastern Jumna Canal) | | | | DOAB No. 2 (Krishni and Hindan River) | | | Remarks |
|--|----------------------------|--|---|--|--|---|--|
| Years | Average rainfall in inches | Average fluctuation of water table during the year (May) | Water pumped during the year in M. c. ft. | Average rainfall in inches | Average fluctuation of water table during the year (May) | Water pumped during the year in M.c.ft. | |
| 1935-36 | 34.60 | 0.03 | 20.10 | 26.90 | -0.59 | .. | Pumping began 1936-37 for <i>Doab</i> No. 2. |
| 1936-37 | 50.30 | 0.12 | 208.70 | 41.73 | 0.49 | 251.78 | |
| 1937-38 | 28.70 | 0.05 | 302.90 | 29.99 | -0.05 | 977.14 | |
| 1938-39 | 11.00 | -2.93 | 500.60 | 14.85 | -2.79 | 2056.85 | |
| 1939-40 | 12.27 | -2.51 | 515.50 | 14.93 | -2.40 | 2252.36 | |
| 1940-41 | 19.13 | -0.56 | 558.40 | 10.99 | -1.78 | 2492.56 | |
| 1941-42 | 14.23 | -1.57 | 580.00 | 13.97 | -1.42 | 2491.11 | |
| 1942-43 | 29.37 | 0.97 | 419.83 | 34.27 | 3.34 | 1884.69 | |
| 1943-44 | 17.95 | 0.24 | 572.786 | 22.18 | 0.25 | 2134.09 | |
| 1944-45 | 24.00 | 0.13 | 471.50 | 20.18 | -0.26 | 2279.48 | |
| 1945-46 | 33.20 | -0.13 | 533.25 | 20.80 | -0.15 | 2049.60 | |
| 1946-47 | 10.50 | 0.50 | 606.58 | 17.30 | -0.21 | 2343.00 | |

The actual method of analysis was the same as adopted previously *vide* Annual Research Report for 1942-43. The correlation coefficient between different pairs of variates are given in Table 7A. II.

TABLE 7A. II
Table of Correlation Coefficients

| Items | Doab No. 1 | Doab No. 2 | Remarks |
|---|------------|------------|--|
| Pre-tubewell period Between δl and R (rainfall in inches). | 0.55 | 0.79 | Pre-tubewell period is from 1920-21 to 1934-35 for Doab No. 1 and 1935-36 for Doab No. 2. |
| Tubewell period Between δd and R .. | 0.5274 | 0.7444 | Tubewell period is from 1935 to 1946-47 for Doab No. 1 and from 1936-37 to 1946-47 for Doab No. 2. |
| Between δd and V (Volume of water pumped). | -0.2557 | -0.3442 | |
| Between V and R .. | -0.7278 | -0.8698 | |

The correlation between δd and R for the pre-tubewell period was not found to be significantly different from that for tube-well period for either of the doabs.

Accordingly, partial correlation coefficients between δd and V , after eliminating R , rainfall, were calculated for both the doabs and their significance was tested. Of course, the partial correlation analysis presupposes linearity of regression.

For Doab No. 1, partial correlation coefficient between δd and $V=0.2199$, and for Doab No. 2 this coefficient= 0.9208 .

Making use of z-test,

where $z = \frac{1}{2} \log_e \left\{ \frac{1+r}{1-r} \right\}$, we find that

$z=0.224$ for Doab No. 1.

and $z=1.595$ for Doab No. 2.

Effective size of the sample= 11 for Doab No. 1 and 10 for Doab No. 2.

Therefore, standard deviation= $\sqrt{\frac{1}{8}}=0.3536$ for Doab No. 1 and $\sqrt{\frac{1}{7}}=0.378$ for Doab No. 2.

It is clear thus that whereas the partial correlation coefficient is insignificant for Doab No. 1, it is quite significant for Doab No. 2 being much greater than twice its standard deviation.

CONCLUSIONS

(1) Pumping is not significantly affecting sub-soil water table for Doab No. 1.

(2) Pumping has significantly affected the water table for Doab No. 2, where it is not being done within safe limits within the area of influence of the tube-wells operating in this doab.

(2) CONE OF DEPRESSION IN THE DEEP SOIL AREAS⁽²⁾**ABSTRACT**

Pumping continuously, it appears, would be costly and cannot compete with deep drains which flow by gravity night and day. Pumping may become economical if cheap electrical power is made available. Other alternative possible at present seems to be to restrict irrigation just enough to saturate the soil and prevent free irrigation water descending to the deep substrata.

DISCUSSION BY THE RESEARCH COMMITTEE

MR. A. P. BHATTACHARYA introduced item (1) and said that the behaviour of the sub-soil water table, as a result of tube-well pumping, was studied for *doabs* No. 1 (between the Yamuna River and the Hindan *Nadi*) and No. 2 (Krishni Hindan *Doab*) in Meerut district, comprising the areas which had been subjected to most intense tube-well pumping.

The findings were that (1) pumping was not significantly affecting the sub-soil water table for *doab* No. 1, and (2) pumping had significantly affected the water table for *doab* No. 2, where it was not being done within safe limits, within the area of influence of the tube-wells operating in this *doab*.

It would be worth while to mention here that these very *doabs* were studied in 1942-43, and no clear indications of over-pumping were available then for any of the *doabs*.

MR. J. P. NAEGAMVALA introduced item (2) and said that it was found that the subsoil water level would not fall by pumping. The conclusion of the note was that the deep soil was not quite suitable for heavy cane irrigation.

MR. N. S. GOVINDA RAO thought that it should be sufficient to meet the requirements of the crop.

DR. J. K. MALHOTRA referring to the United Provinces Report said that the first two or three years, when the tubewell pumping was not fully developed, might have been omitted from the statistical analysis. This would have made the results more reliable.

MR. A. P. BHATTACHARYA said in reply that it was worthwhile to include the first year just to watch the immediate effects of pumping.

RAI BAHADUR M. C. BIJAWAT said that the effect of pumping on the subsoil water table was a very important question. Although the main object of the Central Ground Water Organisation was to carry out exploration work and also to carry out research and investigation in connection with the problems concerning the subsoil water problems but it had not yet been possible to establish the organisation fully, because a suitable man to organise the research work was not available. Recently the services of Dr. Vaidhianathan had been obtained and it was hoped that during the current year it would be possible to organise laboratory and also field work so that next year more information would be available to the Research Committee on the question. RAI BAHADUR BIJAWAT

(²) Poona Irrigation and Research Division, Poona, Public Works Department, Bombay, Annual Report, 1947, pages 19-21.

said that the United Provinces experiments could show that pumping from tube wells was not affecting either water-table or regeneration. There was a lot of doubt in the minds of people that intensive tube-well pumping might affect regeneration and might affect also the movement of the subsoil water table. So far up to this time the United Provinces was the only Province which had carried out extensive work in this direction, pumping roughly about 3,000 cusecs. The tube wells were not spread all over the Province ; and were concentrated in two or three particular tracts. This extensive pumping had not affected subsoil water table to any large extent. The area in which the pumping was being done was near about Narora, where there was not much difference in the regeneration. Although there was not enough data to come to any definite conclusion but indications appeared to be that the subsoil water pumping did not affect the percolation from the rainfall. Experience, therefore, showed that percolation was counterbalanced by regeneration. This new analysis had been effected by observation of rainfall which indicated that there was some other source of replenishment of the ground water. RAI BAHADUR BIJWAT proposed the addition of another item in the sub-head *i.e.* "sources of supply". He said that it appeared to him that despite the percolation from the rain water there were some other sources also. These tubewells showed the effect of pumping on the first two or three water bearing strata. The water was actually drained from the lower strata because the average depth was 700 feet. It, therefore, appeared that if pumping of large quantities was continued it did not have an appreciable effect on the subsoil water level because of the regeneration in the drainage channels. There had been a lot of doubt on this point, and that was why some of the tube well schemes in the Province had been held up. This small investigation showed that there should be no danger in carrying out the tubewell schemes in the Provinces. In the end Bai Bahadur Bijawat promised that by next year Dr. Vaidhianathan would be able to organise and give some more information regarding the effects of pumping on the subsoil water level.

MR. A. P. BHATTACHARYA said that he found that regeneration in the Hardwar Narora reach on the Ganga had not been affected as a result of tube-well pumping. Regarding Rai Bahadur Bijawat's next point "The sources of supply", MR. BHATTACHARYA said that investigations had been carried out in the sub-soil water supplies in the Meerut District and it had been found that 81 per cent. came from rainfall.

RAI BAHADUR H. L. VADHERA said that his experience in West Punjab for lowering water table in water logged areas showed that the ground water table was affected by pumping. Dr. Vaidhianathan was associated with these investigations and it was found that in intermittent tubewell pumping water table was not affected appreciably but when continuous pumping was started it was found that the water table was lowered more than four feet.

In reply to MR. D. Mehta, RAI BAHADUR VADHERA said that the tube wells were situated very near each other.

DR. N. K. BOSE said there were some other sources as well the effect of which had to be considered.

DR. L. A. RAMDAS said that he was not surprised with the observations made by Mr. Bhattacharya because if the soil was really permeable it was just like drawing water and putting it back. Very little water was lost by evaporation, and a good part was getting back quickly to the sub-soil. In the Punjab experiment the difference was probably due to the impermeability of soil.

RAI BAHADUR KANWAR SAIN said that in some parts of the United Provinces pumping had definitely caused lowering of water table. In certain parts of United States of America also water table had been lowered appreciably by means of pumping. In the *Bist Doab*, in the Punjab, the water table had gone down by 15 feet and it was entirely due to the withdrawal by wells.

RAI BAHADUR C. L. HANDA said that perhaps the solution lay half way between the two extremes. Where it was noticeable that the water table was rising, the engineer could not sit tight. At Chuharkana in West Punjab various wells were sunk and the water table was lowered. It was noticeable that in the United Provinces as Rai Bahadur Kanwar Sain had stated there were places where it had gone down 8 to 10 feet. From the Grand Coulee they were pumping now as much as 5,000 cusecs, in order to recharge ground water table. RAI BAHADUR HANDA, therefore, suggested that the engineers and the research workers should examine these problems together.

MR. A. P. BHATTACHARYA replying to R. B. Kanwar Sain's remarks said that there was a series of severe drought years from 1938-39 to 1941-42, in which there was a continuous fall of the water table but it never exceeded three feet in magnitude. They were abnormal years, and that there was replenishment of the ground water table may be brought out by observing that there was rarely any fall in recent years when the rainfall was normal or above normal. Even if there was a fall, it never exceeded 0.5 foot.

MR. B. P. SAXENA said that when it was considered that the water table was not appreciably lower, the loss which had been increasing in the irrigation channels was not really taken into account. In most of the areas, the irrigation channels were very much intermixed with tube wells and there was no record of their losses which would convince anybody to show that the water table was not affected on account of these tubewells. When these tubewells were first constructed in Meerut District, Sir William Stampe had been going round to the villages and telling the people that water table of village wells might not be lowered but it happened otherwise. MR. SAXENA said that he was sorry that he had an honest difference of opinion with some of the engineers but he still felt convinced that the water table certainly fell down.

RAI BAHADUR M. C. BIJAWAT agreed that there should be caution and the United Provinces Government was already acting cautiously there. 1,500 wells had been constructed. It was found in certain areas that the water table did not go down. Whenever any concern was felt regarding the water table, the number was restricted. It was true that water table was affected. Yield of sub-soil water table carried no meaning; yield may be with respect to the area. It had been admitted that most of the losses in the Ganga Canal were due to the seepage. There was perhaps slight affect due to the tubewell pumping also but it was not appreciable. He also explained that the seepage losses had risen

due to the full supply levels being raised in the reaches where power houses were put in.

In reply to Mr. B. P. Saxena's remarks Mr. A. P. BHATTACHARYA said that the regeneration of the Hindan as well as the Ganga at Narora had been studied, and it was found that it had not been affected significantly as a result of tube-well pumping.

As to Mr. Bijawat's remarks, Mr. A. P. BHATTACHARYA said that such a study was carried out by Dr. McKenzie Taylor for western United Provinces, although during the pre-tubewell period. His findings were that 81% of the subsoil water supplies were a direct result of local rainfall, regarding the remaining 19% his presumption was that this was caused by flow from sub-mountainous tracts.

THE PRESIDENT said that this subject was discussed year after year. Every region had to be considered on its own merits. In 1931 most of the villages in the Western States in United States of America the water table had completely depleted. In Los Angeles the water table went down by 300 feet. Pumping was necessary for dewatering of the soil and where water in the subsoil, due to various causes, was in excess, plenty of water could be pumped out but there was a limit. Below that limit the water level would go down but it would be completely wrong to give the general impression that pumping would not affect water level. Statistics could be very dangerous indeed, and great care should be taken in this respect. When an analysis of certain regions was made it was not only one or two factors but every possible factor should be studied to get correct statistical picture.

DISCUSSION BY THE BOARD

There was no discussion.

(iii) Re-charging the underground basin

PRELIMINARY NOTE

The following item was discussed at the 1947 Research Committee Meeting.

- (1) Infiltration (absorption by ground) factors which determine the portion of rainfall which infiltrates, while also considering the effects of plants the configuration of the soil etc., and the importance of these influences, by Mr. D. V. Roy.

Recent Literature

(1) Saving Australia's Artesian Waters. Water and Water Engineering Vol. 50, No. 613, March 1947.

(2) Ground Water Supplies for rice irrigation in the Grand Prairie Region, Arkansas. University of Arkansas, Agricultural Experiment Station, Bulletin No. 457, June 1945.

THE YEAR'S WORK

The following item was discussed at the 1948 meeting of the Research Committee.

- (1) Effect of cane irrigation on the sub-soil water table in a deep soil area

(1) EFFECT OF CANE IRRIGATION ON THE SUBSOIL WATER TABLE IN A DEEP SOIL AREA^(*)

ABSTRACT

Rise of sub-soil water table in a deep soil area as a result of cane irrigation, although slow, is definite.

The fall in water level, after the cessation of cane irrigation, is very slow indicating absence of natural underground drainage. It is like filling a sub-soil pond with water without any outlet.

Measures to add as small quantities of water as possible by way of irrigation for growing cane appears to be the only remedy for permitting cane irrigation in deep soil area without raising the sub-soil water table.

DISCUSSION BY THE RESEARCH COMMITTEE

MR. J. P. NAEGAMVALA introduced item (1).

RAI BAHADUR M. C. BIJAWAT said that there was no doubt that sub-soil reservoir had been studied before in California and some parts of America. The pumping was continued until it was found that water level had gone down to such an extent that it had to be stopped. In India perhaps for a very large number of years it might not be necessary to consider methods of artificial recharging of the subsoil reservoir if one pumped only such quantity of water as was being regenerated.

DR. V. I. VAIDHIANATHAN said that he had certain experiments carried out but he would rather refrain to make any categorical statement as caution had to be used. He said that at some places the rainfall penetrated the soil and affected the sub-soil reservoir and in other cases it did not.

DR. N. K. BOSE said that it was found that substantial amount of regeneration was coming from the Himalayas. In a certain river in Bengal which was a tidal stream, for two or three months there was special supply. In some cases it had been proved that the regeneration came from the river. Therefore, the question of regeneration had got to be gone into very carefully.

DISCUSSION BY THE BOARD

There was no discussion.

(*) Poona Irrigation and Research Division Poona, Public Works Department, Bombay Annual Report, 1947, pages 22—25.

(iv) Evaporation and Transpiration losses**PRELIMINARY NOTE**

A report on the preliminary survey carried out by Mr. R.K. Misra to find the evaporation and transpiration losses of the Damodar Catchment area* presented before the fourth meeting of the sub-committee on 'Water Resource Investigations of the Damodar Catchment Area' and the same appeared in an abridged form in the July 1948 Journal of the Central Board of Irrigation.

There was no contribution under this sub-head, at the 1947 Research Committee Meeting.

THE YEAR'S WORK**DISCUSSION BY THE RESEARCH COMMITTEE**

There was no contribution and hence no discussion took place under this head at the 1948 meeting of the Research Committee.

DISCUSSION BY THE BOARD

There was no discussion.

*This has been given as appendix I of this report.

8 A. Quality of Waters in Relation to (i) Crops (ii) Soils (iii) Structures and (iv) Industries

PRELIMINARY NOTE

The subject 'Quality of Irrigation Waters' was on the agenda of the Research Committee in 1934 and 1935 and it was re-introduced in 1946. At the 1946 Board Meeting the name of the subject, 'Quantity of Irrigation Waters' was changed as above.

(i) CROPS

PRELIMINARY NOTE

The following items were discussed at the 1947 Research Committee Meeting :—

- (1) Suitability of drainage waters for irrigation (Shingwa area).
- (2) Suitability of drainage waters for irrigation (Baramati quadrat).
- (3) Well water in the affluent zone.

The following items were noted without discussion :—

- (1) Sugar-cane experiments under varying doses of 'N' in the form of sewage irrigation, with special reference to the quality of *gur*.
- (2) Sugar-cane experiments under sewage irrigation.

Recent Literature

- (1) Small, J. : *pH and plants* : an introduction for beginners. Bailliere Tindall and Cox, London, 1946.
- (2) Suitability of water for irrigation purposes—Dalip Singh and Dev Raj Chawla. *Indian Farming*, Vol. 7, No. 8, August 1946.
- (3) Lang, J. D. : The upper salinity content in water for irrigation. *Water and water Engineering*, Vol. 50, No. 618, August 1947.

THE YEAR'S WORK

The following items were discussed at the 1948 Research Committee Meeting :—

- (1) Quality of irrigation water.
- (2) Sugar-cane under varying doses of Nitrogen in the form of sewage irrigation with special reference to quality of *gur* produced.
- (3) Sugar-cane experiments under Sewage Irrigation.

(1) QUALITY OF IRRIGATION WATER (1)**ABSTRACT**

The following are the more important observations :—

(1) The results of analysis of soils after first, second and third rice crops showed that there was a gradual increase in the *pH* value of the soil. The *pH* value of the soil watered with 60.0 parts of sodium carbonate per 100,000 parts had become 9.0 after third rice crop. The increase in the case of sodium chloride and sodium sulphate had been lesser.

(2) There was a little increase in the exchangeable (Sodium+Potassium) bases of the soils treated with water having positive salt index.

(3) Waters containing total salts even at 75.0 parts per 100,000 but having positive salt index produced signs of deterioration in soils and crops.

(4) It was concluded that the salt index of the irrigation water could be used as an index for the quality of irrigation water.

(5) The quantity of calcium decreased in the crops with the increase in total salts.

**(2) SUGARCANE EXPERIMENTS UNDER VARYING DOSES OF NITROGEN
IN THE FORM OF SEWAGE IRRIGATION WITH SPECIAL
REFERENCE TO THE QUALITY OF GUR PRODUCED (2)**

ABSTRACT

Crop : Results show maximum yields with 350 lbs. of Nitrogen treatment. This is true even in the case of the aggregate results of cane yield over a total period of five years. The next best is 400 lbs. *N* treatment. The higher doses though not reducing the yield significantly, do show a tendency towards slight decrease in yield with a fall in brix and purity %. The results are not regular for cane grown in deep black soil, though 400 lbs. *N* and 500 lbs. *N* show superior results to other doses. The results show good effects by addition of sludge in sewage irrigation treatment.

Gur Tests : Moistures were estimated in *Gur* on oven dry basis. The results show definite tendency to increase moisture with increased *N* contents. The moisture percentage is upto 5% for treatments of 100 to 200 lbs. *N* for 250 to 400 lbs. *N* it is upto 8.0%. From 500 lbs. *N* onwards it is above 8%. The *Gur* absorbs moisture in monsoon and again gets solid in the Rabi season. The *Gur* from cane in deep black soil—does not show any regularity in moisture absorption but in plant cane the moisture absorption is much higher than that in *ratoon*.

The conductivities of *Gur* also show definite tendency towards increase with higher doses. They are distinctly higher from a dose of 600 lbs. *N* onwards.

(1) East Punjab Irrigation Research Institute, Amritsar, Annual Report, 1947, pages 14—15

(2) Poona Irrigation and Research Division Poona, Public Works Department, Bombay Annual Report, 1947, page 76—80.

(*) SUGARCANE EXPERIMENTS UNDER SEWAGE IRRIGATION (*)**ABSTRACT**

Experiment with sugarcane varieties was continued this year to see the behaviour of different Coimbatore varieties under sewage irrigation. CO 413 and CO 475 were amongst those tried with the usual CO varieties.

The results show that CO 475 stands first from point of view of yield, brix and purity percentage. CO 413 variety stands next in yield. A study of previous figures on this experiment reveals that early plantation is necessary for the proper development of these two varieties. Last years results showed that March planting was no good for proper development of these varieties.

The Ratoon varietal experiment was conducted to see the behaviour of *ratoon* and plant cane under sewage irrigation. First watering to *ratoon* was given on 16-4-1947. Three deep stirrings and weeding were given till earthing up stage. Partial earthing up and earthing up were done at the normal stage in April and July respectively. Harvesting was done by first week of January 1948. In all 24 irrigations were given resulting in a total Nitrogen of 663 lbs. per acre. The total irrigation given was 88 acre inches.

The results show that CO 475 is a good *ratoon*er and has given the highest yield of *gur* even more than its parent plant cane. CO 419 is a runner up. The purity % of juice of all varieties is appreciably higher for the *ratoon* crop than for the plant cane.

Detailed results show that the recovery of *gur* from *ratoon* canes is higher than that from plant cane. The quality of *gur* of *ratoon* is also superior to that of *gur* of plant cane.

Dose. experiment :—

This experiment was continued on previous lines. Sugar-cane was planted on February 1, 1947 and was harvested by March 4, 1948.

The results show a slight increase in yield with increasing doses ; but fall in Brix and Sucrose percent. is not appreciable.

Gur tests :—

The periodical *gur* tests carried out for the *gur* of varietal experiment and dose experiment show increased moisture percentage in monsoon after which there is a fall. They also show lower moisture contents and lower conductivities for *gur* raised on canal irrigation.

The glucose and sucrose contents of *gur* were found out by the beginning of monsoon when the *gur* just began to sweat.

The results show comparatively higher glucose in CO 413 and CO 423 varieties than in the rest, percentage of non-reducing sugars is not varying appreciably except in the case of CO 475.

These results show that it is not these ingredients which are responsible for the sweating of *Gur* in monsoon. The presence of salts appears to be largely responsible for moisture absorption in monsoon. These ingredients are being studied in detail at present.

(*) Poona Irrigation and Research Division, Poona, Public Works Department—Bombay, Annual Report 1947, pages 21—24.

DISCUSSION BY THE RESEARCH COMMITTEE

MR. S. L. MALHOTRA introduced item (1)

DR. D. G. KULKARNI introduced items (2) and (3)

RAI BAHADUR R. L. SETHI said that these experiments were good in their way, but they did not add very much to the knowledge already existing on the subject. It was already known very well that sewage was a very rich manure. It was also known that crops could be raised if sewage could be utilised. The chief difficulty was that wherever sewage was added it introduced insanitary conditions. It gave sewage sickness. It brought up flies. The quality of the crop which was raised was not suitable for direct human consumption. Medical opinion was that the crops raised on sewage brought about diseases like hook worm. The Indian Council of Agricultural Research had sanctioned a very comprehensive scheme at the Indian Institute to be carried out in cooperation with the local Public Health Department. RAI BAHADUR SETHI suggested that in carrying out the tests described in the Poona Report, it would be worth while to consult the local Department of Agriculture as to how far it would be useful to carry out these investigations.

MR. J. P. NAEGAMVALA said that about a thousand acres were on sewage irrigation in Poona. The whole of Poona and a large part of Bombay had vegetables which were grown on sewage. The only conclusion arrived at was that vegetables should not be eaten raw. If eaten raw they should be dipped in permanganate of potash solution for half an hour.

He added that a bacteriological examination had showed no difference between vegetables grown on sewage and those grown otherwise.

DR. N. K. BOSE said that near about Calcutta there were big fisheries where sewage was disposed off and some of the best fishes were obtained from there.

DR. V. K. GOKHALE said that Rai Bahadur Sethi had remarked that (a) the Agricultural Department had already completed investigations about sewage irrigation and should be consulted in this connection, (b) the soil was damaged by use of effluent and became sewage sick and (c) insanitary conditions were produced in the area under this irrigation and the crops produced being contaminated with sewage were injurious to public health.

With regard to item (b) above, DR. GOKHALE said sewage sickness depended on the type of soil under sewage irrigation. A heavy soil was so affected and not a well drained one. The soils at the effluent farm at Hadaspur (Bombay Province) had on the contrary improved year after year.

DISCUSSION BY THE BOARD

There was no discussion.

(ii) SOILS**PRELIMINARY NOTE**

The following item was noted without discussion at the 1947 meeting of the Research Committee :—

- (1) Effect of sewage irrigation on black cotton soil.

Recent Literature

(1) Christiansen, J. E. : Some permeability characteristics of saline and alkali soils. *Agricultural Engineering*, Vol. 28, No. 4, April 1947.

(2) Dalip Singh and Dev Raj Chawla, Suitability of Water for Irrigation Purposes. *Indian Farming*, Vol. 7, No. 8, August 1946.

(3) Lang, J. D. : The Upper Salinity Content in Water for Irrigation. *Water and Water Engineering*, Vol. 50, No. 618, August 1947.

(4) Ramdas, L. A. and Malik, A. K. : Studies on soils, Part I, the upward movement of water and salt solutions in the black cotton soil and Part II—A microscopic study of the behaviour of the black cotton soil in salt solutions. *Proceedings Indian Academy of Science*, Vol. 16, No. 1, Section A, July 1942.

THE YEAR'S WORK

The following item was discussed at the 1948 meeting of the Research Committee :—

- (1) Effect of sewage irrigation on soil profiles.

(1) EFFECT OF SEWAGE IRRIGATION ON SOIL PROFILES (4)

In order to study the various physical and chemical changes that take place in the soil due to the application of sewage irrigation, several typical profiles in the Effluent Farm, Hadapsar, having received known intensities of sewage irrigation were collected. Important physical and chemical tests were carried out.

The results of conductivities of the soil extracts (1 : 5) show higher values for the sewage irrigated soils in comparison with the control soils. These results show increase in percentage soluble salts under sewage irrigation.

In three out of the four comparisons slightly lower capillary rise is noticed in top soil layer under sewage irrigation. In one comparison the sewage irrigated profile shows the highest rise. The lower depths give almost similar indications.

(4) Poona Irrigation and Research Division, Poona, Public Works Department Bombay, Annual Report, 1947 pages 85—93.

Mechanical analysis was carried out by water treatment only. In this case it was found that sewage irrigation increased the amount of finer particles and silt of soils by about 50%. The coarser particles show a reduction in the sewage irrigated soils as compared to the control. These results show that sewage irrigation when applied to soils increased the finer particles of soils in the form of clay and silt. This increase in clay and silt fraction plays an important part in the increase in the soil fertility.

Total Phosphates were estimated in the soil profiles under sewage irrigation and without it, and it has been found that the percentage of phosphates is definitely higher in the case of the sewage irrigated soils. Sewage irrigation increases the total phosphate contents in the upper layers.

Profiles under sewage irrigation also show an increase in the percentage of potash.

As a result of sewage irrigation, the soil has become rich without doubt in its percentage of exchangeable calcium. Calcium in certain forms which are readily taken up by plants or which are available to the plants for use plays an important role in the metabolism of the plant life.

Exchangeable Magnesium shows an increase due to sewage irrigation. This is, however, not much when compared with the increase in the replaceable Calcium.

Out of the four comparisons made, three distinctly show that the exchangeable Na+K have also increased by sewage irrigation, while if the results of the lower profile samples in the sewage irrigated areas are seen, they also show higher exchangeable Na+K figure than in the case of the control. Out of this Na+K, Potassium is an essential constituent for plant growth and as the sewage irrigation increases total potash %, it may be inferred that the higher exchangeable Na+K may be due to this factor, contributing to more of these bases in the soil.

The *pH* values show distinct lowering under sewage irrigation as compared to the control. This is true for the entire depth of the profile.

DISCUSSION BY THE RESEARCH COMMITTEE

DR. V. K. GOKHALE Introduction Item (1).

There was no discussion.

DISCUSSION BY THE BOARD

There was no discussion.

(iii) STRUCTURES**PRELIMINARY NOTE**

The following item was discussed at the 1947 Research Committee Meeting.

- (1) Trade waste experiments in the Bombay Province.

THE YEAR'S WORK**DISCUSSION BY THE RESEARCH COMMITTEE**

There was no contribution and no discussion on this sub-head.

DISCUSSION BY THE BOARD

There was no discussion.

(iv) INDUSTRIES**PRELIMINARY NOTE**

There was no item for discussion at the 1947 meeting of the Research Committee.

THE YEAR'S WORK**DISCUSSION BY THE RESEARCH COMMITTEE**

There was no contribution and therefore no discussion took place under this sub-head at the 1948 meeting of the Research Committee.

DISCUSSION BY THE BOARD

There was no discussion.

9A. Artificial Rainfall

PRELIMINARY NOTE

This subject has been introduced for the first time as a result of the following resolution passed by the Board at its last meeting held in December 1947 :

“ Resolved further that the India meteorological department be requested to organise experiments on ‘ Artificial rainfall ’ in co-operation with other authorities. Cloud control was a subject worthy of study and consideration.

“ It was also decided to include ‘ Artificial rainfall ’ on the agenda of the Research Committee meeting under Section A—Hydrology.”

Experiments on inducing artificial rainfall have also been carried out in Australia, United States of America and Canada. The pioneers in the work are Vincent Schaefer and Dr. Irving Langmuir of the United States of America. Schaefer first started his experiment in 1943, when the Army Air Force asked General Electric Laboratories to find out what caused tons of ice to form on the wings and tails of bombers, dragging them down to destruction. Schaefer early noted that planes flew with impunity through clouds composed of ice crystal. Particles already frozen could not freeze on the wings. If he could not throw out the clouds, Schaefer reasoned, why not freeze them ? This led to experiments in the laboratory, which proved a success when by injecting granulated solid carbon-dioxide or silver iodide in certain formation of clouds, artificial rainfall was induced. The success of the experiments depended on the type of the clouds chosen. The cloud should be an extensive one in vertical direction and its top be at a considerable height above the freezing level. Experiments show that greater the thickness of the layer above the freezing level, the more easy it is to induce rain. The experiments, so far have been made for precipitation from existing clouds.

In a recent article ‘ Artificial Rainfall by Shri Dharam Sheel ’, published in the April, 1948 issue of the Central Board of Irrigation Journal, the author has stated that there can be three possible ways of producing artificial rain *viz.*, (a) precipitation of rain bearing clouds (b) changing the direction of winds and subsequent precipitation of rain and (c) gradually and steadily changing the conditions that control monsoon rains such as deforestation and afforestation. It has also been brought out that the ancients of India knew these methods and quotations from Vedas are also given in support. In the end the author has made the following two pertinent suggestions :—

1. To start with it is proposed that two Vedic Scholars may be appointed who may dig out and collaborate the old literature from all source which should form the basis of fresh research.
2. In the meantime a small research laboratory may be established on some hillock near about Delhi to evolve a suitable design of a heating tank and to record and study its effect on the atmosphere.

Recent Literature

1. Squires, P and Kraus, E.B.—Experiments on the stimulation of clouds to produce rain. *Nature* Vol. 159, No. 4041, April 1947.

THE YEAR'S WORK

The following item was discussed at the 1948 meeting of the Research Committee.—

(1) Man made rainfall by Rai Bahadur Kanwar Sain.

MAN MADE RAINFALL

by

R. B. Kanwar Sain, O. B. E., I.S.E.

Chief Engineer Irrigation Bikaner.

A report published in the Indian News Chronicle dated the June, 24 1947, gave a resume of an interview with Dr. Saidman, Director of the Institute of Actinology, given to some newspaper representative. Dr. Saidman is reported to have said :—

“ The sun-energy can solve the water supply problem of Bikaner by giving to the city inexhaustible quantities of distilled, bacteriologically safe and potable water at a small cost ”.

When his attention was drawn to vast arid tract of Rajputana, continues the report, Dr. Saidman replied :—

“ The entire desert area comprising thousands of square miles lying between Sind, Gujrat and Bikaner can be re-claimed and made productive in a matter of five to ten years and forced to yield abundant grain for the fast growing population of India. ”

Naturally the above report aroused a great hope amongst the people of the Rajputana States and they must be anxious to know to what extent they may expect the fulfilment of the hope held out to them by the reporter of the Indian News Chronicle. On seeing this report I wrote to Dr. Saidman. My letter was transmitted to Dr. Saidman's French Residence, where he had gone for a couple of months during summer. In his reply Dr. Saidman has reiterated his belief :—

“ The condensation of the vapour obtained by boiling the sea-water, will allow its transportation at great distances. In the scientific point of view, there is a possibility of irrigation at great distances from the gulf of Cutch till the Tharr Desert, up to Bikaner ”.

Dr. Saidman is taking up his first experiment in the Nawanagar State. He is hoping to achieve this object by harnessing of solar energy. Now, solar energy is continuously absorbed by the earth, including the atmosphere at a rate equivalent to about 13×10^{12} or 130 trillion horsepower. Some of

this vast supply of energy goes to evaporating water from the oceans, rivers, lakes, forests &c., at the average rate, for the world as a whole, of roughly 16 million tons per second, or the equivalent of a layer of water over the entire earth of about one-tenth of an inch per day. The vapour is distributed mainly through the lower portions of the atmosphere, by diffusion, wind turbulence and thermal convection. Whenever any portion of the atmosphere is cooled to a temperature below saturation point, some of the vapour present condenses.

It will be interesting to know how much energy Nature demands for putting into the atmosphere enough moisture to give one inch of rain over even so small an area as ten miles square. The same amount of energy, exactly the same, must be gotten out of the atmosphere to secure the given precipitation.

The volume of water involved is 232,320,000 cubic feet. Hence to evaporate or condense at 50°F the water of this limited rain—a moderate shower—would require the equivalent of a little more than 36 million horse power continuously for an entire week.

How Dr. Saidman proposes to obtain the energy for effecting adequate precipitation for the whole of Rajputana has not yet been disclosed by him.

It may be asked at this stage, "By what mechanism does Nature contrive to get out so much energy from the atmosphere in order to cause precipitation"? Nature does so by dynamical cooling, incidental to the expansion of rising air. This ascent of the air may be caused in Nature by the hinderance presented by a high mountain, or local reasons causing thermal convection or by the convergence of wind currents. As the air ascends it comes under less and less pressure in proportion to the depth and density of the air column left below. It, therefore, expands as it rises. In so doing, it does work at the expense of its own heat—which is its only source of energy.

As stated above, thanks to the solar energy there is always enough vapour present in the lower atmosphere. The problem is how to divert this vapour laden air to arid tracts and make it drop its load there by some method, which would be within the range of practical economics.

Recently experiments have been carried out in Australia successfully on the artificial release of rain from clouds. The lay press, interpreted the results of these experiments most optimistically and in some cases so fantastically that it appeared that man was already in a position to manipulate rainfall at his sweet will. Thanks to the press, Rocking F Ranch near the California Nevada border is so hopeful of making rain with dry ice over his Ranch next spring that he has filed a claim to the water in all clouds passing over the Ranch, to establish his legal claim before-hand to such water.

The correct present position was given by Mr. G. A. Cook, Secretary of the Council for Scientific and Industrial Research, Commonwealth of Australia,

responsible for the Australian experiments on artificial rain-making, in his reply to me in October, 1947 :—

“ It is not believed that rain-making on a practical scale sufficient to be of importance in agriculture is going to be possible in the near future. The work is regarded rather in the nature of an investigation of the meteorological processes associated with cloud formation and rain precipitation. If after some year's work we are able to understand the physical processes producing rain there may be a slight chance that artificial rain-making would be possible but it is certainly far too early at present for any one to be confident of the practical possibilities ”.

To the meteorologist the main interest of these experiments is the direct confirmation, which they provide of the theory that ice particles as well as water droplets must be present in a cloud if rain is to fall.

It is impossible, however, to discuss such experiments merely as a contribution to meteorological science. What we all naturally want to know is how great is the practical prospect of controlling rain.

Certain critics have already raised the bogey of legal complications. A farmer in trying to protect his own crop may bring down the rain quota of a whole district and cause injury to some other trade, resulting in a claim for damages. Dr. S. K. Banerji, Director General of Observatories has warned us :—

“ We have been getting our rains at the expense of desert regions. If you convert them into fertile regions, some other area will suffer. Nature has its own revenge if you play with it. If you convert deserts into fertile lands, fertile lands might be turned into deserts ”

My reply to such friendly critics is :—

“ There are many tracts near the Himalayan Range, which receive excessive rains not wanted by these tracts, while Rajputana and several other tracts remain dry. Once we succeed in controlling rainfall, we would probably succeed in arranging balanced rains over the various parts of the country. The control of the clouds shall have to be with the Central Government, so that no individual or Province or State may get undue share. A separate Ministry in the Union of India may become necessary to perform the duties and functions of *Indra-deva* (God of rain) ”.

ATTEMPTS IN PRE-SCIENCE DAYS

Mankind has throughout the ages sought to cause precipitation at will by various methods to which they could resort to at the time. This is easy to

understand as food is the most compelling of all human cries. Most of the food comes from the soil and depends largely on the availability of moisture at the right time.

In the primitive stages of man, when magic was believed to solve all human troubles, magical methods were tried to bring rainfall as well. Such methods were tried by various tribes in Australia, South Africa, Sumatra and Russia. These methods consisted of imitating lightning, thunder and rain or mimicking aquatic birds and animals.

In certain countries, the custom of appealing in one way or another to the spirits of the dead for rain is as old as any kind of pure magic.

Help of gods has not been spared in the interest of artificial rainfall. It is said that certain Red Indians of Oronoco, believing that the frog is the god of water, guarded against droughts by keeping frogs in captivity, convenient to beat with sticks, whenever a shower of rain was needed.

Dire threats against gods in case they fail to comply with request for rain have long been a form of human egotism, both in the East as well as in the West. Efforts to obtain rain by devout prayer are common to all types of religions. Congregational and mass prayers are held in Churches, Mosques and Temples, when the country is faced by famine for want of rain.

The man of science, however, does not accept the notion that the phenomena of nature are subject to the wishes of any individual or groups of individuals. Even abstract may respect in the highest degree, since he does not believe that rain can be had by the mere pleading, howsoever earnest.

EARLIER SCIENTIFIC ATTEMPTS

Living as we are in the 20th century, I shall confine myself in this article to the attempts made to obtain rain by the so-called scientific methods.

Every one know that we can and commonly do greatly modify, by artificial means, the state of that portion of the atmosphere which directly effects our bodies. We live in houses artificially heated or cooled, produce a comforting artificial breeze by means of an electric fan ; and otherwise modify our ' personal ' weather to taste instead of taking it as provided by Nature. We cover our vines, tomato and other delicate plants to keep off the killing frost and heat orange groves and apple orchards to save the fruit.

We even sprinkle our lawns with artificial rain through fine shower. But when the average man reads in the newspaper with keen interest the possibility of artificial rainfall, he does not have these small scale measures in his mind. He visualises the production of an ordinary shower of average extent and duration.

The various earlier attempts made under the advice and guidance of men of science are admirably summed up by W. J. Humphreys in his book, "Rain Making and other Weather Vagaries", published in the United States of America, in 1926. A brief account of these earlier methods would undoubtedly interest the reader. These attempts are described under various sub-heads.

Noise

Even many centuries ago Plutarch believed that generally a big battle was soon followed by rain. The explanation was found in the noise of the battle, the clash of the sword and the shield, and the shrieks of the wounded. Later these rains were attributed to the still louder noises of the modern battle-field, the rattle of the musket, and the roar of the cannon. This notion that noise could induce condensation became so popular that the United States Congress as far back as 1891 appropriated \$ 9,000 for experiments in rain-making. Some preliminary trials were made near Washington, but most of the work was done in Texas under the direction of "General Robert Dyrenforth" as "Special Agent" of the Department of Agriculture. Dynamite and hydrogen-oxygen filled balloons made the noise and a little rain did fall, but according to the meteorologist, only that which was already on the map and due to fall in the regular and undisturbed course of the weather.

In 1911 and 1912 C. W. Post tried his luck at shaking rain from the skies. On one occasion, after a bombing scene near Battle Creek, Michigan, a shower occurred that immediately was heralded as incontestable proof that rain could be had from the clouds by merely jarring them with a little dynamite. But those who joyously made these claims overlooked the fact that on that day rain fell all the way from the Pacific Ocean to the Great Lakes and beyond.

Another bit of supposed evidence, urged by some people in support of the idea that a racket induces precipitation was the alleged extra wetness in America on the Fourth of July. However an examination of the records from more than 150 stations widely scattered over the United States, each covering a period of 10 to 40 years, shows that, for the country as a whole and the average, the Fourth of July was not during the years of noisy celebrations, either wetter or drier than other neighbouring days.

The advocate of the noise theory has sometimes argued that the compression of the air, incidental to the passage of loud sound, must drive the cloud particles or even molecules of water so close together as to force their union into rain drops. As a matter of fact, however, this compression during the instant, it lasts, always occurs adiabatically *i.e.*, without gain of heat from or loss of heat to, outside objects, and thereby so raises the temperature of the air as to increase and not to decrease its vapour capacity. The following rarefaction momentarily decreases the vapour capacity. But both these

effects, compression and rarefaction, are amazingly small*, say one part in a thousand for even a deafening roar.

Chemicals

Zinc in open pots of dilute sulphuric acid was honestly proposed, and faithfully tried, as a rain-making scheme at Broken Hill, Australia, during the disastrous draught of 1903. It was argued that the hydrogen gas thus generated, being lighter than the air, would rise, and in so doing set up a vertical whirl and thereby induce precipitation.

There are several weak links in this chain of reasoning. The most important only need be mentioned. For any practical equipment and cost, the stream of gas thus generated hardly could exceed one thousand cubic feet per minute. But to give an appreciable rain many cubic miles of air must somehow be forced to yield a considerable portion of their moisture. Hence, presumably, if we are to get much of a rain by the mechanical action of the rising hydrogen, we should need at least one cubic mile of it. But at the above great rate of delivery *i.e.*, one thousand cubic feet per minute, it would take 280 years to get the cubic mile.

Upward deflecting plane

The familiar facts that more rain falls on the windward than on the leeward side of a mountain, and that up to considerable elevations the amount of this precipitation increases with height, have led many people to suggest that we might get rain by erecting some huge device to act on the air just as a mountain does. This plan for increasing the local precipitation, though logically sound would be impracticable. Even a ridge 100 miles long and one mile high about the smallest structure that would be effective as a rain producer, would require for its building say fifty billion car loads of rock and earth. A single train of freight cars carrying this load would girdle the earth about 25,000 times.

Forced vertical convection

As soon as Espy had shown the great importance of convection in the formation of clouds and precipitation (First announced in 1830 and later included in his 'Philosophy of Storms', published in 1841) the 'practical' rainmaker saw clearly his way to immediate success. All that was necessary to do, if one would have rain, was to drive the air upward by some sort of a

*The proof of this is easy. Since the compression and rarefaction in sound occur adiabatically, the condition of the air as the sound passes, is given by the equation—

$$pv^{1.4} = \text{a constant.}$$

in which p is the pressure, v the volume per unit mass, and 1.4 the ratio of the specific heat of the air at constant pressure to its specific heat at constant volume. Hence for small changes

$$\frac{\Delta p}{p} = \frac{1.4 \Delta v}{v}$$

But Wegel has shown that a change of p equal to one part in a thousand of p , provided p , as in the present case is approximately atmospheric pressure, is about the limit of audible loudness beyond which one's ear is only pained. The change of v , therefore, or of its reciprocal density in the case of the loudest sound, hardly is more than one part in a thousand as stated.

blowing device. Such a scheme was even patented. One scheme contemplated a giant tube, some 1,500 feet high to guide the air. To get rain, air was to be blown up this tube. A modified form of this suggestion was to get the necessary vertical convection by placing a lot of aeroplanes in a circle, wings off for closeness sake, noses down like a ring of musk oxen on defence, and tails up and while anchored in this position, running all propellers at top speed.

The principle on which this rain-making device is based is perfectly sound. The trouble is with the engineering and economic phases of the problem. It can be shown that the power required to cause half an inch of rain over an area about 60 square miles is of the order of 75 million horsepower in an hour.

Fires

Some people have insisted that the needed rain might be obtained by firing dry cane brakes, forest slashings, or other combustible material. Even the noted meteorologist Espy proposed this method of starting precipitation about 1840. However, it has never been put into practice. By simple calculations it can be shown that to get condensation equivalent in amount to half an inch of rain over one square mile about 1,100,000 gallons of oil or 6,400 tons of coal would have to be burnt. Obviously the trouble and the cost of this scheme to say nothing of the injury to the area burnt over will prevent its commercial use as a means of inducing precipitation.

Cold barriers

Many an inventive genius on seeing the abundant sweating of the ice pitcher has shouted his Eureka. Obviously he reasoned and correctly that to obtain any desired amount of water for irrigation or other purposes, we need only find a place where humid air drifts by and there face the wind with a screen of pipes through which is continuously circulated a cooling brine or other refrigerative agent. Here again, though the scheme is amazingly simple and thoroughly sound in principle, the engineer and the economist get into trouble.

If the air were warm and saturated, by the application of principles of physics, it can be shown from the heat of fusion of ice, the heat of vaporization of water and specific heat of air, that at best we could obtain only one ton of condensed vapour per eight tons of ice melted. Hence, if luckily we could manufacture this ice at about three annas per 100 pounds, then after the necessary installation was set up and in operation, the further cost of getting water from the air might not, under very favourable circumstances, greatly exceed Rs. 3,000 per acre-inch. Even this minimum cost will not appeal to the irrigation farmer in India who needs 10 to 50 inches of water per year, and for the whole of which he now is accustomed to pay only about rupees three to ten per acre and that also only if his crop matures. Actually the situation during a severe drought would be even worse as much more air would have to be cooled and generally from a higher temperature than has been assumed in the above calculations.

Dusting the sky

Aitken showed in 1830 that the presence of condensation nuclei such as ordinary dust particles is an essential condition to the production of rain. When such particles are present to the extent of hundreds or thousands per cubic inch, cloud immediately forms as soon as the other essential conditions are attained; but in their absence cloud does not form until the humidity has been pushed to at least a fourfold supersaturation—a condition unknown in the free atmosphere.

This discovery of Aitken's gave a fresh line of action to the rain-maker. He argued "if you want rain, just carry up a load of dust with an aeroplane and powder the face of the sky with it". This method, however, has been tried but it did not meet with any success.

It was further suggested that some sort of hygroscopic dust or spray might be used. Even if the moisture should be brought down by some such substance it would not in general, be available for plant use. Besides, granting a tenfold dilution by weight, probably much in excess of the amount usually obtainable to get an acre-inch of water, one would have to sprinkle out more than eleven tons of the substance used, a quantity prohibitive in initial cost, prohibitive in cost of aeroplane spreading, and prohibitive because of likely injury to vegetation and soil.

Electrically charging or discharging the free air

Another scheme put out as a sure means for obtaining rain at will was that of electrifying the free air at about the level of the lower clouds. Others have suggested exactly the opposite process namely discharging not charging it, as a sure means of getting rain.

Neither plan, however, has anything to recommend it. Lightning as is well known is a product and not the cause of the thunder storm. Neither, so far as yet detected, is precipitation altered, either in quantity or frequency, in the neighbourhood of meteorological kite stations.

Sprinkling clouds with electrified sand

Another view suggested was the sprinkling of electrified sand from an aeroplane. To make success doubly sure it has been proposed that scout, broadcasting cloud forming chemicals, precede the sand man who then promptly precipitates the clouds thus formed into the thirsting earth beneath. But before putting this wonderful scheme into effect one needs to find the innocuous cloud producing chemical. For the present, therefore, since it is impossible for the scout yet to perform his part of the team work, we must regard this scheme as a vision.

Sprinkling from Aeroplanes

Among the many who have devised schemes for producing rain there are a few who instead of trying to be brilliantly original endeavour to play comfortably safe. These seem to have got their inspiration from the time-honoured sprinkling can or municipal cart. They propose flying over parched fields and abundantly spraying them as they go from a suitable water tank either permanently built into the plane or just taken aboard for the special occasion.

Of course this plan would succeed experimentally. Commercially, however, it would be prohibitively expensive many times over, for, in addition to the considerable amount evaporated while falling through dry air, to get the familiar acre-inch of "rain", one would have to take up for sprinkling out 113 tons of water—a prohibitively expensive job.

RECENT SUCCESSFUL EXPERIMENTS IN AMERICA AND AUSTRALIA

The fact that the amount of water vapour that can exist without condensation in a given column rapidly decreases with decrease of temperature led some scientists as early 1925 to argue that to get rain just take some ice up in a balloon and cool the free air. Even the use of liquid carbon-dioxide was suggested for the purpose.

It was, however, then thought that the air thus cooled would become correspondingly denser and would sink to lower levels where it would come to rest at a higher temperature. It was felt by those in authority that indeed a small cloud may thus be pulled down, warmed by compression and then evaporated.

The theory that rain formation is due primarily to the transfer of water from droplets of small ice particles in the same cloud is one of the new ideas which have been contributed by the Norwegian school of Meteorologists.

T. Bergeron⁽¹⁾, who in 1933 put forward the theory of rain formation through ice particles was closely associated with Bjerknes, father and son, in this earlier work. His contribution about rain was based on straightforward laboratory physics.

Natural cumulus clouds at temperatures above 13°C often contain only super-cooled water drops and no ice crystal. If a method could be discovered of planting crystal 'germs' in these clouds, the crystals would grow into larger snow-flakes at the expense of water drops and eventually fall as rain or snow.

Schaeffer carried out experiments in 1946 at Schenectady (U.S.A.) and was successful in artificially producing ice crystals in the laboratory by the sudden cooling of moist air⁽²⁾. These experiments suggested a possible method of planting ice particles in natural clouds. Later Langmuir and Schaeffer succeeded in stimulating the precipitation of snow from supercooled clouds by dropping 'dry ice' pellets into them from aircraft.

The Australian experiments further confirm the above theory. These experiments were made by two scientists E.B. Kraus and P. Squires working in the Radio-physics Division of Australian Council for Scientific and Industrial Research. This Division has its central laboratory situated in the grounds of the University of Sydney and experiments were performed near the City⁽³⁾.

(1) Science Today Vol. No. 48 September, 1947.

(2) Science News letter, Washington (November 23, 1946).

(3) Nature Volume 159 page 489, April 12, 1947.

Out of eight different clouds treated, radar observations indicated rain formation inside the cloud on six occasions and on four of these, heavy rain was observed visually to reach the ground.

The most spectacular results were obtained on February 5, 1947. On that day equatorial air was flowing slowly over the east coast of Australia from a generally north-easterly direction. The coastal plain and Pacific were cloudless, while the inland areas of eastern New South Wales were covered by a cumulus cloud. The cloud base was at 11,000 feet, the freezing level at 18,000 feet, and the top of the clouds uniformly at 23,000 feet.

At 13.45 hour, 100 lb. of granulated carbondioxide was dropped into a cloud, the top of which was slightly below the general level. After five minutes no visual results were observed. The aircraft flew on and another test was carried out about twenty miles to the south-west. At 13.56 hours 150 lb. of dry ice was dropped into a second cloud. The air-craft circled and in less than five minutes rain echoes from within the cloud were recorded on the aircraft's radar equipment. After the release of further 150 lb. of dry ice, the echoes grew in intensity and twenty one minutes after the cloud was first infected an oblique view was obtained which showed heavy rain coming from the base of the cloud. Forty-five minutes later, the aircraft descended to 8,000 feet, well below the cloud base, and a pillar of rain covering at least twenty square miles was then seen to reach the ground. Afterwards the farmers confirmed the occurrence of an isolated rain storm. No other rain was detected within 100 miles of the aircraft.

So far in most of the Australian experiments, dry ice has been used. A preliminary test was made using a liquid precipitating agent but further work on this has been held in abeyance till more detailed information as to the physics of the method of operation of dry ice has been obtained.

The most important point to be noted in these experiments is that the experiments were confined to clouds which were 'marginal' in the sense that their tops were nearly but not quite high enough to give natural rain. The clouds treated in these experiments were unstable. The freezing level was stated to be 18,000 feet and the top of the cloud to be 5,000 feet, higher. They must, therefore, have been ready to be 'triggered off'.

Technique and limitations of Australian experiments

A brief summary of the technique of the Australian experiments was kindly supplied by Mr. E. G. Bowen, Chief of the Division of Radio-physics of the Council for Scientific and Industrial Research in his reply in November, 1947. This may be useful for the benefit of the would-be-experimenters in India and is reproduced with acknowledgements to Mr. Bowen:—

"(i) Preliminary treatment of dry ice

This is obtained from local industrial sources and crushed before use to about 1/4 inch mesh—We are able to obtain the use of a Sturtevant coal sampler and crushing machine for this. The resulting product contains a wide range of sizes from 1/4 inch downwards with perhaps 10% of powder.

(ii) Method of Discharge from aircraft

The pellets are discharged by allowing them to fall through a chute in the floor of the aircraft, in our case a B-24. The dry ice is fed in by hand from bags each carrying approximately 25 pounds and the rate at which it is dispensed need not exceed 100 pound per minute. So far we have no information to define the minimum rate necessary to produce useful rain. It might very well be less than this figure.

(iii) Quantity of dry ice used

In most of our successful experiments we have used 100—200 pounds of dry ice per cloud. Langmuir has stated that there may be danger of overseeding with such quantities and that 10 or 20 pounds would produce a better result. We see no reason for his holding this view and suspect that he is wrong.

(iv) Temperature limits

We usually drop the dry ice into well developed cumuli the top of which are at a temperature between -8°C and 10°C . The process will work over a wider range of temperatures but these appear to be the optimum. We have no data on the actual limits but once made a drop at 2° which failed to work. At the lower end of the temperature scale, there is probably not much point infecting clouds at temperatures below -13° or 15°C because rain is likely to fall from them in any case.

(v) Observations

We have found that the best method of observing the initial formation and growth of rain within the cloud is by radar in the aircraft and on the ground. On a few occasions on which we have been able to make direct observations of the rain coming from the base of the infected cloud, it has usually amounted to about $\frac{1}{2}$ inch over a hundred square miles. In addition to this, there are strong chances of a general deterioration taking place in the direction of the upper wind."

VALUE OF EXPERIMENTS TO INDIA

The South West Monsoon gives India 95 per cent. of its rain. If the total rainfall should be spread equally over the whole country, there would be no famine in any part of India. Yet there are large tracts in Orissa, Rajputana and the Punjab which are very frequently visited by famine.

Thanks to the solar energy which is so active along the long coast of India, there is always enough vapour present in the lower atmosphere. The problem as previously stated is how to divert this vapour-laden air to famine stricken tracts and make it drop its contents by some method, which would be economically feasible. Here is an opportunity for the engineer, the scientist and the meteorologist to pool their knowledge in the service of the common man to remove poverty and disease. Sir C. V. Raman in his presidential address over the 13th session of the Indian Academy of Sciences, pointed out that not

only in Orissa but in every part of India, the gaunt figure of famine was noticed. It was the duty of the scientists to banish famine. The best way in which this could be achieved is to investigate how rainfall could be equalized over the sub-continent of India.

Very little reliable information is available at present regarding the frequency with which unstable cloud conditions exist over the famine stricken tracts in India. During the South-West Monsoon, there are large masses of clouds extending to great heights and it is believed that a good many of these clouds extend vertically above the freezing point and will thus be suitable for treatment with dry ice. The first step obviously in the programme of these experiments should be to collect reliable data on the heights of clouds and temperature structure in and around the clouds.

In addition to the experiments of trying to bring down rain by injecting dry ice into the marginal clouds, the other aspect of the problem which though equally important has not been investigated so far, is the possibility of altering the path of seasonal winds by setting up local convection currents in a manner so as to divert them towards deficit areas. It has been suggested by Mr. Dharam Sheel of the Central Waterways, Irrigation and Navigation Commission that such convection currents may be set up by lighting fires on the top of hillocks of suitable heights and properly spaced so that they are capable of providing a temperature gradient in the path of seasonal winds. Considering that the monsoons depend upon the principle that they always blow from places which have greater barometric pressure to places where it is less and that wind pressure gradient, in its turn, depends upon the rate of heating and cooling, Mr. Dharam Sheel's suggestion deserves to be tried out experimentally. He has further suggested that it may be possible to correlate this with deforestation and afforestation programme.

The study involves availability of aircraft capable of flying to heights of 25,000 feet. By their very nature the experiments are bound to be expensive. But this expense will be amply repaid, if India can make its contribution to this important humanitarian problem. The Rajputana States would be directly benefited. The Government of India and the Rajputana States should contribute liberally to these experiments. In addition rich business community of the Rajputana States should come forward so that the programme of experiments is not held for want of funds.

The experiments should obviously be planned and executed by the Meteorological Department of the Government of India.

ARTIFICIAL RAINFALL IN ANCIENT INDIA

I have been informed that references exist in Rig Veda and Shat-Path Brahmin regarding artificial rainfall. It is somewhat difficult to correctly assess the scientific value of poetic versions of natural phenomena, found in our ancient literature. Sanskrit research scholars and Sanskrit Universities will be rendering a great service to this cause if they can dig out such information from the ancient literature which may throw some light on the technique adopted by our ancient ancestors for actually stimulating or controlling rainfall.

EXPERIMENTS WORTH PURSUING

Even though at present the possibilities of producing artificial rainfall for the benefit of the agriculturist, in the near future appear to be remote, I do not share the view of those pessimists, who would advise a "standstill" policy.

The world is moving forward inspite of the pessimists. People who died 50 years ago, if they could be brought to life, would gasp in wonder at the marvels of achievement wrought by the genius of man. Twenty years ago, who could dream of a plane carrying a group of passengers across the Atlantic Ocean to Europe, smoothly, comfortably and safely in less than two days—and yet it has been done. Already the Pacific has been mastered with planes.

Even a few years ago, who could predict the birth of atomic energy—a power, limitless in quantity, transportable to every region of the world and available for every need of mankind. In the words of Dr. Smythe, "with this new Promethean gift, we can create conditions of paradise for every person on this globe on a scale undreamt of by seers and sages". The application of this power may solve the problem of artificial rain. India has very bright prospect for the development of atomic energy, as she has large reserves of thorium and uranium.

The World of Tomorrow is going to be a very different kind of a world than the one with which we have been associating ourselves for so long a time. We might as well make up our minds to contribute our little bit to achieve this Newer World, the hope that it would be a happier one—one free from hate and greed and wasteful wars. No single factor would go a greater way to achieve such a World than even a halting measure of success in producing "Man Made Rain".

DISCUSSION BY THE RESEARCH COMMITTEE

RAI BAHADUR KANWAR SAIN introduced item (1) and said that at the last Board meeting it was resolved that India Meteorological Department be requested to organise experiments in artificial rainfall. Cloud control surely was a subject worthy of study and consideration. RAI BAHADUR KANWAR SAIN said that he did not know exactly what progress had been made by the Meteorological Department but he studied the literature that was available. He took considerable interest in studying what had been done so far and tried in this paper to show the various methods adopted. He had tried to describe them from a scientific point of view as far as he could and he had tried to show that from a scientific point of view these methods seemed to hold out no practical hope of artificial rainfall. Recently in America, Russia and Australia some successful experiments had been made. He got into correspondence with the experimenters in Australia and by correspondence he found the limitation of these. These experiments were confined to marginal clouds, which were at a height of 18,000 to 20,000 feet. The tops of these clouds were nearly but not quite high enough to give natural rain. The clouds traced in these experiments were unstable. The freezing level was stated to be 18,000 feet and

the top of the clouds to be 5,000 feet higher they must, therefore, have been ready to be triggered off. The aircraft dropped 100 of granulated carbondioxide into a cloud, the top of which was slightly below the general level. No visual results were observed. The aircraft dropped 100 lbs of dry ice into a second cloud. After a release of further 150 lbs. of dry ice the echoes within the clouds grew in intensity and 21 minutes after the cloud was first injected, heavy rain coming from the base of the cloud was recorded. 45 minutes later a pillar of rain covering at least 20 square miles was then seen to reach the ground. No other rain was detected within 100 miles of the aircraft. It was planned by some experimenters that with 15 dollars worth you can bring down an inch of rain. In R.B. KANWAR SAIN's opinions this gave a very good start to the further experiments in this connection.

Continuing he said that the Bikaner Government was keen to start some experiments. He suggested that the Meteorological Department might take up these experiments in the Bikaner State. The Meteorological Department would be given all the facilities and he assured them that there would be no suits for damages. He suggested to the Board to recommend to the Meteorological Department that they should start these experiments.

The Chairman next called upon DR. L.A. Ramdas to speak. DR. RAMDAS said that the subject was a very live one. There was the question whether clouds could be induced to part with moisture.

DR. RAMDAS then read out the following extracts from Mr. A. K. Roy's report on the Australian experiments which stated the present position quite clearly.

".....the views of the present workers in Australia seem to be that, while the experiments so far made have now definitely established the fact that it is possible to produce rain from growing clouds under certain favourable conditions, by planting ice crystal 'germs' by discharge of suitable seeding agents in the cloud, the experiments so far made have not yet reached the stage when one can hold out the hope of practical application of the results in solving the problems of scarcity of rain in a particular area. For, apart from the fact that we have to depend on Nature for development of cloud of the appropriate depth and height, it is necessary that we should be ready with our experimental arrangements at the time when such clouds happen to develop over the area, and should complete the experiment while conditions continue favourable for development of the cloud".

DR. RAMDAS said that every encouragement should be given to the scientific work both in the laboratory and in the open field, but the time has not yet arrived for propaganda and demonstration experiments which may hold out hope to the public prematurely. He said that the deputation of Mr. A. K. Roy to Australia to study, amongst other matters, experiments on rain-making in progress in that continent, may perhaps be regarded as a preliminary step already taken by the India Meteorological Department, which would also probably consider, in the near future, the question of making similar trials at a few centres in India, purely as preliminary scientific research.

DR. RAMDAS pointed out that most of the experiments, so far made in other countries, are confined to fair weather cumulus or cumulo nimbus associated with developing thunderstorms. These are highly localised in nature. On the other hand, the S.W. monsoon, perhaps the most large-scale phenomenon of its type is on too big a scale to be affected by any small scale experiments of this nature. So far as is known, the only agent which brings about an equitable distribution of the monsoon rainfall, particularly in North and Central India is the series of monsoon depression which move across the country, at intervals, from the head of the Bay towards N. W. India. It is no exaggeration to say that in a year in which these depressions are few or absent, monsoon precipitation would tend to concentrate along the Western Ghats and in and around the Himalayan and other ranges in N. E. India. Rainfall in the Indo-Gangetic plain, Rajputana, Central parts of the country, Gujrat, *etc.*, is entirely dependent on the frequency and intensity of the monsoon depressions. No artificial experiments can even hope to achieve what a depression does to the monsoon rainfall.

With regard to references to ancient literature, DR. RAMDAS informed the Committee that the India Meteorological Department had recently taken up the problem of trying to discover the truth that might lie hidden behind the sayings, aphorisms, folk-lore, *etc.*, which have accumulated in our country. The Director General of Observatories had recently appointed a Folk-lore Committee which is engaged in the task of examining every one of the aphorisms that have been collected from all parts of India, selecting those which hold out some promise of forecasting value and weeding out those which have no reference to meteorology as such. The idea is ultimately to subject the selected ones to critical scientific tests with a view to rejecting those which are false and retaining those which are true. DR. RAMDAS mentioned that this would involve a colossal amount of work.

MR. P. R. AHUJA raised the question whether Atom Bomb explosions would have any effect on weather. DR. RAMDAS stated that, in his opinion, there will not be any significant effects.

With reference to RAI BAHADUR KANWAR SAIN'S generous offer of help of Bikaner, DR. RAMDAS promised to communicate this offer of co-operation to the Director General of Observatories.

MR. P. R. AHUJA asked if the depression could be attributed to the question of atomic bomb because that had an effect. Depressions were no doubt obtained after the atomic bomb.

DR. L. A. RAMDAS said the depressions he meant had nothing to do with the atom bomb.

THE PRESIDENT said that the general feeling among workers in this field was that artificial rain would remain in the nature of local experiments and no more. It would be too much to expect that artificial rain could be obtained on a big scale and that the monsoon could be diverted. Further research should, however, be directed to this problem.

DISCUSSION BY THE BOARD

THE SECRETARY described the work done at the Research Committee meeting.

DR. S. K. BANERJI said that this subject was discussed at a considerable length at a recent meeting of the International Union for Geodesy and Geophysics. It was recognised that under certain conditions it was easy to stimulate artificial rainfall but exactly what could be got of it was still to be determined. He read out a general summary* that had been prepared from the analysis of many experiments that had been already made in different countries.

RAI BAHADUR A. R. VENKATACHARY enquired if it was not possible to send carbondioxide in a balloon.

DR. S. K. BANERJI said that it was possible to send some carbon dioxide in a balloon but it was not sure if the balloon would stick to the track and so it would not be possible to decide on the effect of it. Moreover, it would only be like a laboratory experiment.

MR. N. P. GURJAR asked if it was possible to have this in any season in the year.

DR. S. K. BANERJI replied that one would naturally like to do the experiment over an area deficient in rain.

RAI BAHADUR C. L. HANDA asked if one could also ward it off when the rain was not needed.

DR. S. K. BANERJI said that in U.S.A. they altered the cycle of the cyclone by sending it in a wrong direction.

Continuing DR. BANERJI said that even fine powdered dust had been found quite good for creating artificial rain.

DR. J. K. MALHOTRA remarked whether some sort of electric discharge could not be sent out. What he meant to suggest was whether the formation of rain nuclei in the clouds could not be stimulated in this manner.

DR. S. K. BANERJI said that that had not been tried.

THE PRESIDENT thanked Dr. Banerji for the valuable information supplied by him.

**Section B—Theory of Flow and Design
of Channels**

247-243

1B. Flow in Rivers and Canals

PRELIMINARY NOTE

This subject was placed on the agenda of the 1940 meeting of the Research Committee, with the object of examining data and determining the most suitable general flow formulae for rivers and canals. Other aspects which have received attention under this head are back-water curves and the correlation of river gauges.

In 1945 the subject was divided into following sub-heads :—

- (i) Flow in channels with rigid and quasi-rigid boundaries,
- (ii) Flow in channels in incoherent and coherent alluvium, with reference to the design and mechanism of flow.

(i) FLOW IN CHANNELS WITH RIGID AND QUASI-RIGID BOUNDARIES

PRELIMINARY NOTE

The following item was discussed at the 1947 meeting of the Research Committee :—

- (1) Stilling of whirlpool in Kondepudi gorge of the Godavary river.

Recent Literature

- (1) Hickox, G. H. Peterka, A. J. and Elder, R. A. :—Friction coefficient in a large tunnel. Proceedings of American Society of Civil Engineers, Vol. 73, No. 4, April 1947.
- (2) Commons, G. G. and Griffith, L. B. :—Variable flow in level channels Solved by simple chart. Engineering News Record, Vol. 137, No. 14, October 3, 1946.

THE YEAR'S WORK

DISCUSSION BY THE RESEARCH COMMITTEE

There was no contribution under this sub-head and no discussion.

It was decided that the subject should remain on the Agenda.

DISCUSSION BY THE BOARD

There was no discussion.

(ii) FLOW IN CHANNELS IN INCOHERENT AND COHERENT ALLUVIUM

PRELIMINARY NOTE

The following items were discussed at the 1947 meeting of the Research Committee :—

- (1) Design of channels in the Mor Project.
- (2) Formula for velocity at the Chas Road Bridge site on the Damodar.
- (3) Relation between different discharge elements for the river Brahmaputra at Jogigopa.
- (4) Rate of sand attrition in channels.
- (5) Analysis of hydraulic data from selected discharge sites along the barrage canals during 1946.

Recent Literature

(1) Blench, T. Lt. Col.—Theorie de lecoulement turbulent (Theory of turbulent flow). La Houilla Blanche, Vol. 2, No. 3, May 1946.

(2) Sneddon, R.—Investigation of factors that affect fluid flow in porous media. Pages from the Petroleum Engineer, January 1946.

(3) Lacey, G.—A general theory of flow in alluvium. Journal of Institution of Civil Engineers, November 1946.

THE YEAR'S WORK

The following item was discussed at 1948 Research Committee Meeting :—

(1) Estimation of silt particle size from settling velocity.

(1) ESTIMATION OF SILT PARTICLE SIZE FROM SETTLING VELOCITY (1)

The estimation of the sizes of the particles constituting the canal and river sediments is of great use in problems relating to (a) scour below works; (b) silt exclusion and extraction, and (c) the design of stable irrigation channels.

The methods employed for this estimation include :—(1) Mechanical analysis of a sample by graduated sieves into fractions of different size—ranges, and (2) further detailed analysis of the fraction lying approximately within the limits, 0.06 to 0.60 millimetres, by means of a siltometer. Most of the bed silts of the Punjab canal systems lie entirely within this range and can, therefore, be analysed by a siltometer without recourse to sieves.

Both the siltometers developed so far viz., the optical lever siltometer by Dr. V. I. Vaidhianathan and the Puri Siltometer by Dr. A. N. Puri are based on the theoretical connection between (i) the settling velocity of a silt particle in a vertical column of water, and (ii) the 'equivalent' diameter of the silt particle.

The relevant theory for the evaluation of particle diameters from observed values of the settling velocity assumes that the weight of the particle (less the weight of the liquid displaced) is exactly balanced by the resistance of the liquid to the motion of the particle.

The resisting force was shown by Stokes to be equal to $3\pi \cdot e \cdot d \cdot v$ where

e = viscosity of the liquid,

d = diameter of the particle in centimetres, and

v = velocity of the particle, in centimetres per second, supposed to be uniform,

provided the velocity was small.

Equating this to the weight of the particle (less the weight of the liquid displaced), we get

$$\pi \cdot d^3 g \frac{(s-r)}{6} = 3 \pi \cdot e \cdot v \cdot d,$$

where s and r are the densities of the particle and the liquid respectively. Simplifying

$$d^2 = 18 e \cdot \frac{v}{g} (s-r) \quad (1B.1)$$

which gives what is known as the 'Stokes diameter'.

(1) East Punjab Irrigation Research Institute, Amritsar. Annual Report, 1947, pages 16—19.

Later, it was theoretically shown by Goldstein (Proc. Roy. Soc., A. 123, 25, 1929) that the diameter given by Equation (1B.1) was too small and that must be multiplied with a factor, n , to get the true diameter D .

This factor, he showed, was function of the Reynolds' number, R , given by

$$R = v D \frac{r}{e} \quad (1B.2)$$

The values of n were worked out by Goldstein for values of R going up to 20.0. He found that they reasonably agreed with the experimental data obtained by Zahm a few years, earlier (1926).

Some of these values were reproduced in the Punjab Irrigation in Research Publication Vol. V. No. 1, 'An Optical Lever Siltometer', Table 1B.I.

TABLE 1B.I

| Reynolds' number (R) | Multiplying factor (n) | Reynolds' number (R) | Multiplying factor (n) |
|--------------------------|----------------------------|--------------------------|----------------------------|
| 0.4 | 1.04 | 5.0 | 1.33 |
| 0.8 | 1.07 | 6.0 | 1.37 |
| 1.2 | 1.10 | 8.0 | 1.46 |
| 1.6 | 1.13 | 10.0 | 1.54 |
| 2.0 | 1.15 | 12.0 | 1.01 |
| 3.0 | 1.22 | 16.0 | 1.74 |
| 4.0 | 1.27 | 20.0 | 1.86 |

In working out the correction factor, n , however, the obvious difficulty was that in order to get n , one must know R , which in turn required a knowledge of the true particle diameter, D . But D was precisely what we had to find and it seemed that no direct solution was possible.

It was, therefore, assumed (in the Punjab Institute) that it was sufficient to replace D in Equation (1B.2) by the Stokes diameter, d .

Tables for estimating silt particle size from observed values of the settling velocity were prepared accordingly. For comparative purposes and for silt particles of small size, the approximation involved in taking D as equal to d was perhaps not very inexact; but, for particles of larger size, it introduced an element of error, whose magnitude was realized only recently, and a method for eliminating which was worked out during the period under report. This is described below.

From Equation (1B.2), we get

$$\frac{R}{D} = \frac{v \cdot r}{e} \quad (1B.3)$$

Also by definition,

$$D = n \cdot d \quad (1B.4)$$

Multiplying (1B.3) and (1B.4) together

$$R = n \cdot v \cdot d \cdot \frac{r}{e}$$

$$\text{or } \frac{R}{n} = \frac{v \cdot d \cdot r}{e} \quad (1B.5)$$

Thus the Reynolds' number previously calculated was really equal to $\frac{R}{n}$. All that was needed, therefore, was to draw a curve which would give the values of n , for known values of $\frac{R}{n}$. Using the values of R and n , we get the set of values given in Table 1B.II.

TABLE 1B.II

| R/n | n | R/n | n |
|-------|------|-------|------|
| 0.38 | 1.04 | 3.76 | 1.33 |
| 0.75 | 1.07 | 4.38 | 1.37 |
| 1.09 | 1.10 | 5.48 | 1.46 |
| 1.42 | 1.13 | 6.49 | 1.54 |
| 1.74 | 1.15 | 7.45 | 1.61 |
| 2.46 | 1.22 | 9.20 | 1.74 |
| 3.15 | 1.27 | 10.75 | 1.86 |

These values are plotted in Figure 1B.1 and 1B.2.

The procedure for evaluating D , therefore, would be as follows:—

- (i) Calculated d from Equation (1B.1).
- (ii) Work out $\frac{R}{n}$ from Equation (1B.5).
- (iii) Read the value of n from the curves in Figure 1B.1 or 1B.2.
- and (iv) Obtain D from Equation (1B.4).

DISCUSSION BY THE RESEARCH COMMITTEE

DR. J. K. MALHOTRA introduced item (1). He explained that the existing method of estimating particle size from settling velocity involved an approximation which gave appreciably lower values for particles of bigger size. He had formulated a new method which gave the exact size in all cases.

As the resulting correction would affect all the existing values of mean diameters and might involve changes in the regime flow formulae, he would like to have the new method verified by actual physical measurements of particle size and also to have the theoretical basis carefully done over by Dr. N. K. Bose who had initially used the Goldstein Zahm correction to the Stoke's formula.

It was then decided that the subject should remain on the Agenda.

DISCUSSION BY THE BOARD

There was no discussion.

2B. Hydraulic Data of Torrents in Boulder Rivers and Streams

PRELIMINARY NOTE

The note that Mr. Thomas promised to write on the subject has not yet been received from him. A comprehensive resolution* was passed by the Board in 1946, regarding the collection of hydraulic data of torrents in boulder rivers. There was no contribution and no discussion on the subject at the 1947 meeting of the Research Committee.

THE YEAR'S WORK

The following items were discussed at the 1948 Research Committee Meeting :—

- (1) Analysis of hydraulic data of the Nayar river.
- (2) Analysis of hydraulic data for the river Ganga at Hardwar.
- (3) Hydrological data of the river Damodar and its tributaries in the hill catchment for 1947.
- (4) Hydrological data for the rivers Mor, Dwarka and Brahmani for 1947.
- (5) Hydrological data for the river Tista and its tributaries in the hill catchment.

(1) ANALYSIS OF HYDRAULIC DATA OF THE NAYAR RIVER (1)

Hydrological data of the Nayar River is being collected since the year 1946, a series of accurate discharge observations being taken in 1947 with the aid of current meter. An analysis of the latter has been undertaken this year.

*The Central Board of Irrigation Journal, April, 1947, page 121.

(1) United Provinces Irrigation Research Station, Report on Research Progress during 1947, pages 41-42.

A graph between the discharge and the rugosity co-efficient (Kutter's), can be seen in Figure 2B.1. The smooth curve through the points is asymptotic and exhibits a steep fall regarding which a mention has already been made

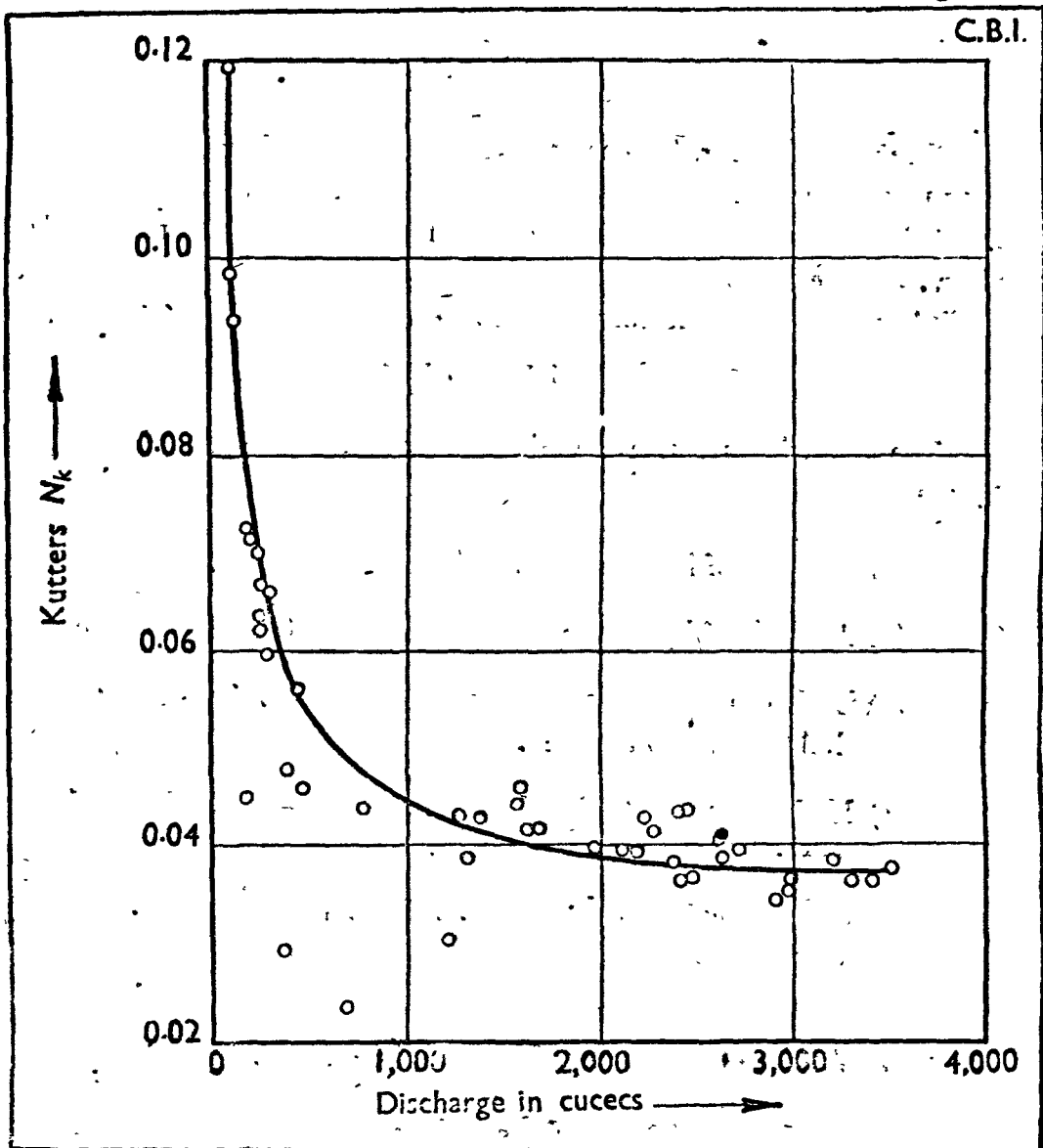


Figure 2B.1 : Showing relation between discharge and Kutter's N (Nayar river).

Along with a study of the actual values of rugosity co-efficients, the variation of the latter by different formulae was also studied, for which the columns (12), (13) and (14) of Table 2B.1 may be perused. It is to be seen that the rugosity co-efficient by Kutter's formula agrees most closely with that by Lacey's formula.

TABLE 2B.I
Analysis of hydraulic data for the Nayar river

| Serial No. | Date | Q | A | P | R | S × 10 ³ | V | Manning's $N_M = \frac{1.4858 R^{2/3}}{S^{1/2}}$ | Kutter's $\frac{N}{K}$ | Lacey's $N_a = \frac{1.3458 R^{2/3}}{S^{1/2}}$ | Barnes' $N_B = \frac{1.428 R^{0.7}}{S^{1/2}}$ | $\frac{N_M - N}{N K} \times 100$ | $\frac{N_a - N}{N K} \times 100$ | $\frac{N_B - N}{N K} \times 100$ |
|------------|-----------------------------|--------|--------|--------|-------|---------------------|-------|--|------------------------|--|---|----------------------------------|----------------------------------|----------------------------------|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 1 | 29-1-47 } to 6-2-47 } | 245.12 | 478.86 | 114.29 | 4.190 | 0.0615 | 0.512 | 0.05916 | 0.06212 | 0.06039 | 0.05962 | 4.80 | 2.82 | 4.06 |
| 2 | 9-2-47 | 767.00 | 571.63 | 122.56 | 4.664 | 0.185 | 1.342 | 0.04206 | 0.04373 | 0.04329 | 0.04254 | 3.82 | 1.01 | 2.72 |
| 3 | 24-2-47 | 452.00 | 518.40 | 118.36 | 4.380 | 0.0923 | 0.872 | 0.04388 | 0.04579 | 0.04494 | 0.04431 | 4.17 | 1.86 | 3.23 |
| 4 | 25-2-47 | 384.00 | 506.70 | 116.48 | 4.350 | 0.007 | 0.758 | 0.04584 | 0.04797 | 0.04692 | 0.04627 | 4.46 | 2.21 | 3.56 |
| 5 | 26-2-47 | 242.00 | 497.80 | 115.77 | 4.30 | 0.0615 | 0.486 | 0.06342 | 0.06623 | 0.06486 | 0.06400 | 5.24 | 3.09 | 4.38 |
| 6 | 19-3-47 | 184.00 | 473.40 | 113.25 | 4.18 | 0.0460 | 0.389 | 0.06723 | 0.07108 | 0.06861 | 0.06778 | 5.42 | 3.47 | 4.64 |
| 7 | 20-3-47 | 275.00 | 484.30 | 114.76 | 4.22 | 0.0615 | 0.568 | 0.05359 | 0.05622 | 0.05474 | 0.05405 | 4.68 | 2.63 | 3.86 |
| 8 | 21-3-47 | 260.00 | 480.00 | 114.56 | 4.19 | 0.0615 | 0.542 | 0.05590 | 0.05980 | 0.05707 | 0.05635 | 6.52 | 4.58 | 5.77 |
| 9 | 27-3-47 | 210.00 | 467.10 | 113.10 | 4.13 | 0.0615 | 0.450 | 0.06667 | 0.07003 | 0.06795 | 0.06717 | 4.80 | 2.97 | 4.08 |
| 10 | 1-5-47 } to 2-5-47 } | 150.00 | 438.41 | 110.99 | 3.95 | 0.0154 | 0.342 | 0.04260 | 0.04464 | 0.04326 | 0.04286 | 4.57 | 3.07 | 3.99 |

TABLE 2B. I—contd.

| Serial No. | Date | | A | P | R | $S \times 10^3$ | V | Manning's $N_M = \frac{1.488 R^{1/2} S^{1/2}}{V}$ | Kutter's N_K | Lacey's $N_L = \frac{1.348 R^{1/2} S^{1/2}}{V}$ | Barnes' $N_B = \frac{1.428 R^{0.7} S^{1/2}}{V}$ | $\frac{N_K - N_M}{N_K} \times 100$ | $\frac{N_K - N_L}{N_K} \times 100$ | $\frac{N_K - N_B}{N_K} \times 100$ |
|------------|---------|----------|--------|--------|-------|-----------------|-------|---|----------------|---|---|------------------------------------|------------------------------------|------------------------------------|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 11 | 29-5-47 | 240.00 | 480.00 | 114.56 | 4.19 | 0.0615 | 0.500 | 0.06056 | 0.06375 | 0.06153 | 0.06105 | 5.00 | 3.48 | 4.24 |
| 12 | 22-6-47 | 297.00 | 421.86 | 107.62 | 3.92 | 0.0308 | 0.230 | 0.08915 | 0.09337 | 0.09048 | 0.08969 | 4.52 | 3.10 | 3.94 |
| 13 | 23-6-47 | 91.50 | 419.08 | 107.18 | 3.91 | 0.0308 | 0.218 | 0.09389 | 0.09835 | 0.09528 | 0.09442 | 4.53 | 3.12 | 3.98 |
| 14 | 24-6-47 | 75.00 | 419.15 | 107.20 | 3.91 | 0.0308 | 0.179 | 0.11430 | 0.11997 | 0.11610 | 0.11500 | 4.72 | 3.22 | 4.14 |
| 15 | 1-7-47 | 450.00 | 535.01 | 119.69 | 4.47 | 0.123 | 0.841 | 0.05318 | 0.05579 | 0.05456 | 0.05373 | 4.68 | 2.21 | 3.69 |
| 16 | 2-7-47 | 280.00 | 506.70 | 116.34 | 4.35 | 0.077 | 0.553 | 0.06285 | 0.06642 | 0.06434 | 0.06344 | 5.38 | 3.13 | 4.49 |
| 17 | 11-7-47 | 384.00 | 393.40 | 176.89 | 2.224 | 0.1294 | 0.976 | 0.02952 | 0.02843 | 0.02858 | 0.02914 | -3.83 | -0.53 | -2.50 |
| 18 | 13-7-47 | 690.00 | 438.80 | 185.15 | 2.37 | 0.2000 | 1.572 | 0.02375 | 0.02327 | 0.02312 | 0.02351 | -2.06 | 0.64 | -1.03 |
| 19 | 24-7-47 | 2,985.00 | 765.00 | 160.3 | 4.777 | 1.035 | 3.902 | 0.03471 | 0.03549 | 0.03582 | 0.03516 | 2.20 | -0.93 | 0.93 |
| 20 | 25-7-47 | 2,382.00 | 720.00 | 156.52 | 4.60 | 0.900 | 3.308 | 0.03729 | 0.03809 | 0.03834 | 0.03770 | 2.10 | -0.66 | 1.02 |
| 21 | 26-7-47 | 2,607.00 | 742.00 | 158.85 | 4.68 | 1.015 | 3.513 | 0.03770 | 0.03855 | 0.03884 | 0.03815 | 2.20 | -0.75 | 1.04 |
| 22 | 27-7-47 | 2,487.00 | 731.30 | 158.63 | 4.61 | 0.880 | 3.401 | 0.03590 | 0.03663 | 0.03693 | 0.03631 | 1.91 | -0.90 | 0.79 |
| 23 | 28-7-47 | 2,410.00 | 712.80 | 161.27 | 4.42 | 0.905 | 3.381 | 0.03561 | 0.03622 | 0.03651 | 0.03596 | 1.63 | -0.86 | 0.66 |
| 24 | 30-7-47 | 2,912.00 | 750.00 | 159.91 | 4.69 | 1.005 | 3.882 | 0.03401 | 0.03464 | 0.03504 | 0.03442 | 1.71 | -1.26 | 0.52 |
| 25 | 10-8-47 | 1,666.00 | 656.00 | 150.46 | 4.36 | 0.79 | 2.540 | 0.04388 | 0.04154 | 0.04493 | 0.04431 | -5.63 | -8.16 | -6.72 |

| | | | | | | | | | | | | | | |
|----|---------|----------|--------|--------|-------|--------|-------|---------|---------|---------|---------|-------|-------|-------|
| 26 | 11-8-47 | 1,587.00 | 647.00 | 149.42 | 4.33 | 0.765 | 2.453 | 0.04450 | 0.04563 | 0.04555 | 0.04491 | 2.48 | 0.18 | 1.58 |
| 27 | 12-8-47 | 1,588.00 | 642.00 | 149.30 | 4.30 | 0.740 | 2.473 | 0.04322 | 0.04427 | 0.4421 | 0.04362 | 2.37 | 0.13 | 1.47 |
| 28 | 14-8-47 | 1,383.00 | 605.00 | 143.37 | 4.22 | 0.587 | 2.286 | 0.04112 | 0.04240 | 0.04200 | 0.04147 | 3.02 | 0.94 | 2.19 |
| 29 | 19-8-47 | 2,216.00 | 737.00 | 157.61 | 4.676 | 0.962 | 3.007 | 0.04286 | 0.04277 | 0.04415 | 0.04337 | -0.26 | -3.23 | -1.40 |
| 30 | 21-8-47 | 3,501.00 | 854.00 | 168.77 | 5.06 | 1.190 | 4.099 | 0.03673 | 0.03788 | 0.03812 | 0.03730 | 3.04 | -0.63 | 1.53 |
| 31 | 22-8-47 | 2,460.00 | 760.00 | 160.34 | 4.74 | 1.071 | 3.237 | 0.04239 | 0.04364 | 0.04372 | 0.04292 | 2.86 | -0.18 | 1.65 |
| 32 | 28-8-47 | 3,202.00 | 839.00 | 167.13 | 5.02 | 1.075 | 3.816 | 0.03741 | 0.03843 | 0.03878 | 0.03796 | 2.65 | -0.91 | 1.22 |
| 33 | 30-8-47 | 2,448.00 | 773.00 | 161.38 | 4.79 | 1.006 | 3.167 | 0.04228 | 0.04353 | 0.04363 | 0.04282 | 2.87 | -0.23 | 1.63 |
| 34 | 1-9-47 | 1,648.00 | 658.00 | 150.57 | 4.37 | 0.041 | 2.504 | 0.04016 | 0.04106 | 0.04113 | 0.04055 | 2.19 | -0.17 | 1.24 |
| 35 | 3-9-47 | 1,255.00 | 594.00 | 142.11 | 4.18 | 0.530 | 2.113 | 0.04201 | 0.04293 | 0.04286 | 0.04235 | 2.14 | 0.16 | 1.35 |
| 36 | 4-9-47 | 1,306.00 | 590.00 | 145.32 | 4.06 | 0.494 | 2.214 | 0.03796 | 0.03860 | 0.03864 | 0.03823 | 1.87 | -0.10 | 0.96 |
| 37 | 5-9-47 | 1,203.00 | 471.00 | 118.70 | 3.968 | 0.423 | 2.554 | 0.02999 | 0.03018 | 0.03047 | 0.03018 | 0.63 | -0.96 | 0 |
| 38 | 8-9-47 | 2,725.00 | 773.00 | 161.38 | 4.79 | 1.000 | 3.525 | 0.03787 | 0.03950 | 0.03909 | 0.03836 | 4.13 | 1.04 | 2.80 |
| 39 | 9-9-47 | 2,266.00 | 713.00 | 156.02 | 4.57 | 0.975 | 3.178 | 0.04020 | 0.04122 | 0.04132 | 0.04064 | 2.47 | -0.24 | 1.41 |
| 40 | 10-9-47 | 1,905.00 | 686.00 | 146.83 | 4.672 | 0.7245 | 2.777 | 0.04024 | 0.04133 | 0.04145 | 0.04072 | 2.64 | -0.29 | 1.48 |
| 41 | 12-9-47 | 2,122.00 | 712.00 | 155.86 | 4.583 | 0.778 | 2.980 | 0.03838 | 0.03929 | 0.03947 | 0.03881 | 2.32 | -0.46 | 1.22 |
| 42 | 13-9-47 | 1,980.00 | 697.00 | 154.65 | 4.507 | 0.718 | 2.841 | 0.03823 | 0.03957 | 0.03925 | 0.03864 | 3.39 | 0.81 | 2.35 |
| 43 | 15-9-47 | 2,170.00 | 713.00 | 155.34 | 4.59 | 0.806 | 3.043 | 0.03838 | 0.03918 | 0.03936 | 0.03872 | 2.30 | -0.46 | 1.18 |
| 44 | 17-9-47 | 2,982.00 | 800.00 | 163.37 | 4.897 | 0.947 | 3.728 | 0.03537 | 0.03615 | 0.03657 | 0.03584 | 2.16 | -1.16 | 0.86 |
| 45 | 21-9-47 | 3,307.00 | 846.00 | 167.66 | 5.046 | 1.017 | 3.909 | 0.03567 | 0.03650 | 0.03696 | 0.03616 | 2.27 | -3.53 | 0.93 |
| 46 | 23-9-47 | 2,609.00 | 781.00 | 162.03 | 4.82 | 0.95 | 3.341 | 0.03911 | 0.04015 | 0.04038 | 0.03962 | 2.59 | -0.57 | 1.32 |
| 47 | 24-9-47 | 3,423.00 | 843.30 | 164.17 | 5.135 | 1.09 | 4.059 | 0.03596 | 0.03688 | 0.03734 | 0.03651 | 2.49 | -1.25 | 1.00 |
| | | | | | | | | | | | Mean | 2.77 | 0.46 | 1.86 |

CONCLUSIONS

(1) Rugosity co-efficient by Kutter's formula may be taken to be the following for the Nayar:—

- (a) 0.1 for discharge below 100 cusecs
- (b) 0.057 for discharge between 100 and 500 cusecs
- (c) 0.039 for discharge between 500 and 3,000 cusecs, and
- (d) 0.037 for discharge between 3,000 and 3,500 cusecs.

(2) For the hydrological data of the Nayar, Lacey's formula for rugosity co-efficient agrees most closely with Kutter's.

(2) ANALYSIS OF HYDRAULIC DATA FOR THE RIVER GANGA AT HARDWAR ⁽²⁾

A number of observations were taken this year on the river Ganga at Spur No. 1 (Dudhia Bund) above Laljewala, and on Kankhal channel at chainage 1,980 along Kankhal *Bund* which were analysed with a view to forming an idea of the rugosity co-efficient, *vide* Table 2B.II.

A run of 500 feet was taken for observing discharges at Spur No. 1 and the reach was fairly straight. The discharge was of the order of 60,000 to 75,000 cusecs.

The mean value of Kutter's rugosity co-efficient worked out to be 0.04206. Rugosity co-efficient were also evaluated by the formulas of Manning, Lacey and Barnes. It was found that the greatest resemblance of Kutter's co-efficient was with Barnes' as may be seen from the mean of column (14) of Table 2B.II, whereas the most divergent values were obtained by Lacey's formula as may be seen from a perusal of column (13). The co-efficient of variance ($=100 \times \text{S.D.} / \text{Mean}$) is more or less the same for Manning's Barnes' and Lacey's figures, all being within 10 per cent.

Another observation was taken on Kankhal Channel, whose discharge was 21,200 cusecs. The reach was very straight in this case and the section regular. Kutter's co-efficient was found to be 0.03124, and resembled Barnes' most. It may be interesting to recall here that a detailed comparative study of rugosity co-efficients was carried out in the year 1942-43. The finding was that Barnes' formula resembles Kutter's most, which is identical with this year's results.

CONCLUSIONS

(1) The value of the rugosity co-efficient (Kutter's for the River Ganga for a discharge of the order of 75,000 cusecs is 0.04206.

(b) The rugosity co-efficient (Kutter's for the Kankhal Channel for a discharge of the order 21,000 cusecs is 0.03124 thus indicating that the rugosity even in boulder channels if straight and regular in section is fairly small.

⁽²⁾ United Provinces Irrigation Research Station, Report on Research Progress during 1947, pages 42-43.

TABLE 2 B. II.
Analysis of hydraulic data of Ganga River at Hardwar

| Date | Q | A | P | R | S 10 ³ | V | Manning's $N_M = \frac{1.4858 R^{\frac{2}{3}}}{S^{\frac{1}{2}}}$ | Kutter's $\frac{N_K}{V}$ | Lacey's $N_L = \frac{1.3458 R^{\frac{2}{3}}}{S^{\frac{1}{2}}}$ | Barnes' $N_B = \frac{1.428 R^{0.7}}{S^{\frac{1}{2}}}$ | Kutter's $\frac{N_K - N_M}{N_K} \times 100$ | Lacey's $\frac{N_L - N_a}{N_K} \times 100$ | Barnes' $\frac{N_B - N_B}{N_K} \times 100$ |
|--|-------|---------|--------|--------|-------------------|--|--|--------------------------|--|---|---|--|--|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| Spur No. 1 (Dudhia Bund) — | | | | | | | | | | | | | |
| 2-9-47 | 61584 | 7387.7 | 398.08 | 18.558 | 1.2 | 8.336 | 0.04329 | 0.04687 | 0.05001 | 0.04586 | 7.64 | -6.70 | 2.16 |
| 4-9-47 | 60033 | 7357.00 | 398.03 | 18.484 | 1.0 | 8.160 | 0.04024 | 0.04289 | 0.04648 | 0.04264 | 6.18 | -8.37 | 0.58 |
| 7-9-47 | 68150 | 7281.00 | 397.83 | 18.302 | 0.98 | 9.360 | 0.03411 | 0.03543 | 0.3938 | 0.03613 | 3.70 | -11.15 | -1.90 |
| 12-9-47 | 74089 | 7545.00 | 398.58 | 18.937 | 1.42 | 9.817 | 0.04053 | 0.04304 | 0.04690 | 0.04297 | 5.83 | -8.23 | 0.16 |
| | | | | | | Mean | 0.03954 | 0.04206 | 0.94569 | 0.04190 | 5.84 | -8.61 | 0.23 |
| | | | | | | Standard deviation | 0.003869 | 0.004786 | 0.004493 | 0.0044110 | | | |
| | | | | | | Co-efficient of variance = (S. D. × 100) / Mean | 9.79 | 11.38 | 9.83 | 9.81 | | | |
| Kankhal channel at chainage 1,980 along Kankhal Bund | | | | | | | | | | | | | |
| 6-10-47 | 21200 | 3635.5 | 401.1 | 9.06 | 0.76 | 5.83 | 0.03054 | 0.03124 | 0.03323 | 0.03159 | 2.24 | -6.37 | -1.12 |

HYDRAULIC DATA OF TORRENTS

(3) HYDROLOGICAL DATA OF THE RIVER DAMODAR AND ITS TRIBUTARIES IN THE HILL CATCHMENT FOR 1947 ^(*)

Observations of gauge, velocity and silt intensity of the river Damodar and its tributaries in connection with the Damodar Flood Prevention Scheme were continued during the year. Another gauge station was opened at the Tilaiya Dam site during the year. The observation stations in the Damodar catchment are the following:—

Damodar river—

- (1) Ramgarh Road Bridge site.
- (2) Ayre Dam site.
- (3) Chas Road Bridge site.
- (4) Sudamdih Railway Bridge site.
- (5) Sonalapur Dam site.

Bokaro river—

- (1) Dana Railway Bridge site.

Barakar river—

- (1) Barhee G. T. Road Bridge site.
- (2) Tilaiya Dam site.
- (3) Barakar (Giridih) Road Bridge site.
- (4) Maithon Dam site.
- (5) Barakar (Asansol) Railway bridge site.

Usri river—

- (1) Giridih Railway Bridge site.

Observations of gauge heights, velocity and suspended silt content and cross sections were taken at all the sites except at the four dam sites, *viz.*, Ayre, Sonalapur, Tilaiya and Maithon, where only gauge heights were observed. At Barhi the Iron Bridge on the G. T. Road was washed away during the flood of September 1946 and a temporary wooden bridge about $\frac{1}{4}$ mile downstream was opened. Observations of gauge, velocity, *etc.*, were ordinarily taken at the temporary wooden bridge site, but during floods when the gauge at the site was wholly submerged in the water, readings were taken on the permanent gauge painted on one of the piers of the iron bridge site. Considerable difficulty for discharge observations was felt at Barhee as no wire rope arrangement was allowed to be put up by the Bihar Public Works Department authorities. The velocity and sectional data have been utilised to calculate the rates of discharge. As already reported in an earlier section the gauge discharge curves for all the sites have also been prepared.

(*) River Research Institute West Bengal, Annual Report, 1947, page 54.

(4) HYDROLOGICAL DATA OF THE RIVERS MOR, DWARKA AND BRAHMANI FOR 1947 ⁽⁴⁾

Hydrological observations in connection with the Mor Project were continued during the year. The different observations sites are:—

River Mor—

- (1) Messenjore Dam site.
- (2) Tilpara Ghat Barrage site.
- (3) Sainthia Railway Bridge site.

River Dwarka—

- (1) Godadharpur Railway Bridge site.

River Brahmani—

- (1) Nalhati Railway Bridge site.

Of these, observations were carried on throughout the year only at the Messenjore site. These include gauge readings, velocity, cross sections and suspended silt intensity. At all the four other sites observations were taken only during the flood season. At the Tilpara Ghat Barrage site only gauge readings were taken while at Sainthia, Godadharpur and Nalhati observations included gauge height, velocity, cross section and silt intensity. Velocity and cross sections were utilised for calculation of discharge from which the rating curves were prepared.

(5) HYDROLOGICAL DATA OF THE RIVER TISTA AND ITS TRIBUTARIES IN THE HILL CATCHMENT ⁽⁵⁾

Hydrological observations at all the eight sites in the hill catchment of the river Tista in connection with the Tista Project were continued during the year. The observations included gauge heights and discharges (velocity). The sites are the following:—

River Teesta—

- (1) Mumring (Rangpo) site.
- (2) Melli Bazar site.
- (3) Tista Bridge site.
- (4) Coronation Bridge (Sevoke) site.

River Rangpo—

- (1) Rangpo site.

River Rangit—

- (1) Naya Bazar (Singla) site.
- (2) Champa Bazar site.

River Ramam—

- (1) Singla site.

Besides gauge and velocity, silt intensity was observed at the Tista Bridge, Melli and Champa sites before the flood season in April and May 1947. During the flood season observations of silt intensity could not be started before the middle of August for want of proper arrangements. Even then sampling was not possible at Tista Bridge, Melli and Champa. At the five other sites sampling was continued till the water was almost clear.

⁽⁴⁾ River Research Institute, West Bengal, Annual Report, 1947, pages 54-55.

⁽⁵⁾ River Research Institute, West Bengal, Annual Report, 1947, page 55.

DISCUSSION BY THE RESEARCH COMMITTEE

MR. A. P. BHATTACHARYA introduced items (1) and (2) and said that he wanted to point out the difference in the nature of the bed at the site of observation in the two cases. The Nayar river at the point had uneven rocky sides with a bed consisting of shingle and small boulders with occasional small rocky cliffs jutting out, while river Ganga had a purely boulder bed.

For the Nayar, the range of discharges, was fairly long consisting of those from 75 to 3,500 cusecs. The rugosity coefficient varied from 0.10 to 0.37.

For the river Ganga, the discharge was of the order of 75,000 cusecs and the rugosity coefficient worked out to 0.04206, except for a single observation of 21,000 cusecs where the coefficient of rugosity was found to be 0.03124.

MR. G. SINHA introduced items (3) to (5).

MR. S. L. MALHOTRA said that U. P. had brought out for the first time that 'n' the coefficient of rugosity depended upon discharge. In his opinion, it depended upon the material of the section alone. The low discharge data referred to appeared to be inaccurate. On February 24, 1947 the discharge was 452 cusecs with a slope of 0.09 per 1000. Similarly for a discharge of 275 cusecs on March 20, the slope was 0.06, and for discharge of 260 cusecs also the slope was 0.06. He suggested that values below 500 cusecs should be rejected.

RAO BAHADUR JOGLEKAR referred to item (4) and said that detailed observations of silt, cross sections, gauges and velocities were made for the Mesenore Dam site, but only gauge readings were taken for the barrage site. It was equally important to have detailed observations for the barrage site as the study of this data would have been very useful for the design of the barrage.

DR. N. K. BOSE replied that such observations were being done at Sainthia bridge site which was only 15 miles downstream of the proposed barrage.

MR. S. T. GHOTANKAR said that there was a tributary downstream of the barrage and upstream of the Sainthia bridge, and enquired if that would not affect the data.

DR. N. K. BOSE replied that the tributary was very small.

MR. C. V. GOLE said that it would have been better, had cross sections been observed at the barrage site.

MR. GOVINDARAO referring to items (1) and (2) said that he would like to know the nature of the strata because in the South it was nothing extraordinary if they found a certain variation in the coefficient of rugosity with the discharge, as the nature of the soil varied with the depth of excavation.

MR. A. P. BHATTACHARYA replied that as already pointed out, the Nayar river at the point of observation had uneven rocky sides and the bed was composed of shingles and boulders with rocky cliffs jutting out occasionally.

As regards the question raised by Mr. Malhotra that the figures for discharge below 500 cusecs should be omitted, he pointed out that even for discharges higher than 500 they got the same conclusion, because co efficient dropped in some methodical order as would be seen from Figure 2B. 1. Discharges were observed by them with Gurley current meter.

RAI BAHADUR JOGLEKAR enquired as to why the co-efficient should vary with the discharge.

MR. A. P. BHATTACHARYA replied that that was a point for investigation.

MR. S. L. MALHOTRA said that the discharge by Gurley current meter for depths lower than 4.0 feet was not reliable.

DR. J. K. MALHOTRA said that 'n' the coefficient of rugosity varied with discharge also in the case of River Beas also at Sujanpur Tira. The reason for these variations was that the conditions at the sites did not conform to the rugosity formulas assumed to be applicable at all stages.

It was then decided that the subject should remain on the Agenda.

DISCUSSION BY THE BOARD

THE SECRETARY described the work done at the Research Committee meeting and said that the note on the subject promised by Mr. Thomas had been received in the Boards office. It was proposed to publish the note in the January 1949 issue of the Central Board of Irrigation for discussion at the next meeting of the Research Committee.

3B. Design of Irrigation Channels

PRELIMINARY NOTE

This subject was introduced on the agenda for the first time in 1947 and was intended to include all questions relating to the distribution of water for irrigation purposes from canals, tubewells *etc.*, on which the design and the capacity of the channels depended. The subject of Equitable Distribution of Irrigation Water in Canal System which had been on the agenda of the Board since its early meetings has now been covered by this subject. The Board has under preparation a publication on this item since 1933. A history of the progress made on this publication was detailed under item XXV, page 170 of the Central Board of Irrigation Publication No. 35 Annual Report (Technical) 1945. In 1945 the Board passed the following resolution :—

“ Resolved that all provinces and states should be asked whether they have any fresh contribution to make on the subject and the secretary should compile a draft publication on receipt of their replies ”.

In response to the above, fresh contributions have been received from Central Provinces and Berar, Bihar, Bombay, United Provinces, Bengal, Mysore, Gwalior, Khairpur, Jodhpur, Indore and Jaipur. The Punjab has referred to their Manual of Irrigation Practice. Orissa, Baluchistan and Patiala have no fresh contributions to make. Replies from others are awaited. There was no contribution and no discussion on the subject last year.

Recent Literature

(1) Navy built aqueduct for San Diego. Engineering News Record, Vol. 138, No. 10, March 6, 1947.

(2) Novak Pavel, Ing., B.Sc., A.M. I. C. E. The T. G. Masaryk National Hydrological Institute, Prague : Experimental and theoretical investigation of the stability of prisms on the bottom of a flume. Second meeting of the International Association for Hydraulic Structures Research, Stockholm, 1948. Paper No. 8.

(3) Bretting A. E., Professor, Denmark : Tekniske Hojskole, Kobenhavn. —A set of practical hydraulic formulae based on recent experimental research ; comparison with older formulae. Second meeting of the International Association for Hydraulic Structures Research, Stockholm, 1948. Paper No. 11.

(4) Meyer-Peter, E. and Muller, R., Professors, Zurich: Formulas for Bed Load Transport. Second meeting of the International Association for Hydraulic Structures Research, Stockholm, 1948. Paper No. 15.

(5) Inglis, Sir Claude, Director of Hydraulic Research, London: Historical Note on Empirical Equations, developed by Engineers in India for Flow of Water and Sand in Alluvial Channels.—Second meeting of the International Association for Hydraulic Structures Research, Stockholm, 1948. Paper No. 19.

(6) Mavis, F. T. and Laushey, L. M., Carnegie Institute of Technology, Pittsburgh, Penn., U. S. A: A reappraisal of the beginning of bed movement—Competent velocity. Second meeting of the International Association for Hydraulic Structures Research, Stockholm, 1948., Paper No. 20.

THE YEAR'S WORK

DISCUSSION BY THE RESEARCH COMMITTEE

There was no contribution under this subject.

It was decided to let it remain on the Agenda, and the next sub-head was taken up.

DISCUSSION BY THE BOARD

THE SECRETARY said that there was no contribution under this subject head and no discussion took place at the Research Committee meeting. The Board in 1945 approved to issue a Board Publication after modifying the contributions received previously on "Equitable distribution of irrigation water in a canal system". Fresh contributions were received from most of the administrations. Reports were still awaited from Madras, Hyderabad and Kashmir.

4B. Design of Drains in Irrigated and Tidal Areas

PRELIMINARY NOTE

The subject ' Surface Drainage ' was introduced on the agenda in 1932 when

" No conclusions were recorded by the Board, but it was resolved that the collection of information on the subject should proceed and progress reported at the next Board Meeting ".

In 1932, " Design of drains " and " Drainage systems in Irrigated areas " were also introduced as separate items on the agenda when a questionnaire on " The design of drains in Irrigated areas " was circulated for eliciting opinion of the various officers.

The following resolution was passed by the Research Committee in 1939 :—

" Resolved that the replies received from the provinces to the questionnaire on ' the design of drains in irrigated areas ' be circulated to the members of the Research Committee for information, and with a view to the modification of the existing questions, and the inclusion of new questions in the light of further experience.

Also resolved that the replies and amendments be brought before the Board at the 10th Annual Meeting to be held in the Autumn 1939 ".

The Board at their 1939 meeting decided :

" That the replies to the questionnaire be referred back to those provinces which have not submitted provincial replies. Thereafter the questionnaire to be printed for the information of the Board ".

This was done.

At the 1940 meeting of the Research Committee :

" The Committee decided that the questionnaire on drainage systems in irrigated areas should contain soil and rainfall maps of India ".

" It was also decided to omit ' drainage system in irrigated areas ' as a separate subject on future agenda of the Research Committee ".

The Board at their 1940 meeting resolved :—

" That the questionnaire on drainage systems in irrigated areas should be issued as a Board Publication, as and when funds were available, complete with soil and rainfall maps of India.

That the subject should be removed from future agenda of the Board meetings ".

At the 39th meeting of the Executive Committee, 5th August, 1944 :

“ It was resolved that the Publication ‘ questionnaire on drainage systems in irrigated areas ’ should not be printed at present, but that it should be considered in five years’ time when more information might be available for inclusion ”.

At the 1947 meeting it was decided to circulate the questionnaire afresh to all administrations for comments and for intimating if any change is required in the draft, and then to print it as a Board publication. In reply the West Bengal Government, Bombay, Central Provinces and Berar and the United Provinces have made some suggestions for additional information to be incorporated in the publication. Burma has no comments to make. Replies from the rest are still awaited. There was no contribution on the subject at the 1947 Research Committee Meeting.

THE YEAR'S WORK

The following item was discussed at the 1948 Research Committee Meeting.

(1) Model experiments for the revival of the Madaripur *Bil* Route and the Lower Kumar River.

(1) MODEL EXPERIMENTS FOR THE REVIVAL OF THE MADARIPUR *BIL* ROUTE AND THE LOWER KUMAR RIVER ⁽¹⁾

ABSTRACT

Describes the history of the problem and construction of the model.

The Lower Kumar river coupled with the Madaripur *Bil* Route was the connecting channel for use by steamers plying from the Madhumati and the Arial Khan river, Figure 4B-1. This route was an important one for steamer connection between Calcutta and Eastern Bengal. The Madaripur *Bil* Route is an excavated channel. It was originally excavated to a bed width of about 130 feet. Under this condition the clear *bil* water that entered at Fatepur divided about equally between the Lower Kumar river and the Madaripur *Bil* Route. The drainage along the Lower Kumar river passed out into the Arial Khan and kept back most of the time the silt-laden water of the Arial Khan river from entering the Lower Kumar river.

A large portion of the *bil* water passing down the *bil* route used to pass out into the *bil* south of the route. This escape of the *bil* water was controlled by an embankment erected on the south side of the channel. Sluices were constructed in the embankment at intervals to allow escape of water when necessary. This control was done when creeping up of the silt-laden Madhumati water up the Madaripur *Bil* Route and consequent silting was noticed ; it had the desired effect, and subsequently no trouble was felt from silting at the Madhumati end.

(¹) River Research Institute, West Bengal, Annual Report, 1947, pages 55-59.

The Madaripur *Bil* Route was gradually widened for easier navigation of steamers. It is now about 275 feet wide in the bed. Owing to this widening, the hydraulic balance was disturbed and more *bil* water was flowing down the Madaripur *Bil* Route. The fall in the water level thus created at Fatehpur was so much that the silt-laden Arial Khan water began to enter the Lower Kumar river at Charmaguria and silt up the channel near that end.

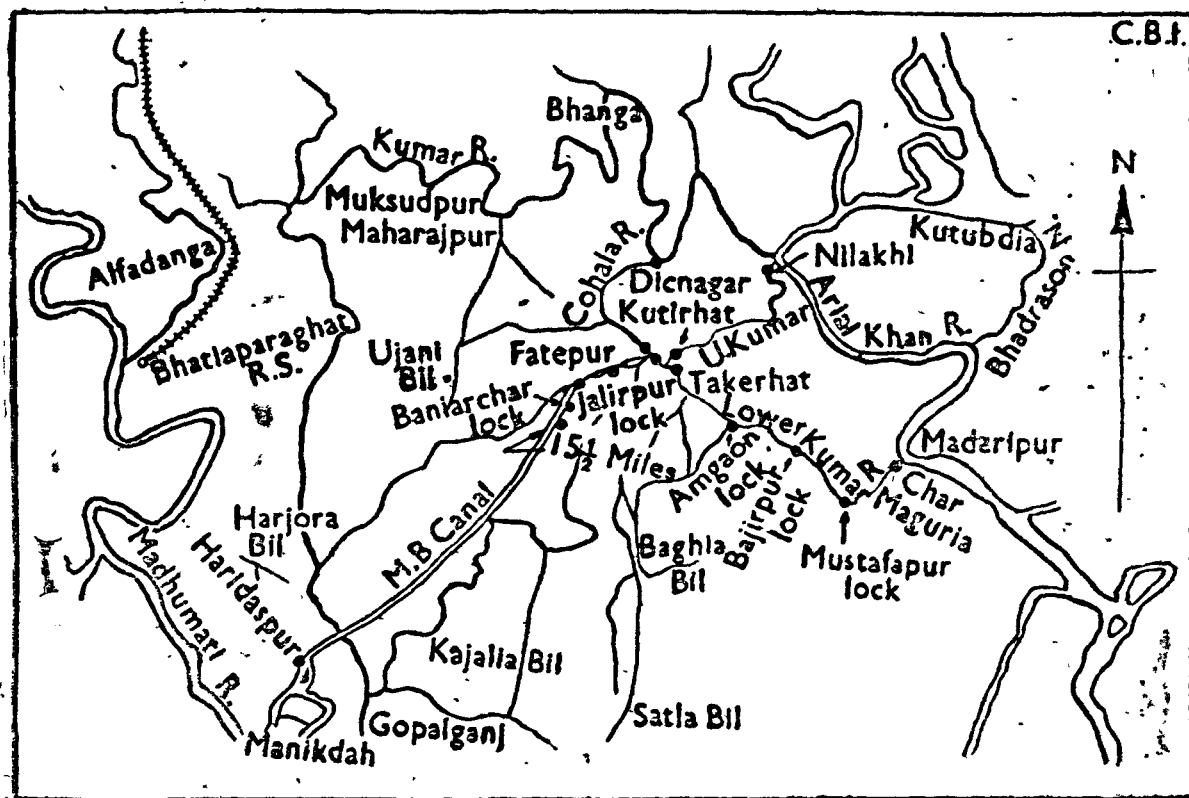


Figure 4B.-1 :—showing Index map of Madaripur Bil Route.

The flow from the Arial Khan was rather slow as the Arial Khan water level was not much higher than that at Fatehpur. At this stage several locks and sluices were constructed to control the flow of the *bil* water in the Lower Kumar river as in the Madaripur Bil Route. But no thorough reversal of current could be produced, and the channel continued to silt up. In order to pass out as much silt as possible, a strong flow out was obtained through the Mustafapur sluice. It reduced silting up to Mustafapur, but on the whole no great improvement was noticed. The position was made worse, it seems, owing to the shortening of the length of the Lower Kumar river due to erosion at Charmaguria.

The initial rapid erosion at Charmaguria started, it seems when the large draw through the Mustafapur sluice was going on. Another erosion started near Nilokhi higher up the Arial Khan. Due to the erosion of the Arial Khan at Nilokhi, the Upper Kumar river was breached in 1929 and silt-laden water of the Arial Khan began to enter the Lower Kumar river

at Takerhat. Thus, henceforth the Lower Kumar river began to get silt-laden water from both its ends and the river began to silt up rapidly. Attempts were made to pass out as much silt as possible through the controlling sluices. But no noticeable result was obtained.

Now the Upper Kumar river is widening and deepening and a large discharge is passing down the river. The Lower Kumar river has silted up rapidly, and it becomes almost dry during the dry season. The Upper Kumar river along with the Kutubdia entrance of the Arial Khan seems to be forming into a separate channel. Development of Bhadrason Nalla as the new offtake for the Arial Khan seems to indicate that the Arial Khan and the Upper Kumar river might be developing into separate channels. The portion of the Arial Khan linking the Upper Kumar with the Bhadrason Nalla is showing signs of silting. The Kutubdia channel is also silting and shrinking in section; it may be trying to assume a section similar to that of the improved Upper Kumar and the Madaripur *Bil* Route.

The discharge of the silt-laden water along the Madaripur *Bil* Route is silting up the channel near Baniar Char. There is a tendency of the shoal elongating downwards. Whether the controlling of the flow in the Lower Kumar and the Madaripur *Bil* Route is good for the channel is a matter which requires consideration. Salt water is coming up in the Satla *bil* area lying behind the Madaripur *Bil* route embankment. This is affecting cultivation in a large area of low lands and the people are demanding erection of embankments to save their crop. The embankments and sluices have stopped the natural deltaic formation. Under this arrangement the low lands will remain low indefinitely.

The scheme proposed for improvement of the Lower Kumar river involves cutting off of the Arial Khan water by a cross dam. A narrow channel into the Arial Khan will be provided for passage of country boats. The water entering through this channel will be negligible. When this work is executed entrance of upland water into the Lower Kumar river and Madaripur *Bil* Route will be considerably reduced, particularly in the dry weather when the saline water creeps up into the Satla *Bil* area.

The proposed scheme will restore the condition obtained before the widening of the Madaripur *Bil* Route when there was considerable silting of the Lower Kumar Route. Will the scheme produce any large benefit to the Steamer Route?

The project therefore in contemplation for the revival of the steamer route to Madaripur through the Madaripur *Bil* canal and the Lower Kumar consists of—

- (1) Closure of direct connection of the Upper Kumar with the Arial Khan at Kavirajpur by a cross dam in Upper Kumar.
- (2) A short cut connecting the Upper Kumar with the Kumar river at Kavirajpur to bring in clear water-supply into the Upper Kumar as before.
- (3) Dredging of the Lower Kumar and the Madaripur *Bil* Route to proper sections.

The question is whether the system thus renovated, will maintain itself. The supply from the Upper Kumar, Gohala *Khal* and Northern *Bil* areas may not be sufficient to maintain a nine feet deep waterway throughout the year. It may not be able to prevent the silt-laden water of the Arial Khan to go up the Lower Kumar from the Madaripur end and silt up its bed again. It may not also prevent the silt-laden water of the Madhumati to go up the Madaripur *Bil* canal from the Manikdah end and drop silt on its bed. If the supply is insufficient, the problem is how to augment it without bringing any harmful silt into the system.

These are problems to be studied in a model before the execution of the project is decided upon. For this purpose, the matter was referred to the Institute for investigation in a model.

The whole system consists of four main channels. The channels bringing in any discharge are the Upper Kumar and the Gohala *Khal*, while those leading out this discharge are the Madaripur *Bil* canal and the Lower Kumar. The supply in the Upper Kumar comes from the Kumar river above as well as from the Arial Khan. The supply in the Gohala *Khal* comes from the drainage area on its two sides and also from the Kumar river. The Madaripur *Bil* canal receives the spill of the *bil* areas on its north and spills into the *bil* areas on its south. The Lower Kumar also spills into the *bil* areas on its right bank (south bank). It receives some spill from its left bank. There are a number of locks and sluices on the south banks of the Madaripur *Bil* canal and the Lower Kumar. These locks and sluices are worked according to certain rules through the year, as water level rises and falls. The hydraulic balance of the whole system is rather complicated. To reproduce them in a model requires very accurate survey data together with gauge, discharge and velocity observations. One full year was required to collect these data.

The following data are available for construction of the model :—

- (1) Plan and cross sections of the Upper Kumar from Kavirajpur to Takerhat.
- (2) Plan and cross sections of Gohala *Khal* from Dignagar to Fatehpur.
- (3) Plan and cross sections of Lower Kumar from Charmuguria to Takerhat.
- (4) Plan and cross sections of Madaripur *Bil* canal from Haridaspur to Fatehpur.
- (5) Plan and cross sections of Link channel between Fatehpur to Takerhat.

For proving and running the model, the following gauge and discharge observations for the period from June 1946 to May 1947 were available :—

- (6) In Upper Kumar at Nilokhi (that is at Kavirajpur) and Kutirhat.
- (7) In Gohala *Khal* at Dignagar and Fatehpur.
- (8) In Lower Kumar at Charmuguria, Amgaon and Takerhat.
- (9) In Madaripur *Bil* canal at Fatehpur, Jalirpar Lock 15½ mile and Haridaspur.
- (10) In Link channel at Fatehpur.

THE MODEL AND THE EXPERIMENTS

The scale of the model was chosen as 1/200 (horizontal) and 1/40 (vertical). The different channels were barely 200 to 400 feet wide and sufficiently long stretches of each were to be incorporated in the model. The length of the Upper Kumar from Kavirajpur to Takerhat is about 10 miles, that of the Gohala *Khal* from Dignagar to Fatehpur about six miles, that of the Lower Kumar from Charmuguria to Takerhat about 12 miles and that of the Madaripur *Bil* canal from Haridaspur to Fatehpur about 8 miles. All these reaches had to be incorporated in the model. At the same time the channel width being rather narrow, a sufficient big horizontal scale had to be taken. A compromise was obtained by using horizontal scale as 1/200. The problem being one of silting and distribution of flow the bed was made rigid and fairly high distortion was given. To make the bed in the model rigid, a weak cement plaster was spread over properly sectioned earth. The locks and sluices of the Madaripur *Bil* canal and the Lower Kumar were constructed as in the prototype. As the quantity of water flowing was small arrangement for measuring discharge by the volumetric method has been made. Gauges have been put at proper places.

Regular work on this model has been started and experiments are now being done to see if the model reproduces prototype conditions properly. The results of some of these experiments are given in Table 4B.I. They show that the reproduction of the model is satisfactory. The work is in progress.

DISCUSSION BY THE RESEARCH COMMITTEE

DR. N. K. BOSE introduced the item and said that he had nothing to add to what he had said in his report. He had some difficulty in arranging the subject under a particular group and he had made reference to the Secretary on that point. He would like to know whether the grouping of the subject had been done properly. The subject of the experiments was not on 'drains' but on tidal rivers though the function of the river in that particular case was to drain water-logged land through which it ran.

MR. T. P. KUTTIAMMU said that the model consisted of a number of streams and also a number of sluices and locks. The scale was 1/200 horizontal and 1/40 vertical. He would like to know if these sluices and locks were also constructed to the same distorted scale and if so, whether any special adjustments were necessary for correctly reproducing the afflux at those structures.

DR. N. K. BOSE replied that they were not made to exact scale but were suitably adjusted.

RAI BAHADUR M. C. BIJAWAT enquired as to what discharge per square mile of the catchment area should be adopted for the design of drains.

TABLE 4 B. I

Result of the experiments in the Madaripur Bil Route system during the month of January 1948.

| Date of Experiment | Upper Kumar | | | | Lower Kumar | | | | Gohala Khal | | | Madaripur Bil Canal | | | Link Channel | | Remarks |
|---|--------------------|---------------|----------------|---|----------------|--------------|-------------------|-----------------------------|----------------|---------------|---|-----------------------|----------------|-----------------|---|---------------|---|
| | Total water-supply | Nilokhi gauge | Kutirhat gauge | Discharge between Nilokhi and Kutirhat (in cusec) | Takerhat gauge | Amgaon gauge | Charmuguria gauge | Discharge above Amgaon Lock | Dignagar gauge | Fatepur gauge | Discharge between Dignagar and Fatepur (in cusec) | Fateh pur (10½) gauge | Jalirfur gauge | 15th mile gauge | Discharge between Sindakhal and Jalirpur (in cusec) | Fatepur gauge | |
| January 7— Observed in the model .. | 2,100 cusec. | 4.40 | 3.80 | .. | 3.40 | .. | .. | .. | 3.40 | .. | .. | 3.60 | .. | .. | .. | 4.00 | In Lower Kumar water reached up to Takerhat only. |
| Prototype value .. | .. | 4.04 | .. | .. | 3.44 | .. | 3.09 | .. | 3.36 | .. | .. | 3.46 | .. | .. | .. | .. | |
| January 8— Observed in the model .. | 18,000 cu. ec. | 15.60 | 14.60 | .. | 14.20 | 14.20 | 13.40 | .. | 15.10 | 14.40 | .. | 14.30 | 14.80 | 14.30 | .. | 14.60 | |
| Prototype value .. | .. | 15.60 | 14.60 | .. | 14.70 | 14.40 | 13.25 | .. | 15.10 | 14.40 | .. | 14.30 | 14.80 | 14.80 | .. | 14.40 | |
| January 9— Observed in the model .. | 33,000 cusecs. | 16.55 | 14.95 | .. | 14.40 | 14.60 | 14.40 | .. | 15.75 | 14.80 | .. | 14.85 | 15.20 | 15.20 | .. | 14.90 | |
| Prototype value .. | .. | 16.55 | 14.95 | .. | 14.80 | 14.80 | 14.20 | .. | 15.75 | 15.00 | .. | 14.85 | 15.20 | 15.20 | .. | 14.90 | |
| January 12— Observed in the model .. | 7,650 cusec. | 7.15 | 6.00 | .. | 5.95 | .. | .. | .. | 5.95 | 5.60 | .. | 6.00 | 5.80 | 5.80 | .. | 6.40 | In Lower Kumar water reached up to Rajair lock. |
| Prototype value .. | .. | 7.15 | .. | .. | 6.15 | .. | 6.60 | .. | 5.95 | .. | .. | 6.00 | .. | .. | .. | .. | |
| January 13— Observed in the model .. | 7,800 cusec. | 13.75 | 12.85 | .. | 12.40 | 11.90 | 11.35 | .. | 13.50 | 12.86 | .. | 12.75 | 12.55 | 12.55 | .. | 13.00 | |
| Prototype value .. | .. | 13.75 | 12.85 | .. | 12.65 | 11.84 | 11.30 | .. | 13.50 | 12.86 | .. | 12.75 | 12.55 | 12.55 | .. | 12.78 | |

RAI BAHADUR R. R. HANDA said that before the partition he was incharge of the Northern Drainage circle which was responsible for the construction of drains in the West Punjab and had to design a number of drains. His jurisdiction lay between the rivers Ravi and Jhelum where the rainfall was not heavy. While fixing the discharges for the drains, the factors that were taken into consideration were rainfall as well as whether the area was flooded by the river or not. From the maximum actual discharge observation in the drains certain formulae were arrived at. These were changed from time to time. They were still in the initial stage because the drains dug by him had not yet been tested. His opinion, however, was that the sections that they had constructed were rather too big.

RAI BAHADUR M. C. EIJAWAT said that so far as upper India was concerned they knew fairly definitely the method to adopt. What he had in mind was that he had to deal with many drains in water-logged areas in Bengal and Bihar. When a drain was passing through water-logged area each Province sent up different discharge in these drains for varying conditions of the country through which the drain was passing. He only wanted to enquire what capacities should be adopted in those water-logged areas because there were rice crops standing on them. They had got to be dewatered. It was in such circumstances that they had got to decide what the drains should carry so that the rice crops should be able to retain enough water.

MR. T. S. VENKATARAMA IYER said that they were carrying on similar work in the delta areas of Tanjore. They had designed the drains for a 2-inch runoff per day. Their effect was yet to be seen.

DR. J. K. MALHOTRA said that he just wanted to give the formula which Mr. Handa had mentioned. A full description was given in the Punjab Research Institute Report for 1945. Mr. Haigh had carried out certain observations and the formula evolved by the institute was

$$Q_{\max} = 16A^{\frac{1}{2}}$$

RAI BAHADUR S. D. KHANGAR said that first, they took arbitrary figure of one cusec or four cusecs per square mile. Later from observations they evolved the formula. They came to the conclusion that it was not necessary to design the drains for maximum discharge. So they first reduced the coefficient to 12.0, then to 8.0. Runoff depended upon the type of cultivation, rainfall, and many other factors.

In Bihar they intended to drain off the flooded area in 45 day to permit *rabi* to be sown and the capacity of the drains was fixed accordingly.

RAI BAHADUR R. R. HANDA said that for design of drains in water-logged areas they had to take the following factors into consideration :--

- (1) The period, which the crops would stand the submergence in water subject to the condition that the top of the crops remained out of water.
- (2) Slope of the country, rain fall, etc.

Normally it was considered that crops would stand submergence of 4 to 5 days in the West Punjab. In the design of the drains the full supply line was kept at natural surface level so as to prevent flooding in all conditions. Later sections were reduced to allow flooding at 1.0 foot. The section of the drains was then designed according to Lacey's theory. He has found during his inspection that wheat could grow in areas where the watertable was as high as 2 to 3 feet below ground level, crops could grow on the land. Naturally this would vary with the type of the soil.

Bed level of the drain should be two to three feet below the ground level.

It was decided to keep the subject on the agenda.

DISCUSSION BY THE BOARD

THE SECRETARY described the work done at the Research Committee meeting.

Section D—Water Power Works

1 D. Estimation of Waterpower

PRELIMINARY NOTE

This subject was introduced for the first time in 1947 to take into account the development of natural waterpower resources of the country as well as the load development of the existing or proposed water projects. There was no contribution under this head at the 1947 Research Committee meeting.

Recent Literature

(1) Salinas Basin Investigations—Summary Report—State of California, Department of Public Works, Division of Water Resources, Bulletin No. 52-B, 1946.

(2) Ballin, H. H. The organisation of electricity supply in Great Britain—Electrical Press Ltd., London, 1946.

(3) New projects for irrigation and power, 1947—Central Board of Irrigation, Popular Series, Leaflet No. 3, 1947.

(4) Water power resources of Canada—Department of Mines and Resources, Surveys and Engineering Branch, Dominion Water and Power Bureau, Ottawa, No 2177, March 15, 1946.

(5) Mayott, C. W. Some federal power commission errors in load predictions and capacity requirements for the electric power utilities in the United States—1945 to April 1946—Federal Power Commission, 1946.

(6) Greene, B. H. Development of the Missouri Basin—Electrical Engineering Vol. 66, No. 2, February 1947.

(7) Waterways of India—their problems and the administrative machinery required for obtaining maximum benefits—Central Board of Irrigation Popular Series, Leaflet No. 4, 1947.

(8) Specifications, Schedule and Drawings, Bhakara dam and Power Plant—Government of the Punjab Public Works Department, Irrigation Branch.

(9) Atomic energy for generation of electric power—Commonwealth Engineer, Vol. 34, No. 5, December 2, 1946.

(10) Electricity supply in wartime—The Engineer, Vol. 183, No. 4752, February 7, 1947.

(11) Electricity supply in 1946—Engineering Vol. 163, No. 4240, May 2, 1947.

(12) Macmillan, F. O. Electric Power in China—Electrical Engineering Vol. 66, No. 1, January, 1947.

(13) Giroux, C. H. Hydro-electric development of the Saint Lawrence River—Electrical Engineering Vol. 65, No 11, November, 1946.

(14) Voorduin, W. L. The multi-purpose development of the Tennessee River—Science and Culture, Vol. 12, No. 11, May 1947.

(15) Multi purpose development of Indian rivers—Science and Culture, Vol. 13, No. 1, July 1947.

(16) Farpur, A. V. Modern power and irrigation structures promote development of North Africa—Civil Engineering New York, Vol. 17, No. 8, August 1947.

(17) McPhail, H. F. Proposed projects develop power and irrigation potentials of Colorado river system—Civil Engineering New York, Vol. 17, No. 8, August 1947.

(18) Lawton, F. L. Hydro-electric development in Quebec—Electric Engineering Vol. 66, No. 9, September 1947.

(19) German Electricity supply in war time—Engineering Vol. 162, Nos. 4223 and 4224, December 20 and 27, 1946.

(20) Use of Snowy River Waters—Commonwealth Engineer Vol. 35, No. 2, September 1, 1947.

(21) Hydro-electric progress in Canada during 1946—Department of Mines and Resources, Ottawa, December 31, 1946.

(22) Hydro in wartime Germany—A. Hoefle-Trans ASME., Vol. 69, No. 5, July 1947.

(23) Electricity supply during the war—Engineering Vol. 163, No. 4230, February 1947.

(24) Hydro-electric power installations in France—The Engineer—Vol. 183, No. 4751, January 31, 1947.

(25) The Hirakud Dam project: Mahanadi Valley development, Government of India, CWINC, June 1947.

(26) Markwell, K. More water conservation for the west—Engineering News Record, Vol. 138, No. 8, February 20, 1947.

(27) Major projects that are and will be making headline news: Power and Irrigation—Engineering News Record, Vol. 138, No. 8, February 20, 1947.

(28) Preliminary memorandum on the unified development of the Damodar River (Abridged) Central Technical Power Board, Simla, 1946.

(29) Report on the nursery power development project in Central Provinces and Berar—Government of India, Central Technical Power Board, Simla, April 1947.

(30) Hydro-electric developments in Scotland—Beama Journal Vol. 54, No. 122, August 1947.

(31) Thick, R. W. Preliminary load survey of Bahawalpur State, Government of India, Central Technical Power Board, Simla 1947.

(32) Water power resources of Canada—Department of Mines and Resources, Survey and Engineering Branch, Ottawa, March 15, 1947.

(33) Brown, K. L. The Ganges Canal hydro-electric system—Central Board of Irrigation Journal Vol. 4, No. 1, January 1947.

(34) Analysis of installed capacity and generation on the basis of population and area in British India and States for the year 1943—Central Board of Irrigation Journal, Vol. 4, No. 4, October 1947.

(35) Nursery power development projects, Central Board of Irrigation Journal, Vol. 4, No. 4, October 1947.

(36) Unified development of the Mahanadi Valley—Central Board of Irrigation Journal, Vol. 4, No. 4, October 1947.

(37) Exploitation of power resources—Public Works Department, Hyderabad Deccan.

(38) Water power resources of Canada—Department of Mines and Resources Surveys and Engineering Branch—Dominion Water and Power Bureau, Canada, March 15, 1947.

(39) Utilisation of the water resources of the Goulburn River Eldon reservoir enlargement—State Rivers and Water Supply Commission, Victoria, General Report 1947.

THE YEAR'S WORK

DISCUSSION BY THE RESEARCH COMMITTEE

There was no contribution and no discussion. It was decided to retain the subject on the agenda.

DISCUSSION BY THE BOARD

THE SECRETARY said that there was no contribution on the subject and no discussion took place at the Research Committee.

RAO BAHADUR G. SUNDARAM stated that so far as he knew, an attempt for estimating the water power available in the country was made some 25 to 30 years back by Barlow and Meyers and he did not know of any agency doing this work now. In Madras, he said a Hydro-electric survey was being made and he believed that some other Provinces were also doing this work. He suggested that the Central Waterpower, Irrigation and Navigation Commission or the Central Board of Irrigation should take this work in hand now.

MR. S. A. GADKARY stated that the estimation of water power was largely dependent on hydrological data. He suggested that methods for collecting this data be standardized. In appreciating the suggestion made by Rao Bahadur Sundaram he thought that it should be possible for the Central Waterpower, Irrigation and Navigation Commission to give a lead in this direction by suggesting the lines along which work could be done. A suitable procedure could then be devised after getting comments from the Provinces.

THE SECRETARY stated that it had been decided to prepare a Water Year Book and the compilation would be done by the Central Waterpower, Irrigation and Navigation Commission. In replying to Mr. Gadkary's question, he stated that a sub-committee was appointed last year to draw up the form and to decide the contents of the Water Year Book. That sub-committee met two or three times last year and they formulated proposals which had been approved by the Board earlier and would be forwarded to the Provinces.

MR. S. A. GADKARY suggested that a copy of the proposals regarding the Water Year Book be also sent to the Chief Engineers, (Hydro-electric) in all the Provinces for their comments and suggestions. He also desired some definite specifications to be laid down in order to have a standard form as he thought that the relationship between the runoff and the rainfall depended on a number of rain gauge stations which if varied would give different results.

THE SECRETARY explained that a decision was taken about two years ago on the number and location of rain gauge stations so that the results obtained were correct within ten per cent. He further stated that some of the catchments had already been fitted with additional rain gauge stations while others were being fitted up in accordance with a directive already issued on the subject.

DR. J. K. MALHOTRA remarked that the estimation of water-power should be based on all the relevant factors, and not only on the stream discharge data. In this connection, he referred to the case of the Rasul Hydro-electric Project, where water assumed to be available for power generation during the winter months was found to be simultaneously required for irrigation elsewhere. It was also found that continuous power would not be generated unless some of the existing irrigation canals were made to run all the year round.

In view of the need for annual closures for repairs to works, this was not an entirely practical proposition.

Even with no closures, the paramount need for irrigation resulted in the figure for the estimated water supply for power generation being cut down from 4,000 cusec to about 1,100 cusecs.

MR. S. A. GADKARY in agreeing with Dr. Malhotra's remarks stated that apart from the quantity of water, rain-fall and evaporation figures, stream flow *etc.*, the question of allocation of water between various requirements wherein power was also one of the major factors had also to be considered in estimating water power. He desired that where immense possibility of additional hydro-power existed, the available data might be collected but where this was not available, it should be made possible to collect an accurate data so that water power estimates might become available to the future generations.

He also suggested the formation of a committee for going into the question of the hydro-electric survey of the entire country as in his opinion, this issue had been tackled in the past on a very narrow scale.

2D. Powerhouse and Equipment

PRELIMINARY NOTE

This subject was introduced for the first time in 1947, with the following sub-heads : (1) General Layout. (2) Structural. (3) Hydraulic works. (4) Turbines and (5) Electrical Works. Discussion on Hydraulic Works so far had taken place under other subject heads.

The following resolution was passed by the Board at its 1947 meeting :—

“ Resolved that the Board is of the considered opinion that the time has come to establish an Electrical Research Wing in our Main Hydraulic Research Laboratories and recommends that early steps be taken to strengthen and equip such laboratories to handle electrical research particularly at the Central Waterways, Irrigation and Navigation Research Station. Highly specialised research work in the interest of the development of the electrical industry, may be dealt with in co-operation with the new National Research Laboratories and other institutions such as the Indian Institute of Science, Bangalore (Power Engineering College). A close liaison should be established between the Central Board of Irrigation representing Power Engineers and such institutions. ”

Accordingly a communication was addressed to the Council of Scientific and Industrial Research and the Indian Institute of Sciences, Banaglore. In response the Governing Council of the Indian Institute of Science, Bangalore passed the following resolution :

“ That the request of the Central Board of Irrigation for the Co-operation of the Institute in solving research problems relating to Electrical Equipment be acceded to, provided that there be no financial liability to the Institute. ”

The reply from the Council of Scientific and Industrial Research is still awaited.

(i) General Layout

PRELIMINARY NOTE

There was no contribution or discussion at the 1947 Research Committee meeting.

Recent Literature

- (1) Maccall W. T. Electrical Engineering, Volumes I & II University Tutorial Press, Ltd. London, 1947.
- (2) Mobile Power Stations for the U. S. S. R.—The Metropolitan Vickers Gazette, Vol. XXI, No. 348, April, 1945.
- (3) Almeras, P. Influence de l'inertie de l'eau sur la stabilité d'un groupe hydro-electric (Influence of inertia of water on the stability of a hydro-electric system)—La Houille Blanche, No. 2, March 1946.
- (4) Denton S.M. Hydroelectric Power system design—American Institute of Electrical Engineers, New York.
- (5) Foundations of the Khatima Power House, Sarda Canal—Annual report on research progress during the year 1946, United Provinces, Public Works Department, Irrigation Branch.
- (6) Electrical installations (General)—British Standards Institute, London 1946.
- (7) Bray O. S.—The Mystic cable tunnel design and construction—Journal Boston Society Civil Engineers, Vol. 33, No. 2, April 1946.
- (8) 1,400 feet calyx holes for Peruvian hydro job—Engineering New Record Vol. 139, No. 6, August 7, 1947.

THE YEAR'S WORK**DISCUSSION BY THE RESEARCH COMMITTEE**

There was no contributions and no discussion under this sub-head. It was decided to retain this on the agenda.

DISCUSSION BY THE BOARD

There was no discussion. It was decided to retain the subject on the agenda.

(ii) Structural**PRELIMINARY NOTE**

There was no contribution or discussion at the 1947 meeting of the Research Committee.

Recent Literature

- (1) Spencer R. W. Maintenance studies on hydro-electric plant structures—Civil Engineering Vol. 17, No. 3, March 1947.

THE YEAR'S WORK**DISCUSSION BY THE RESEARCH COMMITTEE**

There were no contributions and no discussion under this subhead. It was decided to retain this on the agenda.

DISCUSSION BY THE BOARD]

THE SECRETARY said that there was no contribution and no discussion at the Research Committee under these sub-heads.

MR. H. R. BHATIA suggested some specific items of Power House Plant and Equipment to be taken up for exchange of opinion. Referring to hydraulic turbines he mentioned that over-speed and other tests are generally demanded both at the manufacturer's works as well as at site. This increased the capital cost of the plant. It was for consideration if some of the tests at least could not be dispensed with at the manufacturer's works in view of the manufacturer's guarantee as well as subsequent tests to be performed at site. This in his opinion should reduce the capital cost to some extent. Regarding the electrical equipment, he stated that the usual practice in this country has been to earth the neutral point of the generators through a low resistance but he understood that some continental firms advocated earthing the neutral point through high resistance so as to limit the short circuit current to about five amperes.

Coming to the question of Switchgear, he said that recent developments in this direction were the manufacture of air-blast and the minimum oil type circuit breakers for extra high voltages. The minimum oil type circuit breaker offered some advantages inasmuch as the change of oil could be accomplished very rapidly, but he believed that the frequency of such change-over would be considerably increased as compared to the bulk oil type circuit breaker and this in his opinion would prove inconvenient and more costly in maintenance and operation. The air-blast type circuit breakers are cheaper as compared to the bulk oil type circuit breakers for voltages above about 66,000 kV. The suppression of arc in this type of circuit breaker is very effective due to a strong air-blast and therefore the arcing time is very small. This would reduce the necessity of frequent maintenance and replacement of arcing contacts and therefore this type of Switchgear in his opinion offered a considerable advantage.

Referring to spares, he said that practice in the past in many cases has been to order too many spares when first installing any equipment. Some of these spares are not used for several years. He suggested that it would be desirable to order only very essential spares but in order to be able to obtain replacements as and when required, it was desirable that complete technical particulars of each type of equipment should be obtained and kept on record for ready reference to obviate any difficulty due to certain types of equipment or parts thereof becoming obsolete.

RAO BAHADUR G. SUNDARAM stated that experience had yet to be had on the minimum oil type circuit breakers but he had tried some air-blast circuit breakers. In his opinion, it had yet to be had on air-blast type circuit breakers for voltages upto 66 kV under the present conditions but they should prove suitable for voltages above 110 kV. This of course, he said, was subject to verification when more experience was gained.

Speaking on the minimum oil type circuit breakers, he said that as in Madras the major requirement was for out of the way sub-stations and as this type required frequent oil changing and handling, he would not favour its use.

MR. MIRCHANDANI said that they had recently examined quotations from some firms regarding the airblast circuit breakers down to 66 kV and found that their cost was much less than that of bulk oil type circuit breakers.

MR. S. A. GADKARY stated that very little experience had yet been obtained on the use and behaviour of air-blast circuit breakers in this country. He thought that the film on air-blast circuit breakers, which he happened to see recently was rather instructive. He agreed with Rao Bahadur Sundaram that at high voltages these circuit breakers would be economical. He suggested that these might be introduced with advantage on the main trunk lines between Nangal and Delhi firstly because of their lower cost and secondly because they could be built up in units and as the transmission voltage increased, more units could be added, but this was not possible in the case of bulk oil circuit breakers.

Several of the 132 kV lines would have to be converted to 220 kV in the near future such as the line from Nangal to Delhi and the air-blast type might in such cases, prove more economical. He was, however, not sure of their behaviour in the dust storms as might appear in the East Punjab and other areas although he said, the manufacturers had assured that they would have no effect on the circuit-breakers. He further stated that some of the continental firms were providing narrow air gaps between the live and dead portions of their air-blast circuit breakers.

Referring to the minimum oil circuit breakers that they should be tried in a few cases to gain more experience.

Coming to the question of spares, he said that the problem could only be solved if they had the manufacturing firms in India. It would be for individual engineers incharge of the projects to include such spares in their indents as they thought fit.

(iii) Hydraulic Works PRELIMINARY NOTE

The following items were discussed at the 1947 Research Committee meeting under sub-head 3 :—

- (1) Foundation of Khatima Power house—Sarda Canal.
- (2) Verification of the observed lowering of water table at Moham n a c i u Power House by electrical analogy method.
- (3) Model Investigation regarding the project of Mohammadpur Power House.
- (4) Model investigation regarding the design of Pathri Power House.
- (5) Silting above the left forebay of Nirgajni Power Station.

Recent Literature

(1) Niederhoff A. E. Power from pumped water—Western Construction News, Vol. 22, No. 6, June 1947.

(2) Norrby, J. N., Civil Engineer, State Power Board, Stockholm.—The Stilling Basin at the Hollefersen Power Plant. The second meeting of the International Association for Hydraulic Structures research, Stockholm, 1948, Paper No. 23.

THE YEAR'S WORK

There were two contributions for discussion at the Research Committee Meeting :—

- (1) Model investigations regarding the design of Sarda Power House.
- (2) Model investigations regarding the project of Mohammadpur Power House.

**(1) MODEL INVESTIGATIONS REGARDING THE DESIGN OF SARDA
POWER HOUSE ⁽¹⁾**

ABSTRACT

Sarda Power House is being constructed at mile 0-5-90 of a new Power Channel, miles 12-5-275 long, which takes off from the main canal at mile 7-7-60 on its left bank. There are a number of falls ranging from 2.5 feet to 3.5 feet in the main canal between mile 7-7-427 to 19-6-290, the total drop being 59.1 feet, which is combined in one fall for the generation of power. It is proposed to instal three turbines at present which will utilise a discharge of 9,500 cusecs, and a spare bay is provided for installing another machine at a later stage. Gives results of model experiments.

The following model investigations were required to be carried.

- (1) To determine suitable protection for the bed and sides of the main canal and power channel at its off-take and means to relieve action thereon, if any.

⁽¹⁾ United Provinces Irrigation Research Station, Report on Research Progress during 1947 pages 93-102.

- (2) To design guide walls for the least silting up and turbulence in the intake chamber and equitable distribution of water at the forebay.
- (3) To design splay of sides, bed and side protection downstream of the draft tubes.
- (4) To study the effect of silting in front of the draft tubes with different combinations of the machines in commission.
- (5) To devise a suitable arrangement of wells to lower the water table in the foundation pit.
- (6) Pressure determination under the foundations.
- (7) Pressure determination under the foundations of escape and regulator.

For items (1) to (4) above a geometrically similar model comprising of part of Sarda Main Canal, Power Channel and Power House was constructed to scale 1/25. Figure 2D.1 shows a portion of the Main Canal and Power Channel. When the model was run with a discharge of 9,500 cusecs, it was found that velocities on right were comparatively higher than on the left, and there was silting on the inside curve at the junction of the Main Canal and Power Channel. Curves of various radii were tried for equalisation of flow. An arc of radius 335 feet subtending an angle of 62° improved conditions but some silting was still in evidence. The right corner was also rounded off as shown in Figure 2D.1 with an arc of radius 15.0 feet. Some action was noticed on this corner and it is recommended to pitch this curve, shown in Figure 2D.1 for its protection.

Sloping bars of height varying from 1.5 feet to 2.5 feet on right and zero on the left were tried just upstream and downstream of the curve for better distribution of flow below the curve all along the width of the power channel. Bars 2.5 feet high on the right and zero on the left improved conditions considerably. Table 2D.1 gives a fair idea of distribution of velocities as observed in the model by means of a pitot tube in the power channel below the sloping bar.

The 375 feet long sides of the intake chamber were stream lined by providing vertical hyperbolic expansions 1 in 4 as per Figure 2D.2. The model showed improvement in as much as there was no accumulation of silt along the sides which was indicated in the original design. Further, cut waters at the noses of piers of concrete ducts were provided to minimise afflux and turbulence in the intake chamber, Figure 2D.2.

All the bays ending into spiral casing chamber will be fitted with dispersers and isolating rings for the escape of surplus discharge. Only two turbines, out of the three to be installed, in the first instance will be run for normal duty and the third will be kept as standby. As mentioned earlier, there is also going to be an idle bay for future extension.

The model was run with three extreme left turbines functioning, the right bay being closed. There was excessive silting on the right, downstream of the draft tube, on the 120 feet long sloping bed, this being virtually a dead corner.

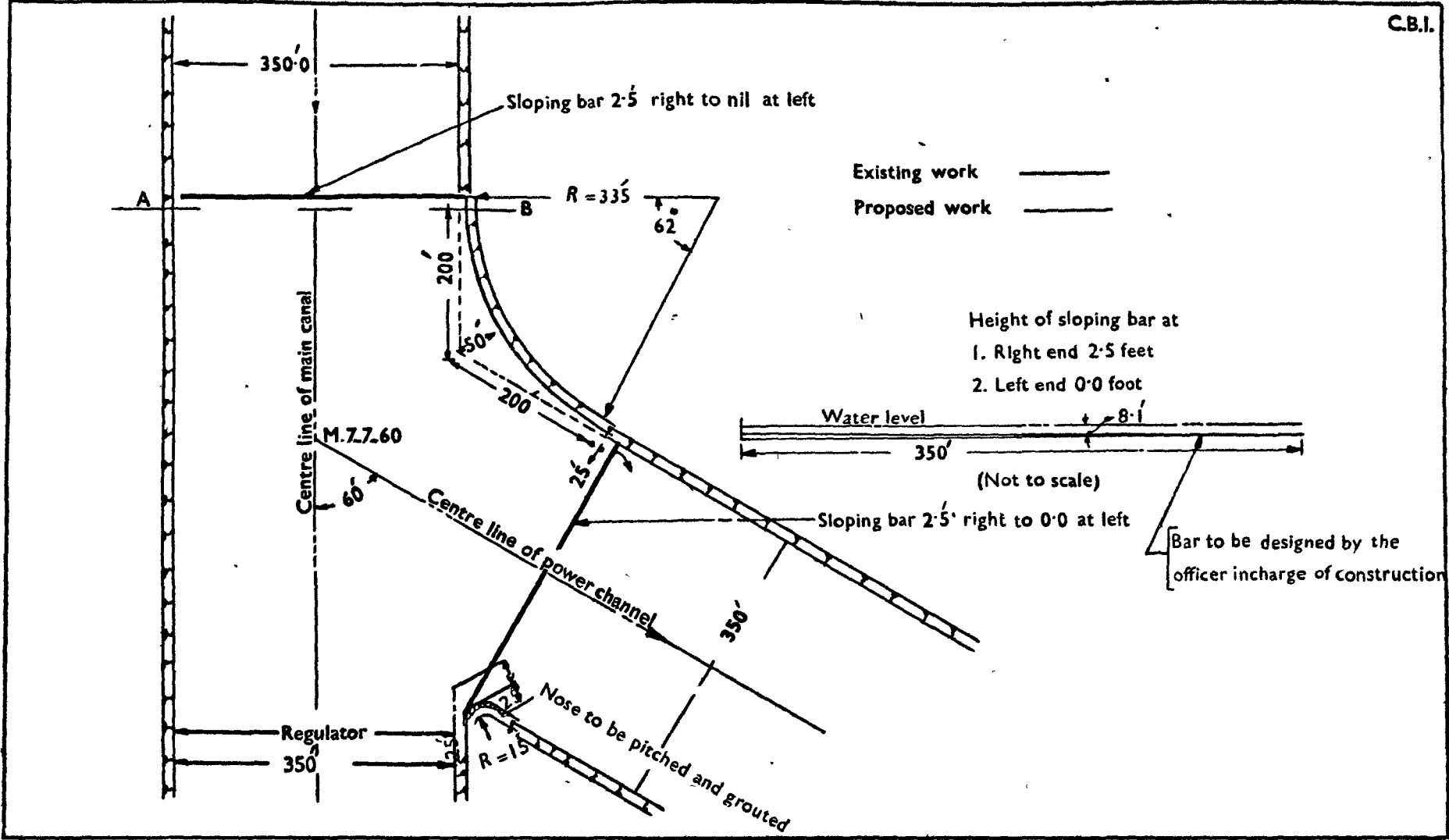
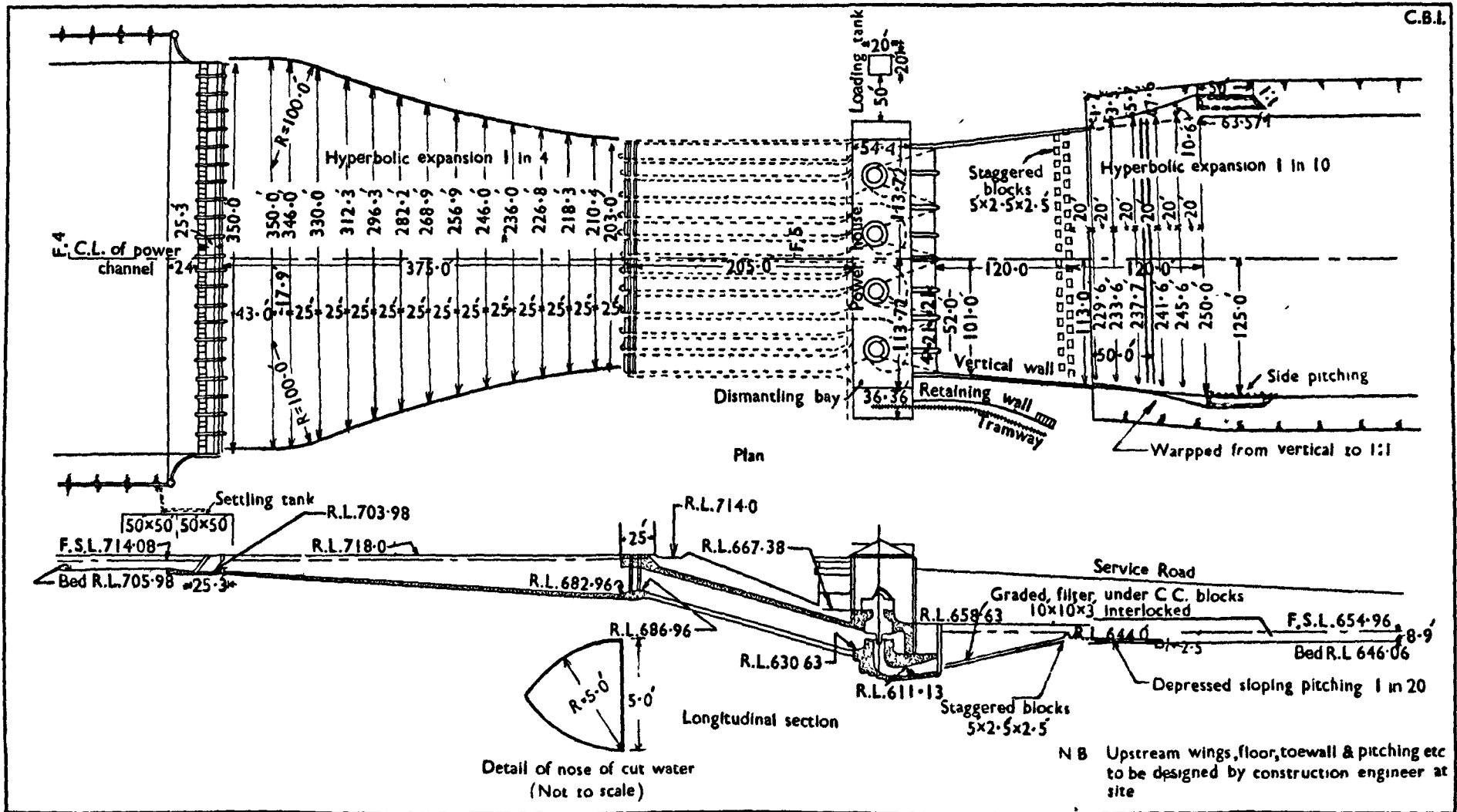


Figure 2D. 1:- Sarda power channel- Showing research proposal of its offtake from main canal



Reg No 2737 XDD (C) '50-1.210 (P.Z.O)

Figure 2D.2:- Showing upstream & downstream protection work (Sarda Power House)



TABLE 2D. I.

Velocity in feet per second as observed in the model to scale $\frac{1}{25}$.

| Serial No. | Distance in feet from centre to the left. | | | | | | | 0 | Distance in feet from centre to the right. | | | | | | | Remarks |
|------------|---|------|------|------|------|------|------|------|--|------|------|------|------|------|------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 1 | 1.65 | 2.00 | 2.60 | 2.60 | 3.00 | 3.65 | 4.20 | 4.45 | 4.70 | 5.15 | 4.45 | 5.15 | 4.45 | 3.35 | 1.03 | Original design. |
| 2 | 1.00 | 2.60 | 2.60 | 3.00 | 3.25 | 3.65 | 3.65 | 3.65 | 3.65 | 3.65 | 3.65 | 3.65 | 3.00 | 2.60 | 1.00 | With inside curve of radius 335 feet and on right with radius of 15.0 feet. |
| 3 | 0 | 2.25 | 2.60 | 2.60 | 2.60 | 2.60 | 2.60 | 3.30 | 2.60 | 2.60 | 2.60 | 2.60 | 2.60 | 2.60 | 0 | With two sloping bars 2.5 feet high on right and zero on the left, in addition. |

As will be seen from Figure 2D.2 draft tubes in each bay are divided into two parts for structural needs and the left portions intercept most of the supply from the clockwise vortex descending from turbine chamber, so that little discharge passes in the right portion resulting in some silting on the right in front of every draft tube and shooting currents from the left portions. On carefully observing the velocities with the help of pitot tubes the order of velocities anticipated at the proto-type was about 25 feet per second at the exit of the draft tube which, proceeding as a shooting jet, gradually was reduced to eight feet per second at the end of the sloped portion, 135 feet long. This suggested the construction of a *pucca* floor in this reach.

Further down in the Power Channel, there was excessive side erosion on the left and also bed scour in general. To provide against this, the downstream banks of power channel are splayed with hyperbolic expansion 1 in 10, and 50 feet long side pitching added to it. Further, 50.0 feet wide bed pitching, slope 1 in 20, is provided in conjunction with a row of staggered blocks 5.0 feet \times 2.5 feet \times 2.5 feet at the end, which greatly minimised the bed scour, however, there was still some side action.

To avoid silting in front of the draft tube on the right, the extreme left turbine was closed and the remaining three were run. With the devices proposed, there was neither any side nor bed scour. Silting in front of the bays was also negligible. Since only two turbines will function for the present, the model was run with possible arrangement of turbines for minimum action downstream, and it was found that two centre ones gave the best combination. Table 2 D II shows a comparative study of silting in front of the forebays, bed and side erosion downstream of the Power House, in all cases examined at the Research Station.

DEWATERING OF FOUNDATION PIT (POWER HOUSE)

A model, to scale 1/400, was prepared to study the problem by electrical analogy.

Data.

| | |
|--|-----------|
| Spring level before starting the work | R.L. 670 |
| Spring level reduced by digging see page drains upto | R. L. 658 |
| Lowering of spring level expected by the drains down to | R. L. 641 |
| Assuming that lowering is to be affected by the wells from | R. L. 650 |
| Spring level required to be lowered to | R. L. 605 |
| -Total lowering to be affected (with wells) | 45 feet. |

TABLE 2D II

| Serial No. | Arrangement of turbines examined | Devices proposed | Bed scour in feet | Side erosion in feet | Siltng in front of draft tubes |
|------------|---|-------------------------------------|-------------------|----------------------|---|
| 1 | Three left ones running and extreme right one closed. | Original design without any device. | 7.25 | 12.0 | Excessive silting on the right. |
| 2 | do. | With devices proposed | 2.5 | 5.0 | do. |
| 3 | Three right ones running and extreme left one closed. | Do. | Nil | Nil | No silting. |
| 4 | Two left ones running and two right ones closed. | Do. | 2.5 | 5.0 | Excessive silting as in Experiment No. 1. |
| 5 | Two centre ones running and end ones closed | Do. | Nil | Nil | Very nominal silting on the right. |
| 6 | Two right ones running and left ones closed. | Do. | Nil | Nil | Little silting on the left. |

Assuming suction head to be 20 feet for the centrifugal pump, the depth in the well should not exceed $45+20=65$ feet. Hence the percentage drop in potential should not be less than

$$\frac{45 \times 100}{65} = 69.2$$

Lengths of strainers tried for the system of 14 wells considered as suitable for lowering the water table uniformly were 40 feet and 50 feet which gave a lowering of 59 percent. and 62 percent. at the centre of the cofferdam. As this was not to the required depth, a length of 65 feet was tried which gave the distribution of potentials as shown in Figure 2D3. It will be observed that this length is sufficient, and lowers the water table uniformly. For observing the discharge, current output from the system was measured and it gave 0.26 amperes. A single wire representing six inches diameter 100 feet long strainer gives under similar conditions a current of 0.07 ampere, equivalent to 1.5 cusecs approximately in nature under a depression head of 10 feet for the strata similar to that obtained at the site of the pit. In the ultimate stage these wells will work under an average depression head of $\frac{65+20}{2}=42.5$ feet. This gives a total discharge of

$$\begin{aligned} \frac{0.26}{0.07} \times \frac{42.5}{10} \times 1.5 \\ = 23.6 \text{ cusecs.} \end{aligned}$$

or 1.7 cusecs per well, with 14 wells arranged as per Figure 2 D. 3.

To be safer, it is recommended that 70.5 feet strainer length should be used for these 1.7 cusecs wells around the pit. Apparently all the six inches strainers of

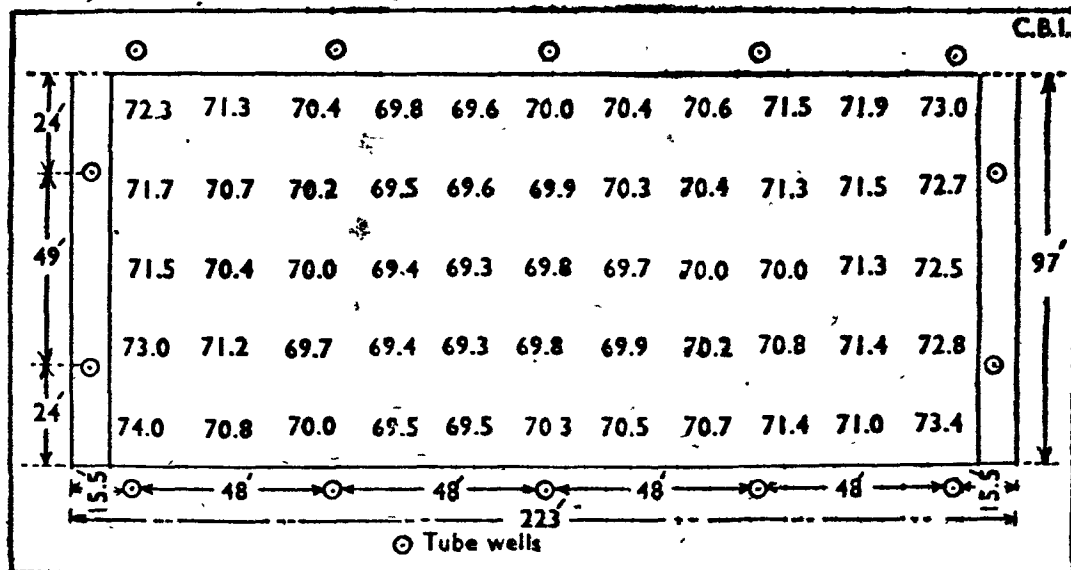


Figure 2D. 3 : Showing location of wells for dewy-ring of Sarda Power House Foundation pit.

| Sketch | Pressures percentage | | | | | | Toe pile (T) * |
|----------------------------|----------------------|------|-------|-------|------|------|----------------|
| | Pile numbers | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | |
| <p>1 Original proposal</p> | 100.0 | 83.8 | 46.7 | 39.2 | 29.5 | 17.2 | 1 |
| | 89.3 | 82.1 | 45.2 | 37.4 | 24.9 | 16.1 | 2 |
| | 84.9 | 79.8 | 43.0 | 35.8 | 19.4 | 0 | 3 |
| | -12.0 | -5.4 | -23.9 | -29.8 | 14.4 | 18.1 | 1 |
| <p>2</p> | 100.0 | - | 52.1 | 49.4 | 40.0 | 30.8 | 1 |
| | 84.8 | - | 50.5 | 48.4 | 37.0 | 27.8 | 2 |
| | 83.7 | - | 50.0 | 47.5 | 35.0 | 23.4 | 3 |
| | - | - | - | - | - | - | - |
| <p>3</p> | 100.0 | - | - | 50.3 | 40.0 | 30.4 | 1 |
| | 87.3 | - | - | 48.8 | 38.0 | 27.2 | 2 |
| | 83.1 | - | - | 47.7 | 34.9 | 23.5 | 3 |
| | - | - | - | - | - | - | - |
| <p>4</p> | 100.0 | - | - | - | 40.0 | 30.6 | 1 |
| | 87.5 | - | - | - | 38.2 | 27.3 | 2 |
| | 83.2 | - | - | - | 35.0 | 23.5 | 3 |
| | - | - | - | - | - | - | - |
| <p>5</p> | 100.0 | - | 51.6 | 40.1 | 30.9 | 1 | |
| | 84.1 | - | 45.7 | 37.7 | 27.7 | 2 | |
| | 81.2 | - | 48.6 | 35.4 | 23.8 | 3 | |
| | - | - | - | - | - | - | - |
| <p>6</p> | 100.0 | - | - | - | 41.1 | 32.4 | 139 |
| | 85.6 | - | - | - | 38.8 | 29.2 | 121 |
| | 83.7 | - | - | - | 36.9 | 25.2 | 0 |
| | - | - | - | - | - | - | - |
| <p>7</p> | 100.0 | - | 51.9 | 40.4 | 31.3 | 12.7 | 1 |
| | 87.2 | - | 50.8 | 37.7 | 27.4 | 8.5 | 2 |
| | 83.9 | - | 49.7 | 35.8 | 23.4 | 0 | 3 |
| | - | - | - | - | - | - | - |

* The pressures at 1, 2 and 3 with respect to a pile (adjacent figure)

Figure 2D.4:- Showing comparative pressures of piles in the foundation of Sarda Power House

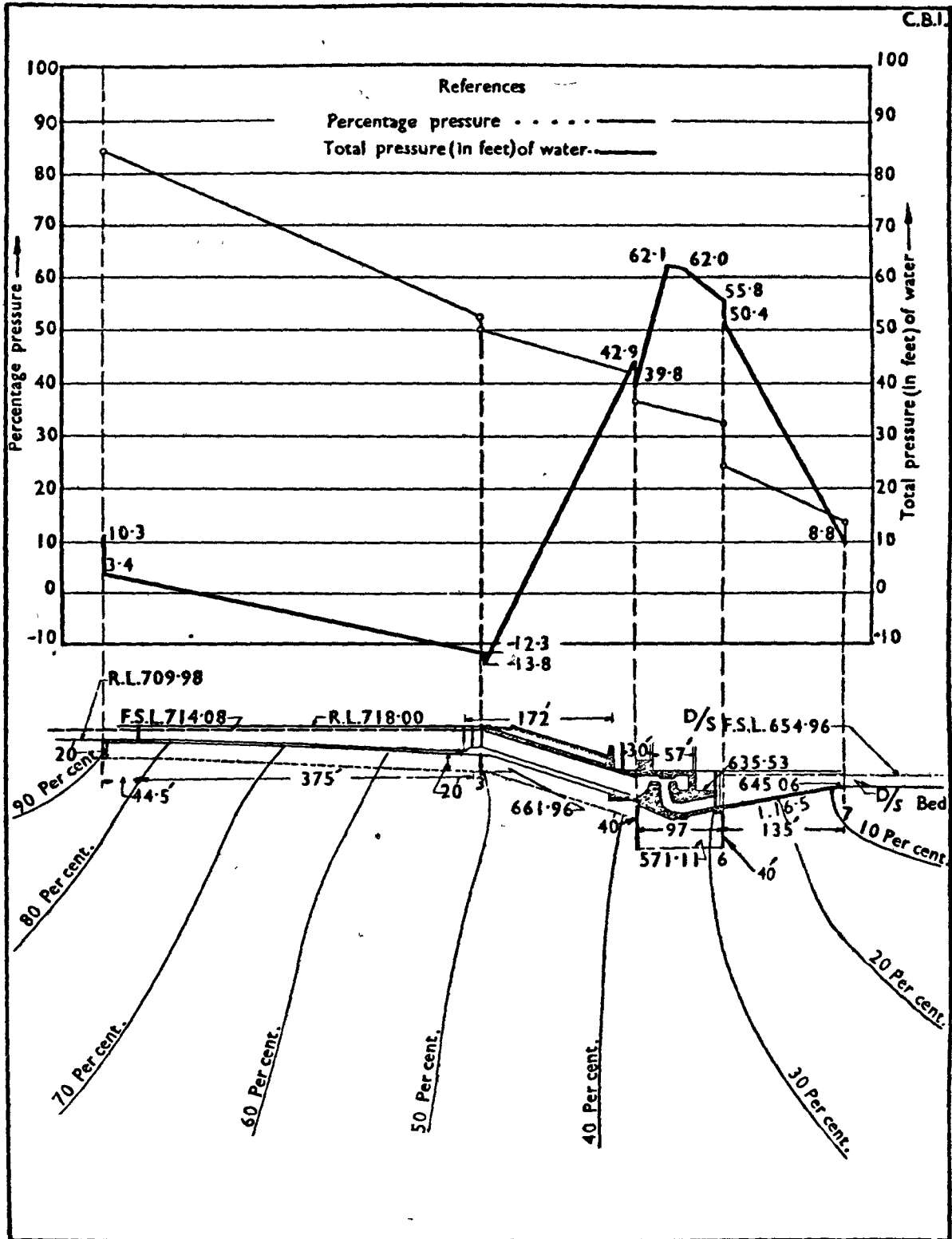


Figure 2D.5:- Curves showing pressures under the floor of Sarda power house (top) and proposed arrangement of sheet piles (bottom)

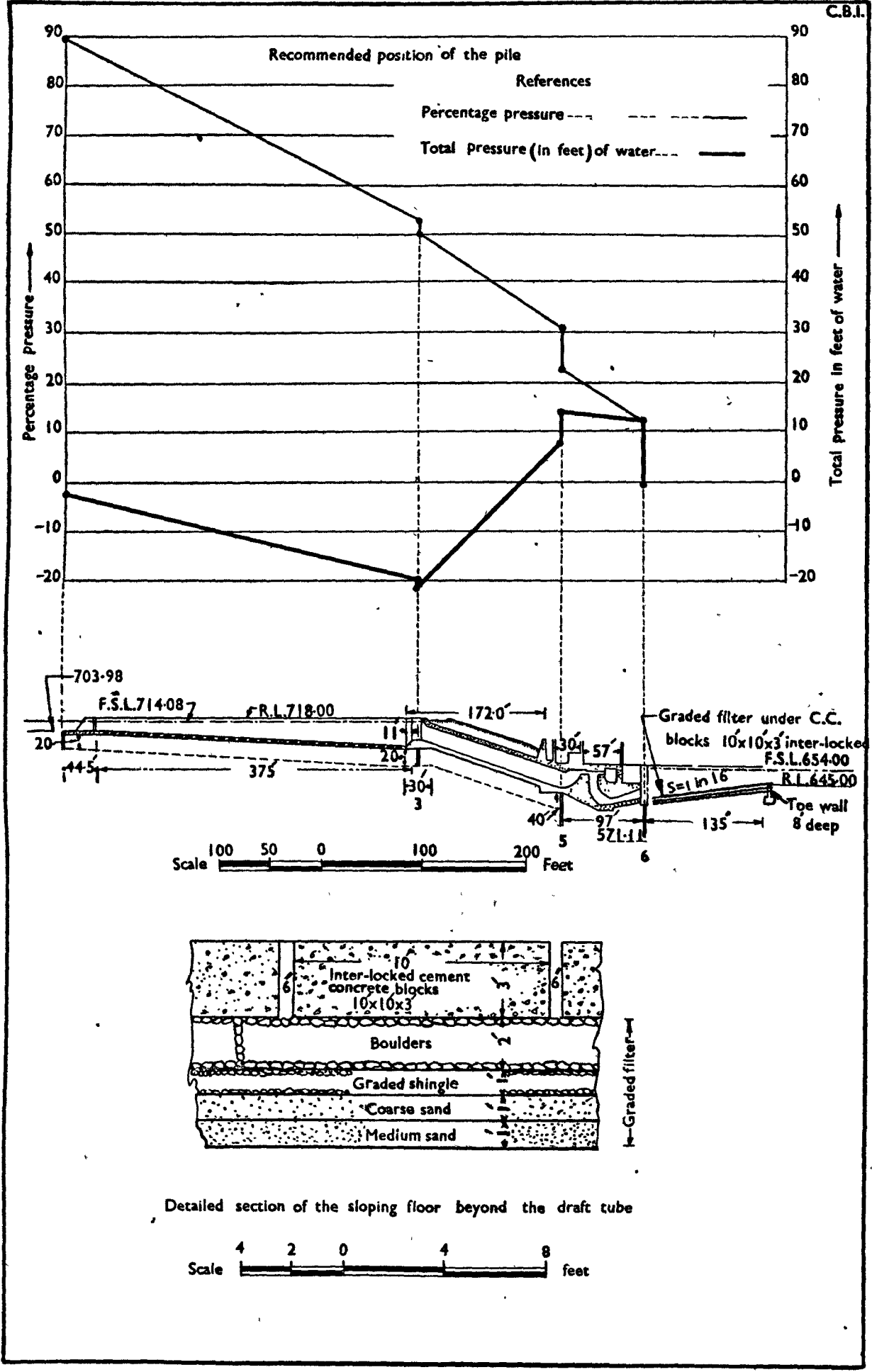


Figure 2D.6:- Curve showing pressure under the floor of Sarda Power House

length 70 feet shall have to be placed below R. L. 580 to allow a margin of 25 feet for the depression. Initially the pumping set has got to be placed higher up as the digging proceeds. It is advisable therefore, that suitable lengths of blind pipes are located from R. L. 580 upwards which will be gradually removed as soon as depression in the well exceeds 20 feet for a particular position of the pumping set. The ultimate position of the pumping set will have to be at R.L. 605 so as to keep the water-table lowered to the bottom of the pit. If bore hole pumps are used, this arrangement will not be required and the shafts will be reduced from above.

PRESSURE OBSERVATIONS UNDER THE FOUNDATIONS OF SARDA POWER HOUSE BY ELECTRICAL ANALOGY

The Sarda Power House design, as submitted to the Research Division, contained six piles marked 1, 2, 3 up to 6, as per No. 1 on Figure 2 D.4. Pressures have been observed with different arrangements of piles keeping the structural requirements in view and given in table of Figure 2 D. 4.

From the study of pressures obtained under the proposed and the subsequently changed arrangements, it will be noticed that piles No. 2 and 4 are not serving any useful purpose because of their closeness to the piles No. 1 and 3. Actually there is a certain amount of interference between the piles of each pair. It was, therefore, decided to remove them and the pile No. 3 shifted a little so as to bring it right under the piers as shown in Figure 2D. 5 on a bigger scale. Piles 5 and 6 could not be touched although only one of them, No. 6, was required for lowering the pressures under foundations. These piles are driven to form the cofferdam and will be left there to serve as sheet piles.

From the model study of the action of water coming out through the draft tube, it has been found that the sloped portion beyond the pile No. 6 needs to be made *pucca*. With this arrangement, *i.e.*, with piles 1, 3, 5 and 6, and *pucca* sloping floor, we find that the exit gradient comes out to be infinity which is not safe for the structure as it will induce piping. To remove this defect, it was decided to add at the end of the floor one of the two 20 feet sheet pilings which have been removed from the pairs 1-2 and 3-4. This arrangement gives us the pressure distribution as shown in graph *vide* Figure 2D. 5. This gave a factor of safety of five against floatation which is quite adequate. The above design tentatively worked out for hydrodynamic requirements, however, shows excessive pressures under the floor between piles 6 and 7 *vide* Figure 2D. 5, and as such this arrangement will prove very costly. As a compromise between the hydrodynamic and pressure requirements, it is proposed to make this floor of inter-connected cement concrete blocks with a filter underneath *vide* Figure 2D.6.

PRESSURE DETERMINATION UNDER SARDA POWER HOUSE REGULATOR AND ESCAPE AT MILE 1-7-375

Figure 2D.7 shows the head regulator for the tail race escape. The pressures have been observed along the sections AD and EH. The results obtained on the electrical analogy apparatus, Figure 2D.8, are shown on Figure 2D.9 and 2D.10 which were communicated to the Construction Division.

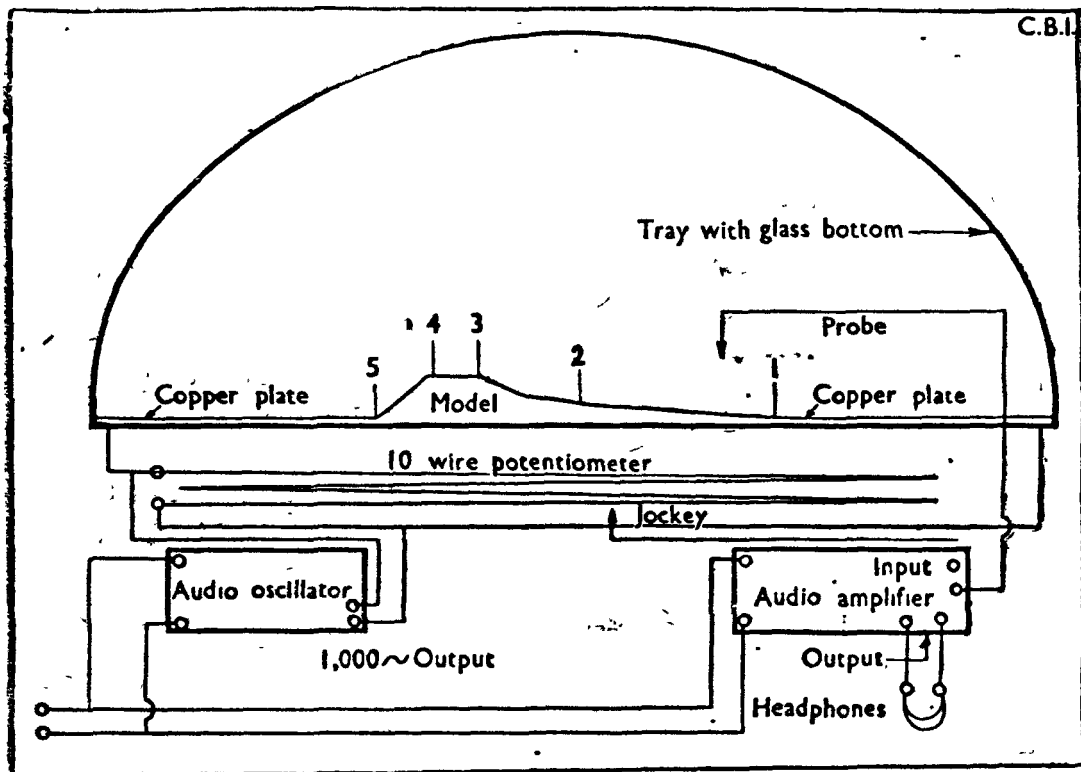


Figure 2D.8 : *Electrical analogy apparatus showing pressure observation under Sarda Power House foundations.*

CONCLUSIONS

The following recommendations have been sent to the Superintending Engineer, Sarda Power House Construction Circle:—

- (1) The left and right corners at the junction of Main Canal and Power Channel to be rounded off in curves of radii 335 feet and 15.0 feet respectively, the right one along with 50.0 feet straight portion on either side to be pitched and grouted as per Figure 2D.1.
- (2) Two sloping bars 2.5 feet high on right and zero on the left to be provided in the bed, one at the entrance of curved portion in the Main Canal, and the other 25 feet beyond the exit in the Power Channel as per Figure 2D.1.
- (3) The wings of lined intake chamber to be provided with vertical hyperbolic expansions 1 in 4, and noses of piers provided with cutwaters, as in Figure 2D.2.

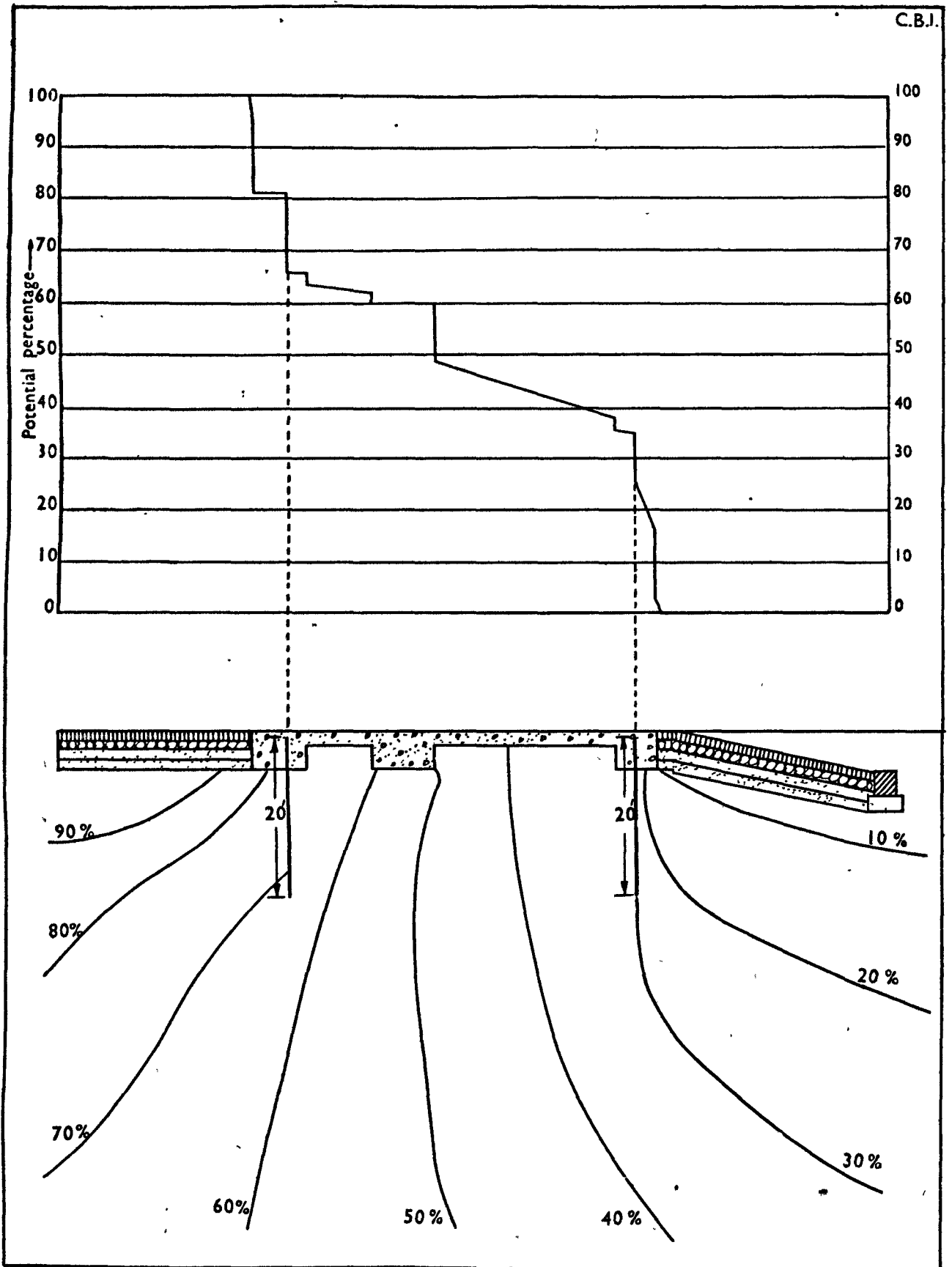


Figure 2D.9:- Showing pressure under the floor of the combined head & regulator for tail race escape at M.1-7-375 along section AD (Figure 2D.7) (Sarda power house)

Scale 20 10 0 20 40 60 feet

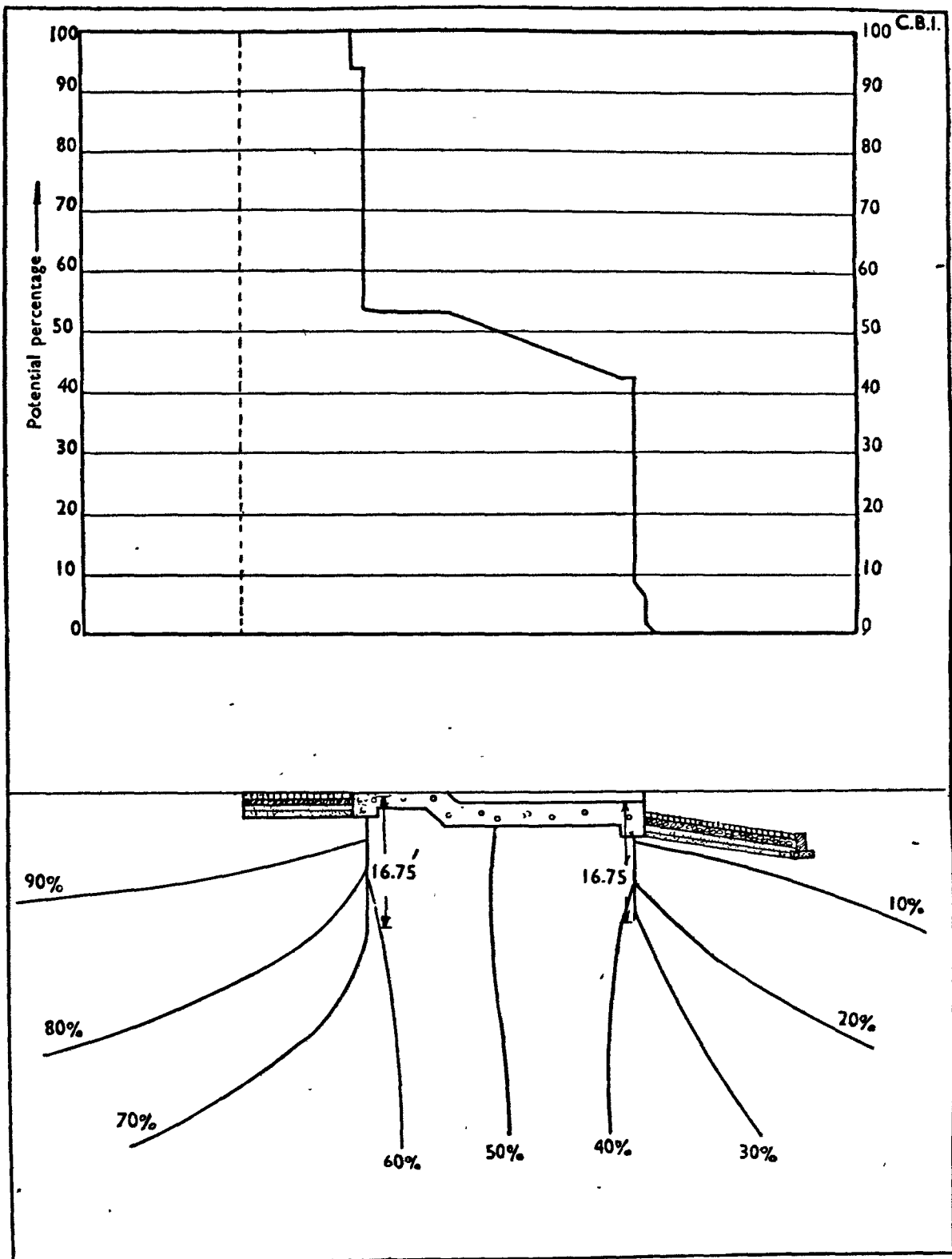
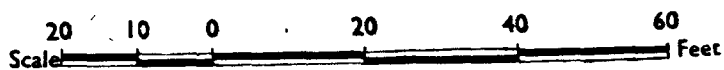


Figure 2D.10:- Showing the pressure under the floor of the combined head & regulator for tail race escape at M.1-7-375 along section EH (Figure 2D.7) (Sarda PowerHouse)



4. The banks of power channel below the power house to be splayed with hyperbolic expansion 1 in 10, and 50 feet side pitching added to it; also, the bed to be provided with depressed pitching, slope 1 in 20, in a length of 50 feet.
5. A row of staggered blocks 5 feet \times 2.5 feet \times 2.5 feet to be provided at the end of the upwards sloping bed, downstream of the draft tube.
6. For dewatering the foundation pit, an arrangement of 14 wells with 70 feet of six inches strainer has been recommended. All the strainer length to be provided below R. L. 580. Above it are to be blind pipes in suitable lengths which will be removed as the digging proceeds.
7. The arrangement of piles originally proposed has been altered to that shown in Figure 2D.6, wherein the pressure distribution has also been shown. The upward sloping bed downstream of the draft tubes will consist of a five feet graded filter underneath interlocked concrete blocks 10 feet \times 10 feet \times 3 feet to resist hydrodynamic action and to release pressures.
8. Pressure under the two sections of the Power House regulator and escape have been observed by electrical analogy method and communicated. These are shown in Figures 2D.9 and 2D.10.

(2) MODEL INVESTIGATIONS REGARDING THE PROJECT OF MOHAMMADPUR POWER HOUSE ⁽²⁾

ABSTRACT

Model investigations regarding the project of Mohammadpur Power House ⁽³⁾ were concluded last year. It was desired to fill in the blank space on the left side of each bay in front of the draft tubes by suitable curves to do away with the gaps created by the abrupt junction of the draft tubes with the wings and divide walls. Two designs were supplied for investigation by model experiments to know, if the filling of these gaps will affect the flow conditions in any way and the best form of curves to be suggested. Gives results.

A model of Mohammadpur Power House and the subsidiary fall was constructed to scale $\frac{1}{25}$. When the model was run, it was found that the filling of these gaps seemed to have no material effect on the conditions of flow. Under the circumstances, either of the two curves can be adopted at site.

As studied on the same model, the vortex formation was found to be very unsatisfactory in all the three turbine chambers. It is probable that there will be some hunting, particularly on the left machine, and, as such, the efficiency of all the three machines is not likely to be high.

⁽²⁾ United Provinces Irrigation Research Station, Report on Research Progress during 1947, pages 102-104.

⁽³⁾ U. P. Technical Memo. No. 15, 16 and 17.

Similar trouble existed in the left bay of Nirgajni Power House and it was remedied by the provision of a vane. (4).

Initially, the power generated at this machine used to be 2,500 kW, which, immediately after the power house was put into commission, was reduced to 2,250 kW. As a result of the improved vortex and prevention of silting upstream of intake chamber, the machine is now generating 2,500 kW without any hunting *etc.* Encouraged by the proto-type results at Nirgajni Power House, vanes of various sizes and shapes were tried for Mohammadpur Power House as well, and it was found that a vane, as per Figure 2D.11, if provided in each bay, improved vortex motion considerably, the minimum afflux experienced was of the order of 1.5 feet. In the event of a lower efficiency of the machines after trial, these vanes may be tried in one, two or three bays to improve the same. It is difficult to say what is likely to be the exact afflux at site, as, while the model indicated four inches afflux for Nirgajni Power House, there is none whatsoever obtained at site, after putting the vane. Due to development of negative pressure within the draft tube, the model does not represent this in a scalar ratio. If trouble, as anticipated, occurs, the vanes might be tried one by one.

SUBSIDIARY FALL

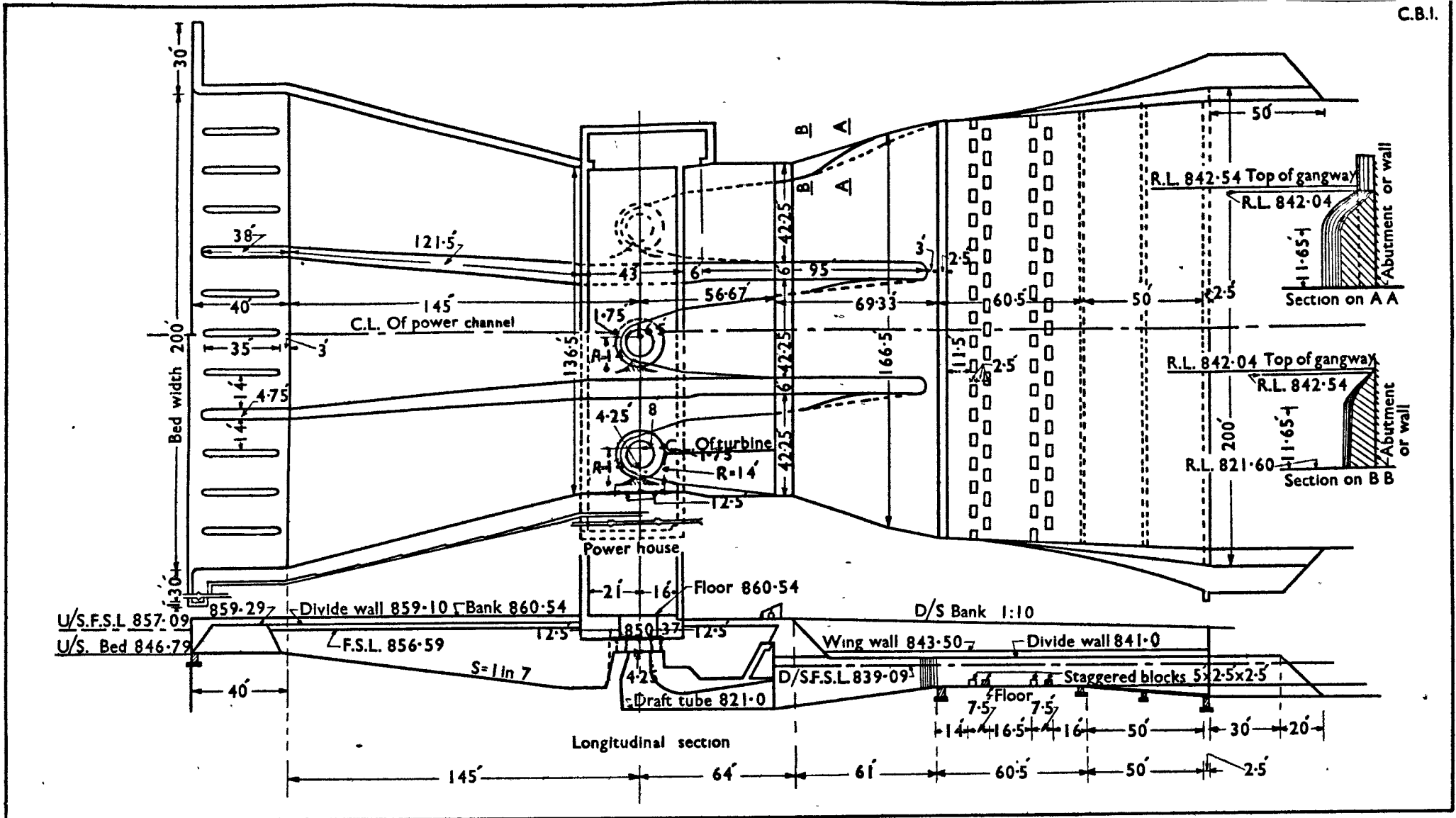
It was intimated that the floor of the subsidiary fall had to be strengthened as per Figure 2D.12 against uplift pressure. This was likely to prevent the formation of standing wave in part length above the crest due to decreased depth of the cistern on the right, which might create bed scour and side erosion *etc.* downstream. When the model, to scale 1/25, was run, it gave bed scour 4.5 feet deep in the presence of staggered blocks *etc.*, and 10 feet side erosion in a length of about 100 feet.

To do away with this one sided action addition of sloping crests ranging from 0.75 foot to 1.75 feet on the right and zero in the centre of the vertical fall were tried. Addition of 1.0 foot height to the crest at the right end, sloping to the existing level in the centre, gave no bed and side action.

CONCLUSIONS

- (1) Either of the two curves proposed for filling the gaps may be built at site, as none of them affects the normal flow conditions in any way.
- (2) Provision of vanes for better vortex formation at the three turbines is suggested. The possibility of creating an afflux of 1.5 feet has to be considered, and vanes should be tried only in case a low efficiency of the machines is indicated.
- (3) Addition of one foot in the height of the crest of the subsidiary fall at the right, which is to be sloped down to the existing level in the centre of the crest, is recommended for preventing action on the right as a result of subsequent modifications.

(4) U. P. Technical Memo. No. 17, page 37.



Reg No. 2737 XDD (C) '50-1.250 (P.Z.O).

Figure 2D.11:- Showing proposals for better flow conditions (Mohammadpur Power House)



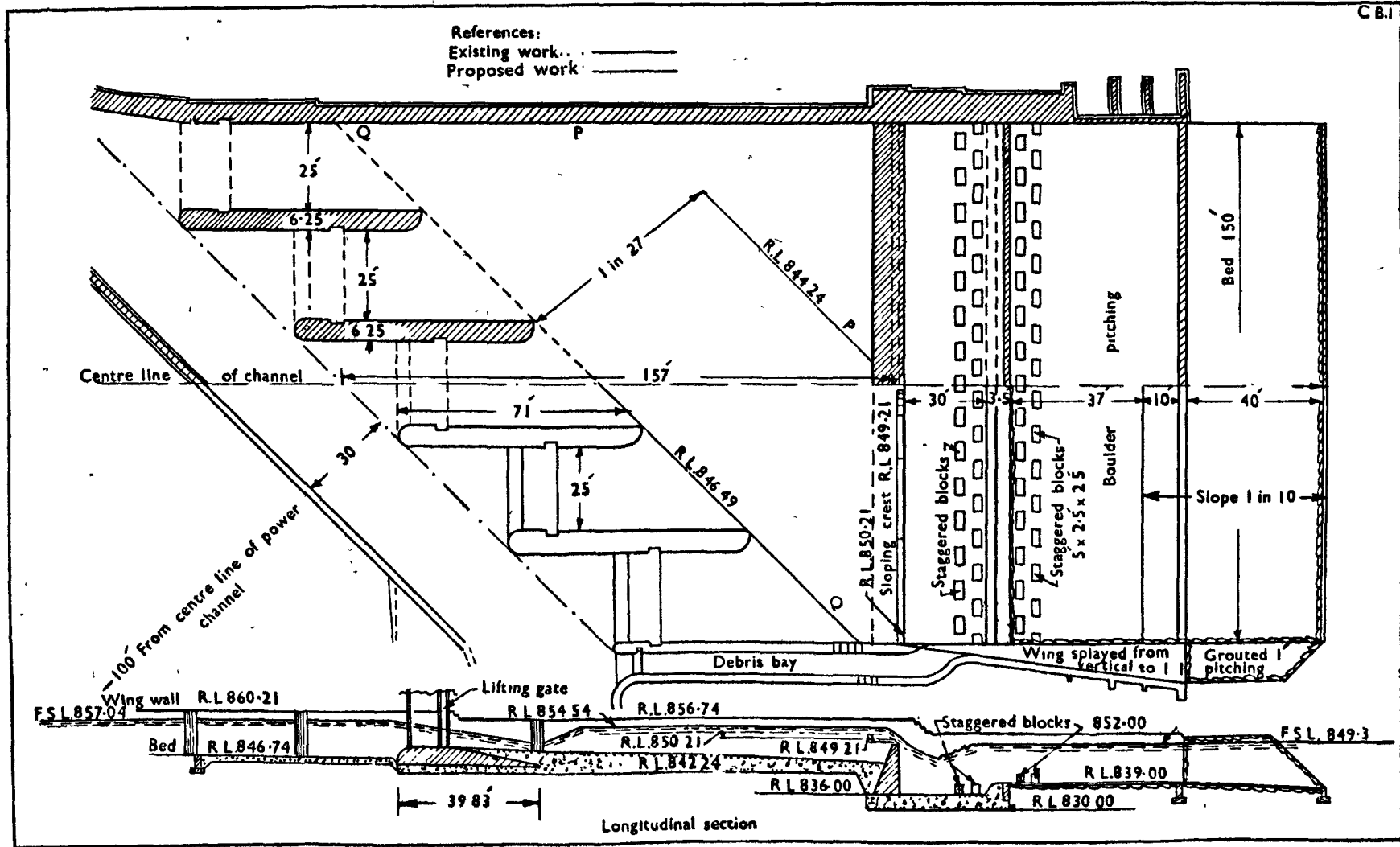


Figure 2D.12:- Subsidiary fall at Mohammadpur Power Station showing proposals in downstream crest

DISCUSSION BY THE RESEARCH COMMITTEE

Introducing item (1) MR. GUPTA said that the Sarda Power House was under construction at mile 7-7-60 of Sarda Canal. The total drop available was 59.1 feet and 41,000 kilowatts would be generated, when all the four units had been installed.

The design of the Power House was tested at United Provinces Research Station with a view to studying its hydraulic aspects. Figures 2D.1 and 2D.2 showed the improvements proposed for stream line flow, for the minimum silting upstream of the Power House and for maximum dissipation of energy downstream of it.

Referring to item (2) MR. GUPTA said that it was noticed in the model of Mohammadpur Power House, that a vortex did not form clearly in all the three turbine-chambers and there was likelihood of hunting which would lower the efficiency of the machines. Figures 2D.11 gave the design of a vane ensuring perfect vertex formation. It would be recalled that a similar vane was recommended for the left bay of Nirgajni Power House *vide* page 85 of U. P. Technical Memo. No. 17. The prototype results indicated that the efficiency of the turbine was restored to its original figure as a result of elimination of the effect of hunting.

Referring again to item (1) MR. MITTAL said that in order to find a suitable arrangement of wells for dewatering the Sarda Power House, a model to a scale of $\frac{1}{400}$ was prepared to study the problem by the electrical analogy method. A system of 14 wells was proposed as shown on Figures 2.D3. With an expected total discharge of 23.6 cusecs in the final stage of un-watering.

The information so far received from the Construction Division revealed that there would be a close agreement between the laboratory experiments and the prototype observations.

In order to design a safe foundation against uplift and exit gradients for Sarda Power House, experiments were performed by electrical analogy apparatus.

Figure 2D.8 showed the apparatus used, with an audio-amplifier to facilitate finding of the well point. Various combinations of sheet piles were tried. Figure 2D.4 showed a comparative statement of pressure under the foundations.

Figure 2D.6 showed the arrangement of piles that had been recommended. The curves showed percentage pressure and total pressure in feet of water under the floor of Sarda Powerhouse.

Attention was drawn to the provision for interlocked cement concrete blocks, 10 feet \times 10 feet \times 3 feet placed on a graded siltter as shown in Figure 2D.6. This was necessary to ensure the floor against the fast current of water issuing out of draft tubes and to provide for pressure release.

Pressures were also determined under Sarda Power House Regulator on the same apparatus. The results were shown *vide* Figures 2D. 9 and 2D.10 and had been communicated to the Construction Division.

DISCUSSION BY THE BOARD

The Secretary explained that two items were discussed at the last Research Committee meeting but there was no resolution.

RAO BAHADUR G. SUNDARAM pointing out the importance of manufacturing power plant in India suggested that a resolution be framed on the subject.

MR. P. B. ADVANI moved the following resolution which after discussion was passed unanimously.

In view of the fact that the manufacturing capacity of England, other European countries and the United States of America for heavy Power Plant is stated to be barely sufficient for replacements and projected development in those countries during the next several years, the multipurpose and other power projects in India cannot be developed to programme unless arrangements are made to secure high priority for supply of such plant from abroad during the next two or three years and there after for its manufacture in India. The Board reiterates its considered opinion that the production of power plant is fundamental to the economy of the country both in times of peace and war and accordingly resolves that the Government of India be requested that they should themselves set up one or more factories for the manufacture of Power Plant in India and ensure that production actually starts not later than 1951.

(iv) TURBINES

PRELIMINARY NOTE

There was no contribution or discussion at the 1947 meeting of the Research Committee.

Recent Literature

- (1) Fergusson F. F. Turbines for low-head Hydro-electric development—Central Board of Irrigation Journal, Vol. 3, No. 4, October 1946.
- (2) Voorduin W. L. Selection of hydraulic turbines and power house dimensions—Thacker, Spink & Co., Ltd., Calcutta, 1947.
- (3) Escher Wyss—A century of water turbines—Escher Wyss Engineering Works Ltd., Zurich.
- (4) Escher Wyss Kaplan Turbines—Escher Wyss Engineering Works, Ltd. Zurich.
- (5) Dahl H. O. The official tests of the Kaplan turbine at Lillaedet—Reprinted from Engineering, May 20, 1947.

THE YEAR'S WORK

One contribution was made to the Research Committee—

- (1) Simple turbine for small canal drops.

(1) SIMPLE TURBINE FOR SMALL CANAL DROPS⁽⁵⁾

ABSTRACT

These investigations were undertaken to evolve a suitable type of turbine that could be used on low heads in the drops that occur in the Nizamsagar

⁽⁵⁾ Hyderabad Engineering Research Laboratories, Annual Report, 1947, pages 12-14.

Distributaries of the State. These drops vary from three to eight feet with discharges varying from a few cusecs to 200 cusecs.

Most of these drops occur in rural areas where it is not possible to get the expert servicing needed for working and maintaining the reaction type low-head turbines. These turbines have therefore to be of a very simple type, capable of being repaired and maintained by clever artisans of the rural areas such as the village carpenters and blacksmiths. Thus though a reaction turbine could give better results for such low-heads, yet simplicity demands an impulse type (wherein the complexities of draft-tube etc., would be eliminated) even at the cost of some efficiency.

EXPERIMENTS AND RESULTS

A six inches runner was made working under a head of nearly 2.5 feet. This consisted of 32 blades with a chute designed to lead the water to the blades with no shock at entry. The velocity triangles of the turbine are shown in Figure 2D.13. The energy supplied to the runner was calculated from the

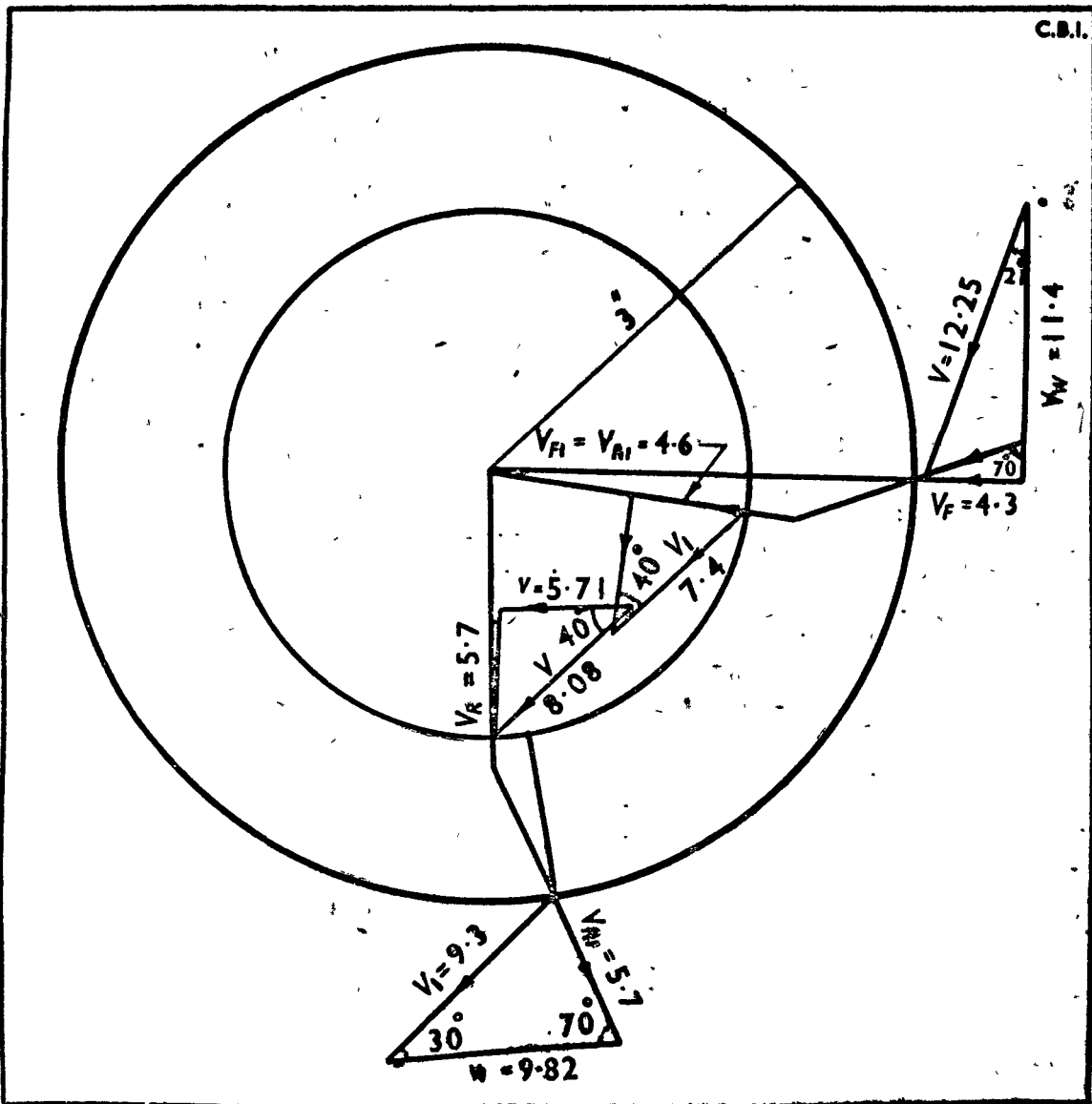


Figure 2D.13 : Showing velocities for 5 inches runner (Model 1).

discharge and the head of the water. The power out-put at the shaft of the turbine (B. H. P.) was measured by applying a brake to the shaft-pulley. The ratio of the B. H. P. to I. H. P. gave the efficiency.

The discharge was varied from 0.2 to 1.2 cusecs. Between discharges of about 0.5 to 1.0 cusec relatively good efficiencies were obtained, the efficiency falling down at higher discharges. The specific speed obtained was in the vicinity of 25 at the maximum efficiency of 35 percent. and the corresponding speed of the runner about 200 to 240 r. p. m. depending on the discharge.

Figure 2D.14 shows the typical or characteristic curves for the 32 blade runner. The unit speed at maximum efficiency=150 nearly. The power-efficiency graphs are all straight lines and the maximum power generated (depending on the discharge) amounted to nearly 0.24.

To find the optimum number of blades for good efficiency another six inches runner of the same blade angles but of 24 blades was made and experimented upon. The maximum efficiency and specific speed in this case rose to 41 percent. and 28 nearly thus showing a decided improvement. Figure 2D.15 shows the characteristic curves for this runner. The best efficiency is obtained for a discharge of about 0.52 cusec and as in the previous runner the power and efficiency fell down for discharges above one cusec.

A third runner made of same blade angles but 20 blades was tested. Figure 2D.16 shows the typical curves for this runner. This gives a better unit-power than the previous runner at high discharges and also better efficiency (of about 43 percent.), but at low discharges. Figure 2D.17 gives the relationship between specific speed and efficiency for this runner and the curves as shown in the figure are obtained. The figure shows that as the discharges are increased better specific speeds are obtained but at the cost of some efficiency. The specific speed for this runner rose as high as 30 and this clearly shows the runner is not behaving as a simple impulse turbine.

The first set of experiments were conducted with a simple guide chute with no guide vanes. Thus one blade at a time receives the jet of water at the proper angle. Hence a guide chute was designed that would direct the water at the proper angle through guide vanes over about a quarter of the wheel. Experiments are still to be conducted with this chute, but the impulse in this case being greater, higher efficiency and better results are expected.

The model of the runner, Figure 2D.13 shows that the same jet of water would hit two blades successively as can be seen from the velocity-triangle. But it is possible that when six to seven jets strike different blades, the jets after the first impulse would splash with each other thus making the second impulse well nigh impossible.

Thus it was thought it would be better if the blade angles are such that almost all the energy of the water would be tapped at the first impulse itself, *i.e.*

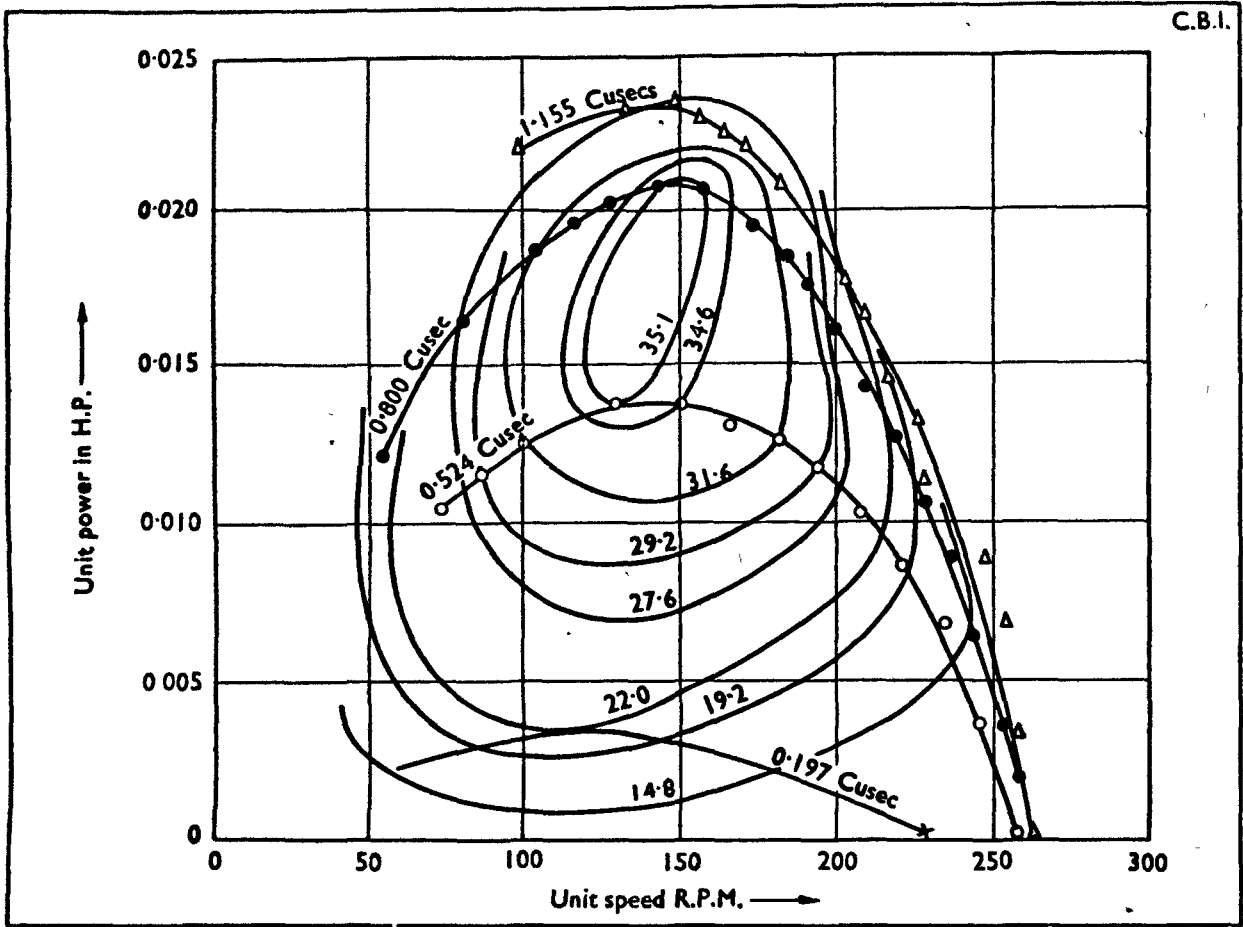


Figure 2D.14:- Showing speed power graph (6-inch turbine, model 1,32 blades)

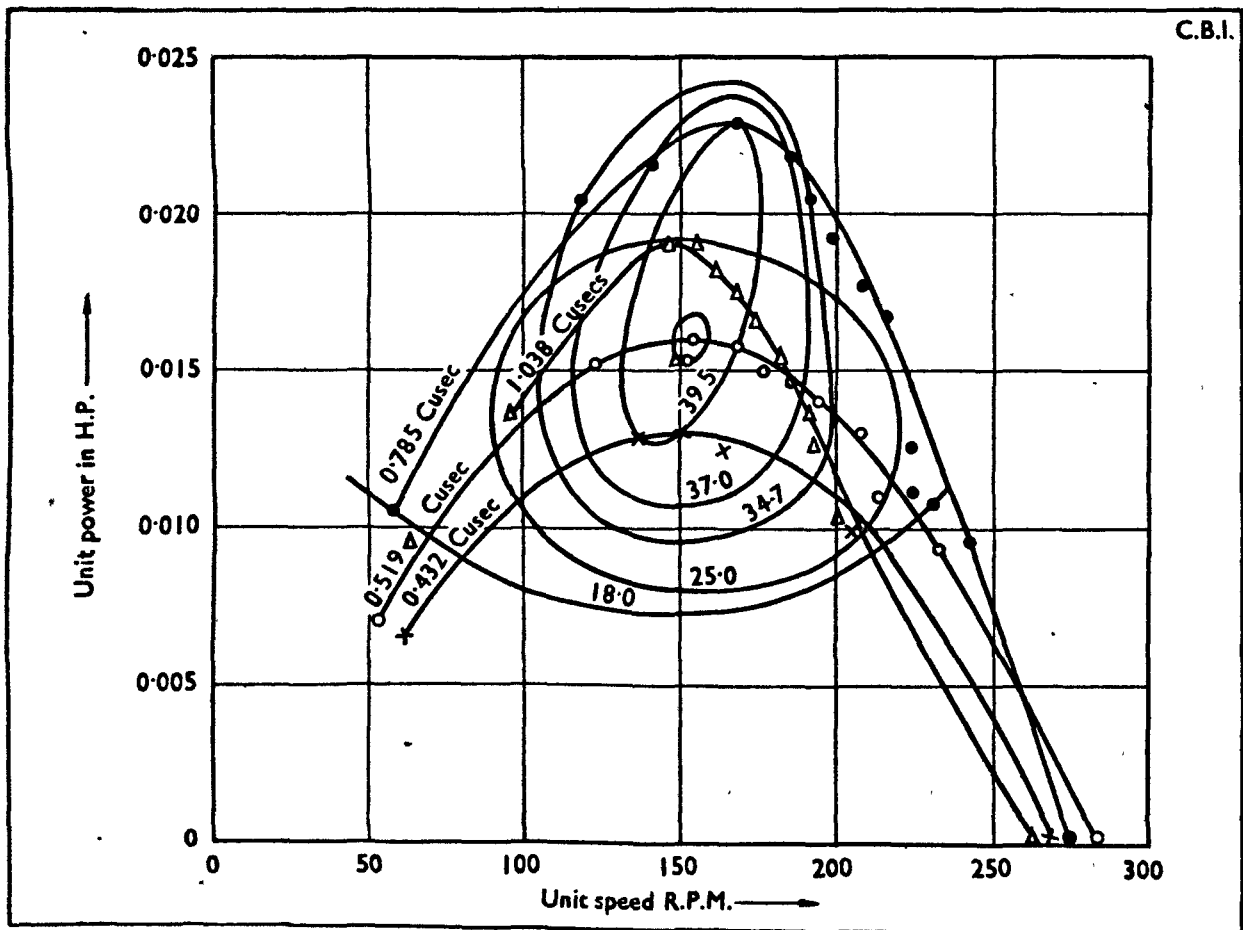


Figure 2D.15:- Showing speed power graph (6-inch turbine, model 1,24 blades)

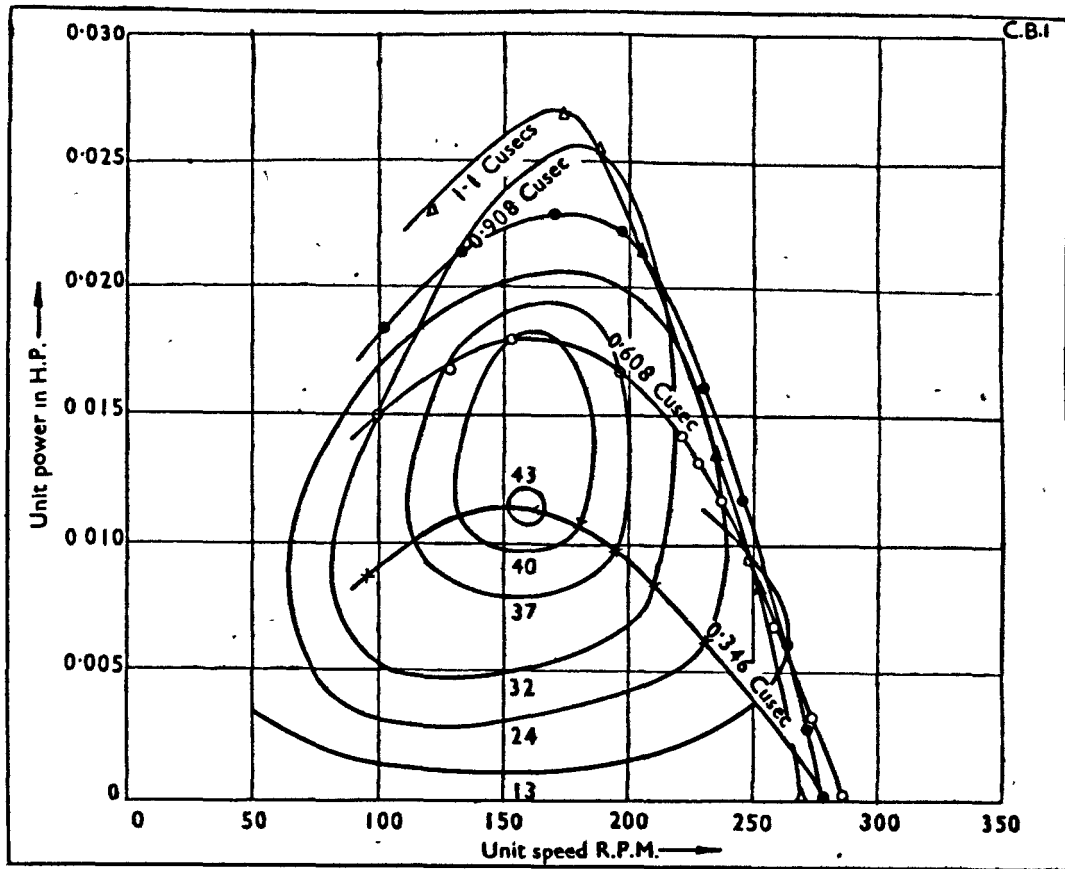


Figure 2D.16:- Showing curves for 6-inch runner (Model I, 20 Blades)

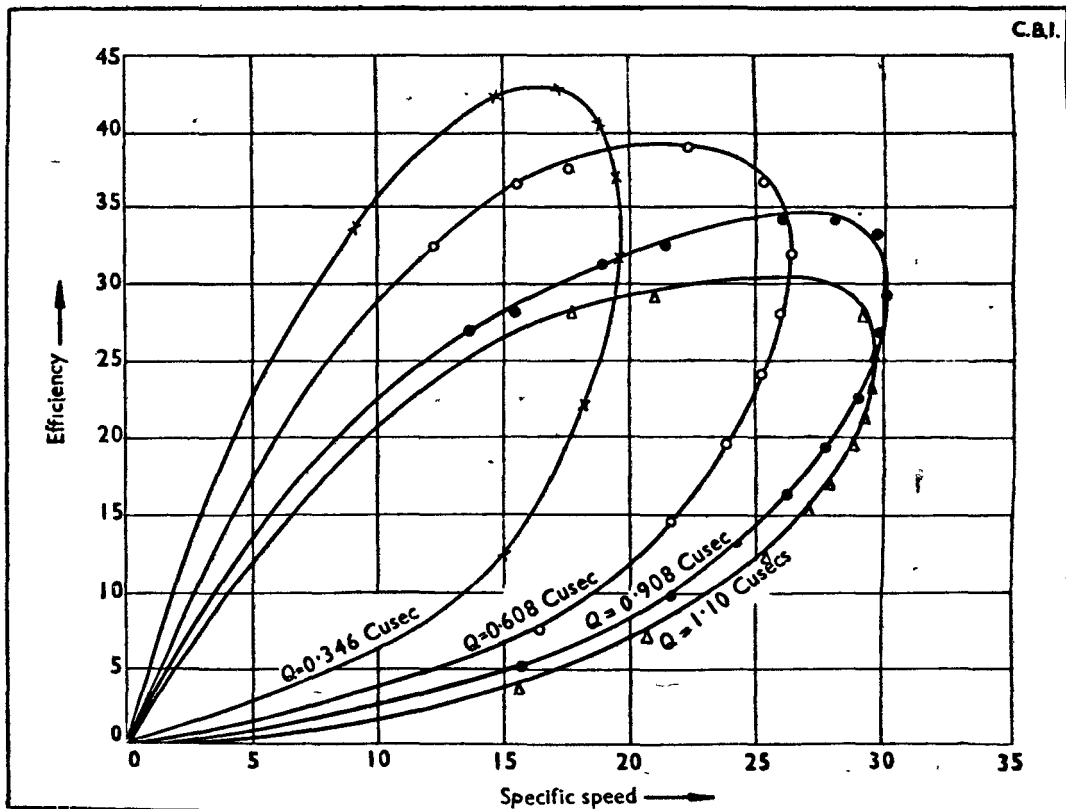


Figure 2D.17:- Showing specific efficiency 6-inch turbine (Model I, 20 Blades)

the velocity of flow at the exit tip of the blade be as small as possible. Figure 2D.18 shows a runner with the blade angles designed to satisfy these conditions.

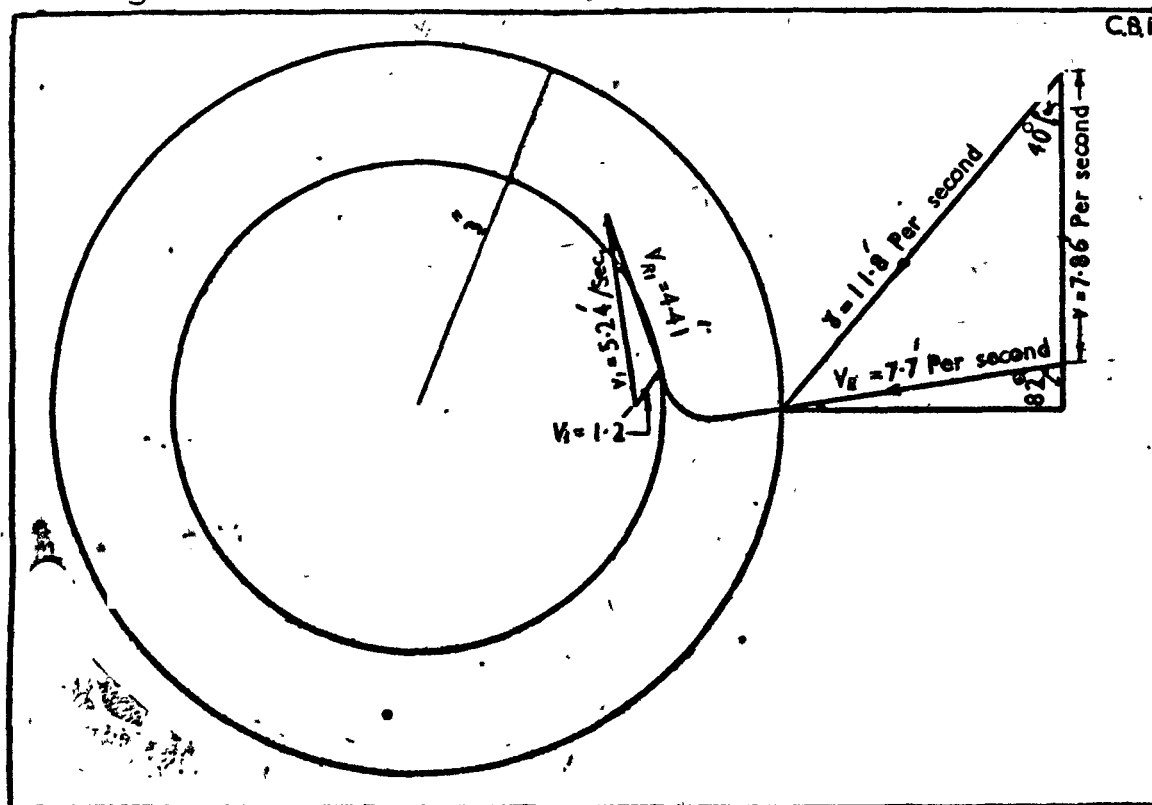


Figure 2D.18 : Showing velocity for proposed 5 inches runner (Model 2)

In this runner the ratio of the inner to outer radii is 2 : 3 and the outer diameter six inches. The peripheral velocity was calculated for the runner making 300 r.p.m. The relative velocities at inlet and exit were related so as to allow for the centrifugal head impressed on the runner by the formula

$$\frac{V_{RI}^2}{2g} = \frac{V_R^2}{2g} - \left(\frac{V^2}{2g} - \frac{V_1^2}{2g} \right)$$

As a first approximation friction losses were neglected and a mean coefficient of velocity of 0.95 was assumed. The theoretical efficiency of the blades comes to 99 percent. Experiments are to be conducted on this runner, and better results are anticipated.

Many more models are to be made and experimented upon before a simple and yet a highly efficient turbine can be evolved. Also it is a point of interest that turbines of the above type are outside general practice and it is difficult to elicit a detailed information regarding this type and thus even from the view point of pure research the experiments excite keen interest.

DISCUSSION BY THE RESEARCH COMMITTEE

In the absence of Mr. Hardikar, the item was taken as introduced.

DISCUSSION BY THE BOARD

There was no discussion. It was decided to retain subject on the agenda.

(v) Electrical Works**PRELIMINARY NOTE**

There was no contribution or discussion at the 1947 meeting of the Research Committee.

Recent Literature

- (1) Installation and care of electrical power plant—Mechanical World Monographs 23, Emmott & Co., Ltd. London, W.C. 2, 1946.
- (2) The Krangede Power Station—The Krangede Power Co., Ltd.
- (3) The Hammarforsen Power Station—The Hemmarforsen Power Co. Ltd.

THE YEAR'S WORK**DISCUSSION BY THE RESEARCH COMMITTEE**

There was no contribution and no discussion under this sub-head.

DISCUSSION BY THE BOARD

THE SECRETARY explained that no contribution was received on the subject. He, however, drew attention to the Board's resolution on page 194 of Part II—Technical of the Programme of Proceedings of the Nineteenth Annual Meeting of the Board, 1948 for taking up electrical research and said that little notice appeared to have been taken of the resolution.

MR. H. R. BHATIA thought that the electrical research was very much connected with the manufacturing industry and unless the industry started functioning in India no objective research could be carried out. He suggested some sort of research and investigations on transmission lines and thought that the best place for that would be the Indian Institute of Sciences, Bangalore where students could also take advantage of it.

MR. R. L. NARAYANAN explained that they were already doing some work. He thought that the only investigation which would be practicable at the present moment was on transmission lines.

THE SECRETARY mentioned that some suggestions were made by some members last year about research aiming at the use of local materials.

MR. R. L. NARAYANAN was of opinion that the local research centres could concentrate on the utilisation of materials that were available in the country. He understood that one of the reasons why high tension insulators were not being manufactured in India was for want of the testing equipment and it was not possible for the small manufacturers to go about installing this plant for the investigation of materials which could be utilised for this purpose.

THE CHAIRMAN invited concrete suggestions for advising the research stations on the lines along which the research might be taken up:

MR. P. B. ADVANI said that he personally agreed that so far as fundamental research in electrical matters was concerned, they were not able to go far. He was of the opinion that the manufacturing industry itself would have to possess a very large research laboratory from its the very commencement so that a large number of personnel could be trained up. So far as he knew there was no institution in India at present that could carry on any research problem on the application side except the Indian Institute of Science, Bangalore.

RAO BAHADUR SUNDARAM said that the manufacturer should take immediately the research work along with the setting up of factories. Referring to Mr. Narayanan's earlier remarks about insulators, he said there were both research facilities as well as testing facilities at the Indian Institute of Science, Bangalore. There was, in his opinion, no need for widening the testing facilities. There were quite a large number of research problems associated with the operation of power systems and he said that it might be noted that the Bangalore Institute was thinking of having a net work of analysers. It was going to help a long way in solving the transmission problem.

MR. S. A. GADKARY agreed that the research in electrical line could not be viewed in the same way as research on problems connected with river valley projects. This was more or less a fundamental issue and it was very directly linked with the industries. Under the existing facilities he said, this research could never progress. He suggested that the Board should await the industries to develop.

It was decided to keep the item on the agenda.

3D. Plant Accessories

PRELIMINARY NOTE

This subject was introduced for the first time in 1947, and there was no contribution or discussion on it.

Recent Literature

(1) Petersen H. J. The design of mechanical Auxiliaries for T. V. A. Hydro-electric plants—Transaction American Society of Mechanical Engineers—1946.

(2) Allan A. and Amer D. F. The extinction of arcs in air blast circuit breakers—Engineering Vol. 163, No. 4427, January 17, 1947.

(4) Sykes J. H. M. The development of the circuit breaker—Indian and Eastern Engineer Vol. 100, No. 2, February 1947.

(5) Brown M. J. and Derr W. A. Automatic control of hydro-electric generating stations—American Institute of Electrical Engineers, New York, Technical Paper No. 47-57, December 1946.

(6) Rosslyn J. Power transformers—George Newnes Ltd., London.

THE YEAR'S WORK

DISCUSSION BY THE RESEARCH COMMITTEE

There was no contribution or discussion at the 1947 meeting of the Research Committee.

DISCUSSION BY THE BOARD

THE SECRETARY said that there was no contribution and no discussion at the Research Committee meeting.

4D. Regulation

PRELIMINARY NOTE

This subject was introduced for the first time in 1947, and there was no contribution or discussion on it.

Recent Literature

- (1) Gaden D. Stabilité de Réglage d'un groupe hydro-électrique (Stability of regulation of an hydro-electric system)—La Houille Blanche, No. 5, September-October 1946.

THE YEAR'S WORK

DISCUSSION BY THE RESEARCH COMMITTEE

There was no contribution or discussion at the Research Committee Meeting.

DISCUSSION BY THE BOARD

THE SECRETARY said that there was no contribution and no discussion at the Research Committee meeting.

5D. Transmission

PRELIMINARY NOTE

This subject was introduced for the first time in 1947. There was no contribution or discussion at the Research Committee meeting, but the Board passed the following resolutions on the subject :—

“ In view of the restrictions which the Posts and Telegraphs Department are imposing upon the proximity of power transmission lines and tele-communication lines which are causing embarrassment to power engineers and delay in the development of electric power transmission projects, the Board resolves that the Government of India be requested to convene an early meeting of power engineers and telephone and telegraph engineers under the presidentship of the Chairman, Central Technical Power Board to consider and report to Government an agreed solution to be adopted throughout the Indian Union.

“ In view of the fact that neither the Indian Telegraph Act nor the Electricity Act provide sufficient safeguard to the owner of Power Transmission lines against demands for re-alignment subsequent to erection, unless considerable expenditure is incurred for the acquisition of land, rights, and wayleaves, the Board resolves that as widespread electrification in the Indian Union involving the construction of major transmission lines is under implementation, the Government of India be requested to appoint a committee comprising Power Engineers, legal experts and other interests to examine the acts in force and to recommend such additional legislation as may be necessary in the National interest to overcome the present difficulties. ”

As regards the first resolution the Government of India have replied that the matter is already under their consideration.

The second resolution of the Board was communicated to the Government of India and at the instance of the Ministry of Works, Mines and Power, a meeting comprising representatives of the Central Electricity Commission, Ministry of Works, Mines and Power and the Secretary of the Board was held in April 1948. It was decided that the Central Electricity Commission should (i) find out the legal provisions and the practice followed in the United States of America, Canada, Australia and the United Kingdom ; and (ii) address some of the Provincial Governments like the United Provinces, Bombay, Madras and East Punjab to find out as to how they managed to get over the difficulties put forward at the meeting, and when this information is collected a small subcommittee would be set up to examine the matter further and to suggest the amendments of the relevant Acts in such a way as to ensure healthy development of electricity in the country.

Recent Literature

(1) Linder F. W. Graphical method of calculating fault currents on rural distribution systems—American Institute of Electrical Engineers, New York.

(2) Jackson W. High frequency transmission lines—Methuen and Co., Ltd., London, 1947.

(3) Ruedy R. Power transmission over long distances—translated—National Research Council of Canada, July 1946.

(4) Peattie J. D. and Hacking J. The British Grid system in war time—Engineering Vol. 163, Nos. 4234 and 4235 March 21 and 28, 1947—Journal Institution of Electrical Engineers Vol. 94, Part II, October 1947.

(5) Perkins G. H. Concrete stubs—Indian Concrete Journal, Vol. 21, No. 9, September 1947.

(6) Barrows E. J. Industrial High Voltage distribution and public supply—Isaac Pitman & Sons Ltd., London, 1946.

(7) Specifications for tubular stool poles for electric line construction—American Standards Association, New York.

(8) Specifications for design of concrete transmission poles—Proceedings of American Railway Engineering Association, Chicago, Vol. 48, 1947.

(9) Testing transmission towers to failure—F. Mendel Engineering News Record Vol. 139, No. 8, August 21, 1947.

(10) Kulkarni, H. S. and Raghavan, V. R.—Co-ordination of Power and tele-communication lines.

THE YEAR'S WORK**DISCUSSION BY THE RESEARCH COMMITTEE**

There was no contribution or discussion at the Research Committee Meeting.

DISCUSSION BY THE BOARD

THE SECRETARY referred to the two resolutions passed by the Board last year which are on page 304. Both the resolutions were forwarded to the Government of India for action. The present position, he said, was that Rules under the Electricity Act were under revision and it was proposed to incorporate therein proposals for land acquisition *etc.* As regards interference between the tele-communication and power transmissions he said, the Ministry of Works, Mines and Power of the Government of India was in correspondence with the Director General of Posts and Telegraphs.

MR. H. R. BHATIA explained that they had a conference sometime back with the Telegraph Department. The East Punjab Electricity Department wanted to run a 220 K.V. power line from Ambala to Delhi parallel to the existing telegraph line. The Posts and Telegraph Department had selected the same side of the road on which the power line was proposed to be run. For convenience of maintenance it is impracticable to run a power line at more than about two furlongs from the road. The question remained under correspondence with the Indian Posts and Telegraph Department for a considerable period and the last reply received from that Department was that the Electricity Department could proceed with their power transmission line provided the fault current was kept below 23 amps. This condition was impracticable and therefore the work could not be proceeded with.

THE SECRETARY explained that two Ministries were involved on this question namely, the Ministries of Works, Mines and Power and of Communications. The matter was not yet finalised but he thought, some solution would be found shortly.

MR. S. A. GADKARY pointed out that the matter had also been followed up through the Electrical Commissioner's Office.

MR. H. R. BHATIA stated that in the East Punjab, the main transmission line was costing about one *lack* per mile. It was therefore, very important to have a proper comparison on the economical cost of transmission lines. Unless a comparative study of the various types of conductors was available, he said it was very difficult to reach a really economical solution. Comparative study in his opinion, could not be made without an expert knowledge of tower design. He suggested that as a number of long transmission systems had yet to be erected in India, a central organization should be set up for tower design and for carrying out a comparative study of different types of transmission lines using different types of conductors and supports.

MR. S. A. GADKARY in agreeing with Mr. H. R. Bhatia said that so far it was being taken for granted that the A.C.S.R. and certain types of towers were more economical than others but they had not studied the matter in detail themselves and whether it would not be cheaper to introduce wooden structures. He was of opinion that some authoritative study should be made, and suggested that the Central Electricity Commission should undertake this work.

MR. P. B. ADVANI was of opinion that so far as the economical study was concerned, there were really two questions involved. One was the design of towers for which one still had to go abroad and the other was the utilization of the material in the country for towers *etc.* In England or America he said there were two very highly specialized firms who did this work for everybody. This facility was lacking in India at present. He suggested that the possibility of having some organisation in India on the design of towers should be given a careful consideration.

RAO BAHADUR G. SUNDARAM was of opinion that transmission line designs could be done by any Provincial Government, as they, in Madras had been doing it for the last three years. They were making towers themselves in Madras and were also testing them. He further stated that towers for about 200 miles of line were at present under manufacture of which half the length had been already completed. These towers were being manufactured in accordance with their own designs.

MR. S. A. GADKARY pointed out that probably non-standard sections were being used.

RAO BAHADUR G. SUNDARAM in reply to Mr. Gadkary said that they were using standard sections. He further stated that the towers were being fabricated in their own workshops and were also tested by them. In his opinion, the Provincial Governments should have their own workshops as in Madras they had set up two such and they were working satisfactorily. They were now making 16 to 17 towers for the crossing of Godavari river which were designed by them. On completion, they would be tested in their own workshops. They for their part, did not therefore, need to go to foreign firms for towers. In reply to the question of comparative study of various materials, he said that it was not possible to formulate any views because it was all a question of economics and the rates of materials fluctuated. Aluminium was for instance a controlled commodity and so was copper. The relationship between copper and aluminium was of a very high level. The prices had to be paid these days as they were demanded. Once the conductor was decided upon it would depend upon the type of structure to be used. Explaining his point further, he said that if steel could be had at cheap rates they could use it but if it was not available as it was now, then timber could be used. Therefore, all these things had to be taken into consideration. Therefore, he did not know in what manner they could issue instructions to any particular research organisation to carry out some investigations because there were so many variable factors involved.

MR. H. R. BHATIA agreed that every Province or Department could design the towers. In East Punjab, for instance, they had designed their line completely but that did not mean that they had taken into consideration all the possible types or combinations that could be available. Explaining his point he said that before the conductor was selected, it was very essential to compare the various designs. If for instance hollow copper was selected the span would be different than if other conductor material was selected. Therefore, in his opinion, to design a tower properly it required quite a long study. He said that the Central Electricity Commission with a big organisation and not having any immediate job in hand at the moment could probably undertake such a study which would be very useful to all the Provinces.

MR. R. L. NARAYANAN wanted to know as to how the rate of the towers manufactured in Madras compared with the imported towers.

RAO BAHADUR G. SUNDARAM in reply to Mr. Narayanan stated that he was unable to answer the question straight away as their own designs had at times to be twice or thrice modified.

6D. Financial Aspects

PRELIMINARY NOTE

This subject was introduced for the first time in 1947 with the following sub-heads.

- (i) Operating costs.
- (ii) Electricity tariffs, accounts and procedure

Discussion under the subject "Projects, existing and proposed", at the 1946 meeting of the Board revealed the necessity of appointing a Sub-Committee to write up notes about costs of generation and utilization of hydro-electric projects. It was also felt that some standard procedure about maintaining capital accounts for generation and transmission would be useful. The consensus of opinion was that there should be some sort of yard-stick by which relative merits of different projects could be judged. A handbook on the subject was desirable :

"After some discussion it was decided that an enquiry be made from the Central Technical Power Board regarding the information available with them or published by the Electrical Commissioner regarding costs of generation, tariffs and accounts of electric undertakings in different parts of the country. This information should be put up to the Board at its next meeting when the question of forming a sub-committee to write a hand-book on the subject would be considered."

The discussion at the Board meeting was communicated to the Central Technical Power Board and on a request having been made, Mr. Mathews very kindly contributed an article on the subject in the Central Board of Irrigation Journal. This was published under the heading "Power costs and tariffs in hydro-electric projects."⁽¹⁾

An All India Rate Book has recently been issued by the Electrical Commissioner's office. In this book are being given all approved tariffs for supply of electric energy to different classes of consumers in force in all public supply undertakings in India. This book was reviewed in the Central Board of Irrigation Journal, July 1947 issue.

Since the 1946 meeting of the Board, the Electrical Commissioner's office has issued three books of statistics namely,

- (i) Public Electricity Supply—All India Statistics 1939-43.
- (ii) Public Electricity Supply—All India Statistics, 1944.
- (iii) Public Electricity Supply—All India Statistics, 1945.

(¹) Central Board of Irrigation Journal vol. 4 No. 3 July 1947.

A similar Volume for 1946 is in press.

The three reports already published were reviewed in the Central Board of Irrigation Journal. The 1939-43 report contains a tabulation of basic statistical data relating to public electricity supply covering the period 1939-43. It contains annual summaries of data showing installed capacity particulars of generation and the segregation of energy sales under various categories for all provinces and major Indian States. It also contains details of individual utilities including systems of supply, maximum demand and energy generated and sold in each year.

The 1944 report is more comprehensive and gives in addition to the information stated above interesting National Totals which give at a glance an over all picture of the country's development in electric supply. The main tables relate to 526 individual public electricity undertakings which are listed under two broad classifications, viz. those with generating stations and those receiving block supply.

The 1945 volume of statistics includes some new features, listed below :—

- (a) Generation, sales and generating plant data expressed in terms of ownership amplified.
- (b) Transmission line data giving voltages and route miles.
- (c) Number of electrified towns and villages classified on a population basis.
- (d) Total fuel consumption in all utilities and also a study of coal consumption, load factor and approximate cost of generation in important stations.
- (e) Electricity consumption in three major industries, viz. Cement, Iron and Steel and Cotton Textiles.
- (f) Tables showing growth of installed capacity aggregate maximum demand, Kwh. generated and sold and overall annual load factor from 1939 to 1945 inclusive.

The 1946 volume contains some additional features. These are :

- (a) Breakdown of energy generation and sales into A. C. and D. C.
- (b) Classification of supply undertakings in terms of voltage of generation.
- (c) Figures in respect of total boiler capacity, All India.
- (d) Classification of undertakings in accordance with the aggregate of maximum demands.
- (e) Per capita figures for energy sales for Provinces and States.
- (f) Consumer data under three major groups in the Provinces, States and All India.

It is felt that the statistical information contained in the reports issued by the Electrical Commissioner, the All India Rate Book and the article by Mr. Mathews published in the Central Board of Irrigation Journal in July 1947 supply most of the information that the Board felt was lacking.

(i) Operating Costs

PRELIMINARY NOTE

There was no contribution or discussion at the 1947 meeting of the Research Committee.

Recent Literature

(1) Mathews H. M. A note on power costs and tariffs in hydro-electric projects—Central Board of Irrigation Journal, Vol. 4, No. 3, July 1947

(ii) Electricity tariffs, accounts and procedure

PRELIMINARY NOTE

There was no contribution or discussion at the 1947 Research Committee meeting.

Recent Literature

(1) Dale F. A. Santee Cooper Generating Plant completes five years of service—Civil Engineering, New York, Vol. 17, No. 8, August, 1947.

(2) Mathews H. M. A note on power costs and tariffs in hydro-electric projects—Central Board of Irrigation Journal, Vol. 4, No. 3, July 1947.

THE YEAR'S WORK

DISCUSSION BY THE RESEARCH COMMITTEE

THE PRESIDENT regretted that there were no contributions under these subjects.

THE SECRETARY pointed out that these subjects had only recently been introduced in the agenda of the Research Committee Meeting. He hoped there would be a much better response in future years.

THE PRESIDENT asked if any one wanted to raise a discussion on any of the subjects on the agenda.

On being requested to speak on transmission, MR. GADKARY said that he would be glad to answer specific questions.

Speaking on transmission voltages, he said that voltage was a very important factor for transmission over long distances. Various countries were using different voltages. In India, 110 kV. was first used by Tatas some 30 to 40 years back. 132 kV. was used on Mandi Hydro-electric and 220 kV. was being advocated now by the Centre. He explained some of the important factors that determined the transmission voltage.

Referring to the importance of inter-project or inter-state grid, he said that sooner or later a National Grid in India would have to be established and for this reason power houses and transmission lines should be designed with identical characteristics.

He suggested that provincial technical designs should be referred to Central Organisation for proper co-ordination.

MR. GADKARY then referred to the allocation of costs between different components of a multi-purpose project and said that any note on the subject should deal with items of percentages which were comparable between different projects.

MR. P. V. S. AYYAR stated that from the studies made by him on the economics of voltages in Assam, he found that the cost of constructing 220 kV. line was not much higher than that of 110 kV. though the power transmitted was increased fourfold.

MR. H. S. KULKARNI of the Central Electricity Commission, giving a brief account of the general scope of work of the C. E. C., said that it consisted of three divisions, *viz.*,

- (i) Planning.
- (ii) Utilization.
- (iii) Commercial.

The Planning division comprised :

- (i) a section for designing transmission and distribution lines, receiving stations, sub-stations *etc.*, and
- (ii) a section for designing large thermal stations, *e.g.*, one in the coal-field area in Bihar with a capacity of 200,000 kW.

The Utilization division comprised five sections, *viz.*,

- (i) Co-ordination and allocation of raw materials for electric power projects, and emergency procurement of plants ;
- (ii) Erection of generating plants, particularly of emergency requirements ;
- (iii) Compilation of technical data relating to all public electric utility generating stations and electric power systems in India ;
- (iv) Formulation of rural electrification projects ; and
- (v) Carrying out of load surveys for electrification schemes.

The Commercial division had the following sections :—

- (i) Operating statistics of all public electric utility undertakings ;
- (ii) Electricity Legislation and Agreements (Indian Electricity Rules—Electricity act—Electricity Supply Bill, *etc.*).
- (iii) Study and analysis of Electric Power Tariffs for various types of electrical power systems.

Speaking on the inter-provincial grid, he said that the Central Electricity Commission had suggested a scheme for the interlinking of U.P., Delhi and East Punjab for purposes of power supply to the capital town. Although there was some reluctance in certain quarters previously, it was expected that the matter would shortly be discussed across a table in the near future. MR. KULKARNI said that it would be very helpful if the provincial Electricity Departments would send to the C. E. C. and to the CWINC, copies of detailed project reports. These would enable these Commission to appreciate in proper perspective various aspects of the projects and to give adequate support to the provincial organizations which they could not do without such data. Secondly, he pointed out that while considerable attention was being paid to the planning for steel, raw materials and other requirements of these projects, it was also necessary that suitable planning should be undertaken to train the required number of

technical persons for the projects being undertaken. If the provinces made an estimate of the staff needed at the end of the next 3 or 5 years and type of experience required, it would be an economical proposition to recruit now even fresh men and to train them up on either their own or neighbouring power systems so that they would be ready to fill up posts of junior responsibility when the projects are completed.

MR. KULKARNI emphasised that erection of generating plants and transmission lines should, as far as possible, be carried out by the departments undertaking these projects. Mysore had erected the Sivasamudram generating plant with its own men even as long back as 1919. For the Jog plant commissioned recently, four men were sent to the manufacturers' works for training during the construction stages of the plant, and the Mysore engineers were erecting all the plant themselves.

With reference to the remarks made by Mr. Gadkari on the allocation of costs, the SECRETARY said that he had already received some notes in response to the Board resolution on the subject passed last year. He, however, invited all others who had not sent their notes but wanted to contribute, to do so by the 31st of August 1948, so that they could be compiled for discussion at the next Board Meeting.

Speaking on the proximity of telephone lines to power lines, Mr. S. SWAYAMBU said that the resolution passed by the Board last year was being acted upon and the Central Electricity Commission was in contact with the Postal authorities.

A small technical committee had been set up to revise the Electricity Rules and Electricity Law.

In reply to Dr. J. K. RAO's question, Mr. SWAYAMBU referred to his paper in the July 1947 issue of the Central Board of Irrigation Journal and said that Rs. 120/- per kW. per year was a fair figure for the cost of generation for hydro-electric power from reasonable economic projects. This is equivalent to about 2.5 pies per kWh assuming 100 per cent. load factor or about five pies per kWh assuming 50 per cent. load factor. This cost, he said, may increase from six to seven pies per unit for consumer's loads of the order of 1,000 kW. located not too far away from the generating station.

MR. SAXENA feared that Central organizations were being set up to monopolise all the authority which rightly belonged to the Provinces.

THE CHAIRMAN in his concluding remarks assured Mr. Saxena that the Centre was not out to monopolise authority but was working in a spirit of service. Speaking of transmission lines, he said, that in Sweden the transmission distances went up to 800 miles, 220 kV transmission lines were common practice in that country and some lines with 330 kV were under construction. Experiments were in progress on 550 kV transmission voltage. 220 kV lines were in use in Scotland and France. In the latter country the construction of 440 kV lines was under consideration.

He said that the suggestion made by Mr. Kulkarni for training the personnel in advance was very valuable.

DISCUSSION BY THE BOARD

“ THE SECRETARY said that there was no contribution but discussion took place under these sub-heads. Suggestions were made by Mr. Kulkarni of the Central Electricity Commission for the training of the personnel in advance of their actual requirement. There was however, no resolution.

Several suggestions were then made regarding the training of engineers on the construction of projects and on maintenance to take charge later of works now under investigation, or construction. The following resolution was unanimously adopted :—

“ In view of the fact that many large Hydro-Electric projects now being undertaken or planned in different parts of the country will require for their construction and operation a large number of trained Engineers of different ranks, the Board recommends to the Provincial and State Governments concerned to employ young engineers, on permanent basis, in advance of their actual requirements and to train them on construction work in progress and operation, on Hydro-Electric works that exist in some parts of the country. The Board trusts that the provinces and agencies incharge of the construction and operation of Hydro-Electric work will provide necessary facilities for the training of engineers from their own and neighbouring Provinces and States ”.

7D. Miscellaneous

Recent Literature—

(1) National Electrical Code—International National Fire Protection Association, Boston, 1947.

(2) Kimberly E. E. Electrical Engineering—International Textbook Co., 1946.

(3) Nelkon M. Principles of Technical Electricity—Blackie and Son Ltd., London and Glasgow, 1946.

(4) Ballin H. H. The Organisation of Electricity Supply in Great Britain—Electrical Press Ltd., London, 1946.

(5) Opinions and decisions on the Federal Power Commission with appendix of selected orders in the nature of opinions—U. S. Government Printing Office Washington, Vol. 4, 1946.

(6) Lincoln E. S. Electrical measuring instruments, measurements and surveys—Essential Books, 270 Madison Avenue, New York.

(7) Electricity bill as amended in committee for the establishment of a British Electricity Authority and area electricity Boards, *etc.*—His Majesty's Stationery Office, London, July, 24, 1947.

THE YEAR'S WORK

DISCUSSION BY THE RESEARCH COMMITTEE

There was no contribution or discussion at the 1947 meeting of the Research Committee.

DISCUSSION BY THE BOARD

It was decided to retain the subject on the agenda.

Section E—Soil Science

1 E. Soil Mechanics

PRELIMINARY NOTE

This subject appeared on the agenda for the first time in 1942.

In 1947 it was decided to divide the above subject under five sub-heads.

In 1945 a permanent sub-committee was set up to draft a directive on Standardization of methods and equipment for testing soils. This sub-committee included members from Railway Board, the Indian Army and the Indian Roads Congress. The directive finalised by the sub-committee is now in press.

(I) FUNDAMENTAL RESEARCH

PRELIMINARY NOTE

The following resolution was passed by the Board at its 1947 meeting :—

“ In view of the necessity of providing protection to the water face of earthen dams and embankments against wave wash, the board resolves that experiments be undertaken on field scale with regard to the use of various materials for the purpose including (a) graded and treated soils, (b) *surkhi* concrete, and (c) cement concrete.

“ Resolved further that investigation be undertaken also to evolve suitable methods for protection against wave wash ”.

In response to this resolution information has been received that the question of providing protection to water fall has received considerable attention in Ceylon. In the ancient days large slabs of stones were used. In most of the ancient tanks which have been restored this pitching is still preserved.

The standard method now in use in construction works in Ceylon is to protect bunds with concrete slab pitching about four feet by four feet by three inches cast in place and not reinforced. Rubble pitching has also been used in some works.

An attempt is also being made to use bitumen or tar coating with metal rammed from $3\frac{1}{2}$ inches loose to two inches thickness for spills. This type of spill has worked satisfactorily in the case of small village tanks.

The following items were discussed at the 1947 Research Committee Meeting :—

- (1) Determining the shrinkage factor of soils.
- (2) Protection of Usehat *Bund* from wave wash with stabilised soil.
- (3) Experiments in connection with the determination of (a) optimum moisture content (b) bearing capacity and (c) Calcium Chloride (hygroscopic) required for optimum bearing power in different typical soils.
- (4) Field capacity in terms of clay content.
- (5) Standardisation of tests of engineering properties of soils.

Recent Literature

- (1) Bertram, G.E.—Soil tests for military construction. American Road Builders' Association, Chicago, Ill. Technical Bulletin No. 107, 1946.
- (2) Tan Ek Khoo.—Stability of soil slopes. Proceedings of American Society of Civil Engineers, Vol. 73, No. 1, January 1947.
- (3) Soil Mechanics fact finding survey progress report Triaxial Shear research and pressure distribution studies on soils. Waterways Experiment Station, Vicksburg, Mississippi, April 1947.
- (4) Harlow, E. H.—Chart facilitates determination of unit weight of soil Engineering News Record, Vol. 139, No. 12, September 18, 1947.
- (5) Marshall, T. J.—Mechanical composition of soil in relation to field description of texture. Council of Scientific and Industrial Research Bulletin No. 224, 1947.
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THE YEAR'S WORK.

The following items were discussed at the 1948 Research Committee Meeting:—

- (1) Variation of dry bulk density of soil with different amounts of cement mixed with it.
- (2) Comparison of the different deflocculating agents added to disperse the soil in the mechanical analysis of soils.
- (3) Stabilised soil as a building material.
- (4) Hardness of the soil crust.
- (5) Comparative study of soil samples from (1) Santa Cruz Air Field (Konkan zone, West of Ghats) near Bombay and Gangapur Storage (Transition zone, East of Ghats) near Nasik.
- (6) Economical limit of rolling by Sheeps' Foot Roller.

(1) VARIATION OF DRY BULK DENSITY OF SOIL WITH DIFFERENT AMOUNTS OF CEMENT MIXED WITH IT ⁽¹⁾

To study this effect, a sample of a soil was taken and subjected to standard Proctor's test. Then it was mixed with cement in different ratios and again subjected to Proctor's compaction tests. The results are shown in Figure 1 E.1.

For this particular soil dry bulk density decreases with increase in the amount of cement.

⁽¹⁾ United Provinces Irrigation Research Station, Report on Research Progress during 1947, Page 107

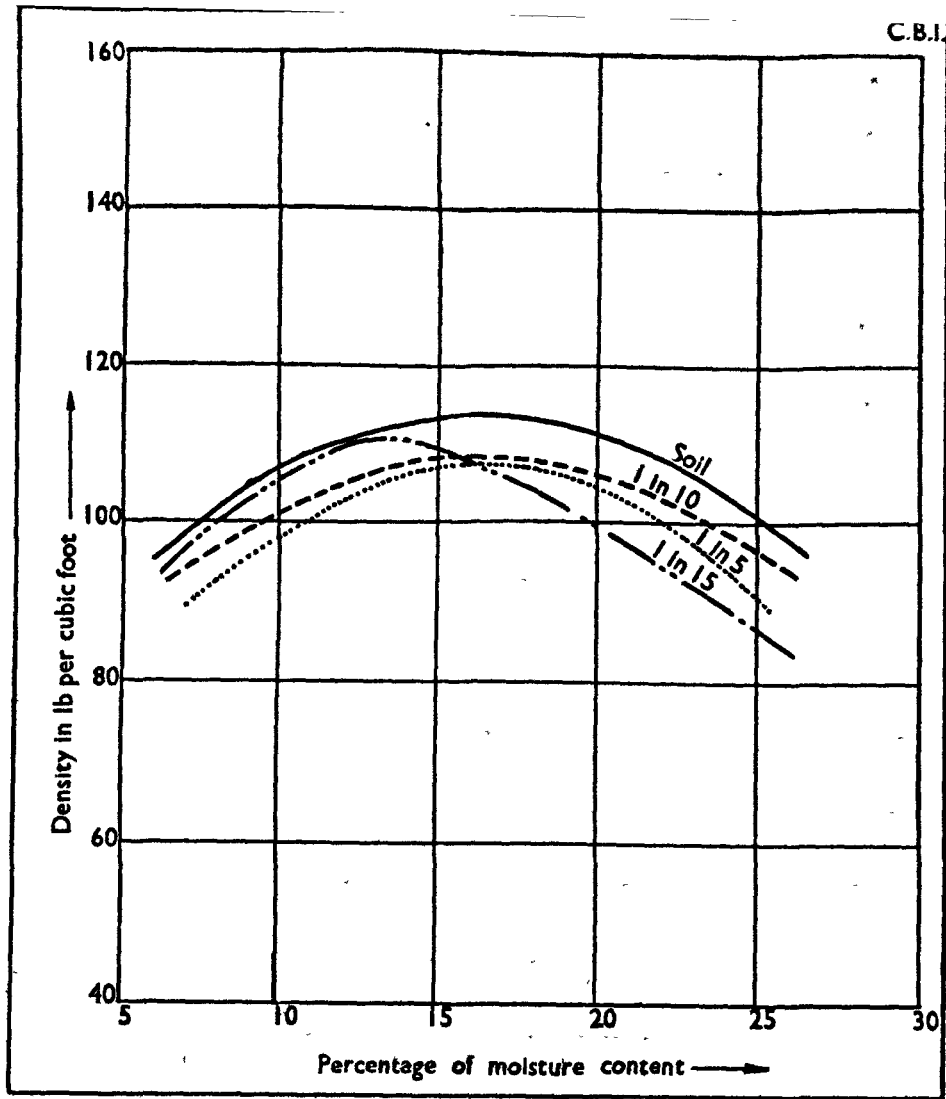


Figure 1E.1:- Curves showing variation of density with cement percentage in the soil

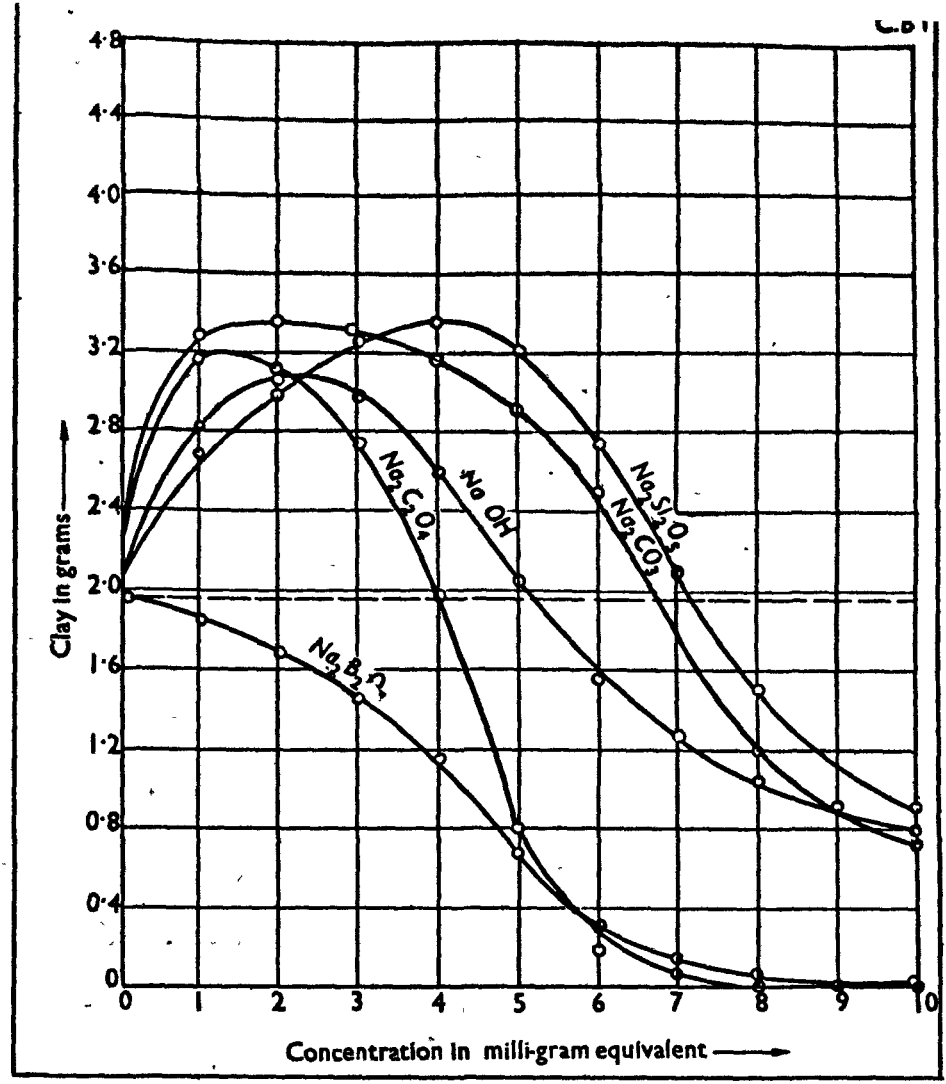
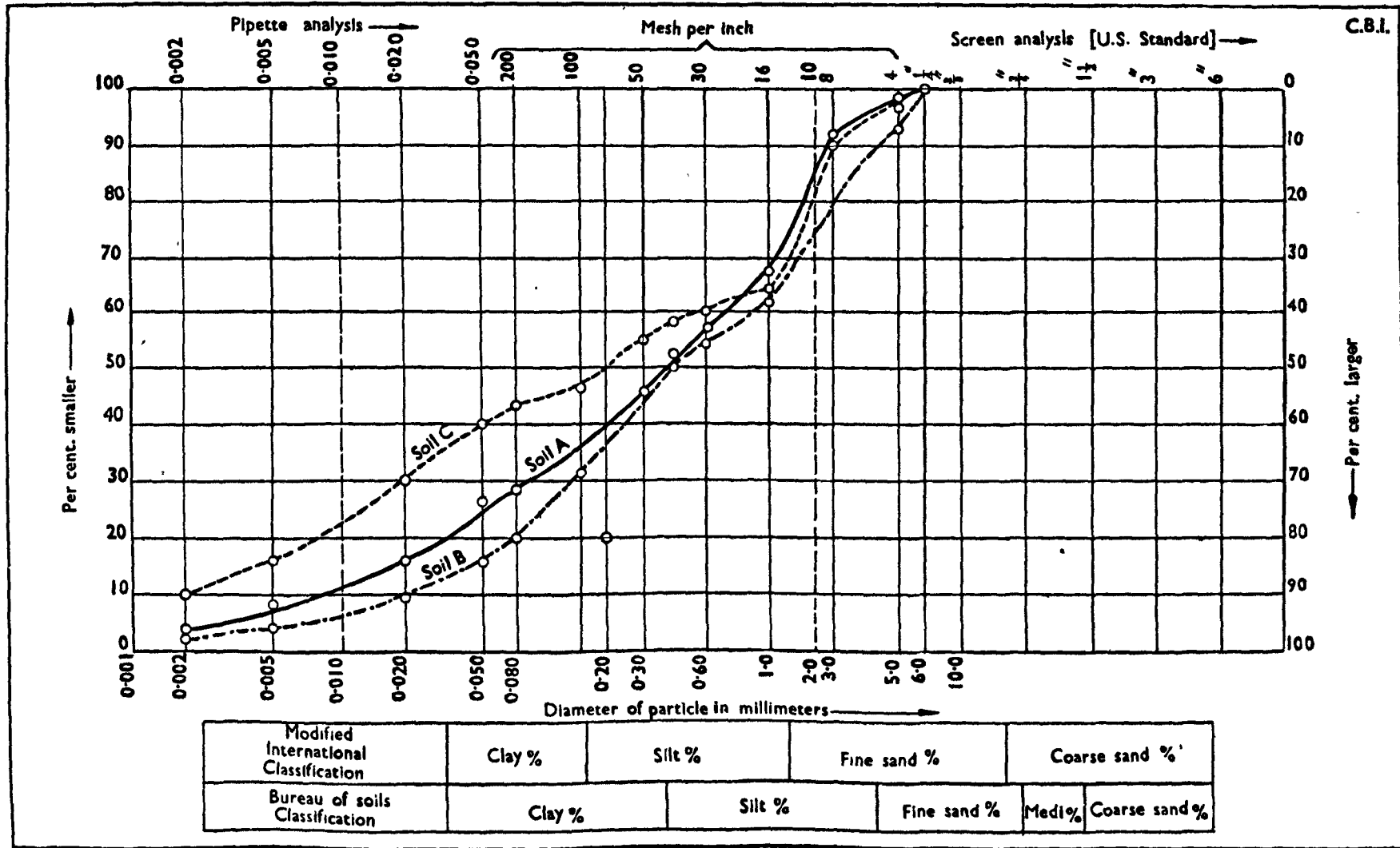


Figure 1E.2:- Showing effect of different deflocculating agents on soil dispersion



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Figure E.3:- Graph showing the gradings of soil obtained by mechanical analysis tests

(2) COMPARISON OF THE DIFFERENT DEFLOCCULATING AGENTS ADDED TO DISPERSE THE SOIL IN THE MECHANICAL ANALYSIS OF SOILS (2)

Five deflocculating agents, namely (1) Sodium Silicate, (2) Sodium Carbonate, (3) Sodium Hydroxide, (4) Sodium Oxalate and (5) Sodium Borate, which are commonly used to disperse the soil, have been studied and compared.

First of all clay was separated from the bulk of the soil by saturating the soil with Na-ion by leaching with 1000 cc. of Sodium Chloride and kept in a cylinder about 35 cm. high for 24 hours. The liquid at the top was decanted. This contained all the clay, *i.e.*, particles of 0.002 mm. and below. This was collected on filter paper, thoroughly washed first with water and finally with absolute alcohol.

Five gm. of the clay was shaken with different quantities of chemicals in 250 c.c. suspension. 25 c. c. of the suspension was pipetted out after a fixed number of hours recommended for clay analysis by pipette method. The clay filtered out on a filter paper and was converted to Ca-soil by leaching with a normal solution of Calcium Chloride so as to have a common basis for comparison.

Figure 1 E. 2 shows the relation between the quantity of clay pipetted out and concentration of different chemicals.

CONCLUSIONS

1. The efficiency of the chemicals, as is evident from the curves, is in the following order.

Sodium Carbonate = Sodium Silicate > Sodium Oxalate > Sodium Hydroxide > Sodium Borate.

2. Sodium Carbonate is the best chemical to be used because (a) smaller quantities are needed and (b) it permits greater latitude in the allowable concentration of the salt. This is clearly indicated by the flat portion of the curve, for this salt, of Figure 1 E. 2.

(3) STABILIZED SOIL AS A BUILDING MATERIAL (3)

Three soils were selected representing the usual types of soils available in the Deccan Plateau. Grading and other properties of the soils selected have been shown in Figure 1 E. 3. Soil A is a gravelly sandy loam (termed *morum* locally), and soil B is gravelly sand (the local *Chowka* Soil). Soil C with more percentage of fines has been prepared by mixing the locally available *morum* and B. C. Soil in 2 : 1 proportion. All these soils were prepared past $\frac{1}{4}$ inch for laboratory investigation and the grading shown is of the prepared samples as these only are proposed to be used in the constructions for the problem.

(2) United Provinces Irrigation Research Station, Report on Research Progress during 1947, pages 107-108.

(3) Hyderabad Engineering Research Laboratories, Annual Report 1947, pages 47-52.

The above three soils were tested for determining the optimum percentage of cement, and it was found that the suitable percentage of cement for use with the above soils was 7.5 per cent., 8 per cent. and 9 per cent. respectively.

To determine the suitability of the above treated soils, as building material, bricks of 9 inches \times 4½ inches \times 3 inches size were made by compacting the soils at the respective optimum moisture content. These prepared bricks after one week's curing were tested for comparison with the locally burnt bricks and the comparative test values are shown in Table 1E. 1 which indicates that the stabilised soil moulds compare well with the local burnt bricks.

TABLE 1E. 1

Comparison of Properties of Experimental Stabilised Bricks with Hyderabad Burnt Bricks

| Serial No. | 1 | 2 | 3 | 4 | 5 | Remarks |
|---|-------|------|-------|--------------------|-------------------|---------|
| Sample No. | A | B | C | Asaf-nagar bricks. | Domalguda bricks. | |
| Cement percent added | 7.5 | 8.0 | 9.0 | .. | .. | |
| Compressive strength in lb. per square inch in Dry state. | 594 | 578 | 465 | 167 | 427 | |
| Compressive strength in lb. per square inch in saturated state. | 408 | 428 | 352 | 90 | 98 | |
| Absorption % after 24 hours wetting .. | 10.1 | 9.84 | 9.90 | 13.60 | 11.25 | |
| Absorption % after 5 hours boiling & 24 hours saturation. | 11.23 | 9.90 | 13.30 | | 16.00 | |
| Saturation Coefficient | 0.91 | 0.92 | 0.77 | 0.86 | 0.69 | |
| Percent loss of material after 12 cycles wetting & drying. | 2.40 | 1.30 | 11.89 | 3.66 | 3.83 | |
| Tensile strength in lb. per square inch .. | 49 | 45 | 35 | .. | .. | |

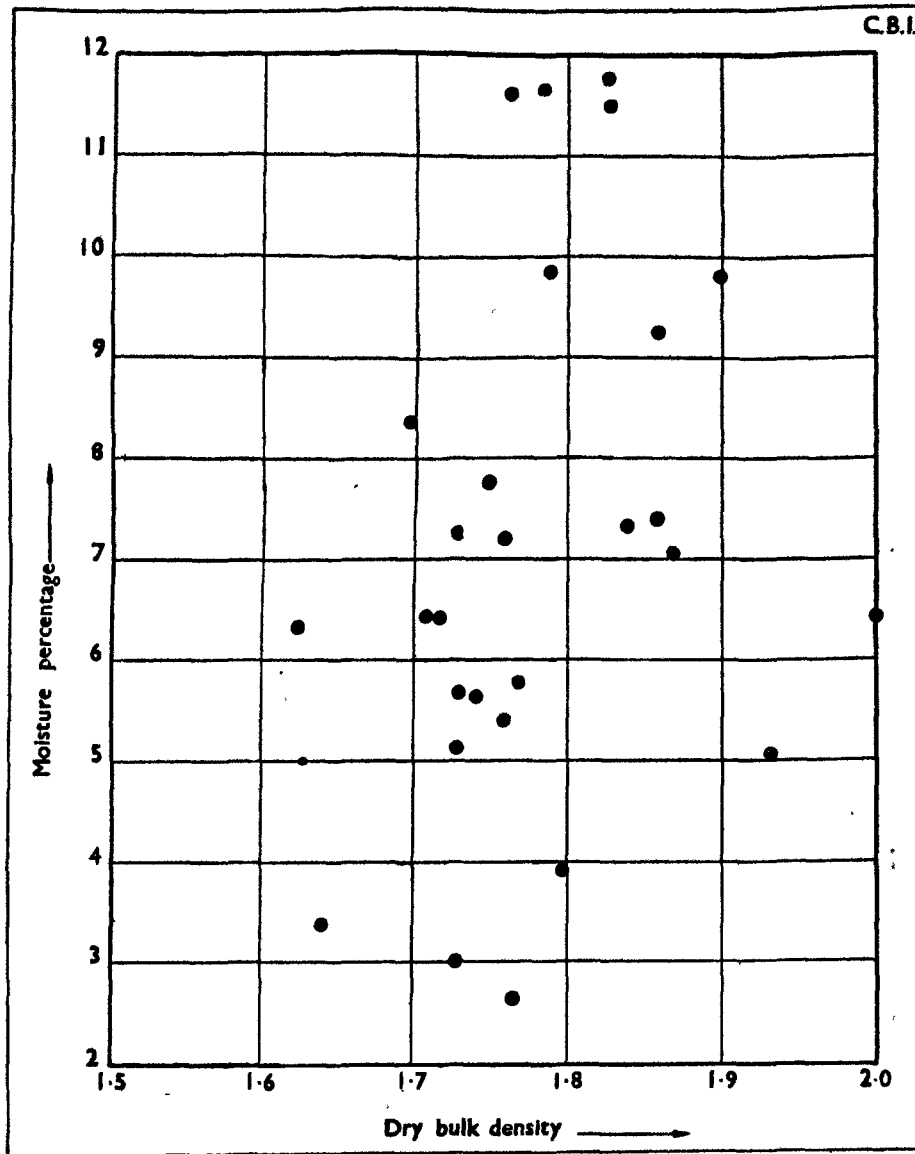


Figure 1E.4:-Showing relation between dry-bulk density and moisture content

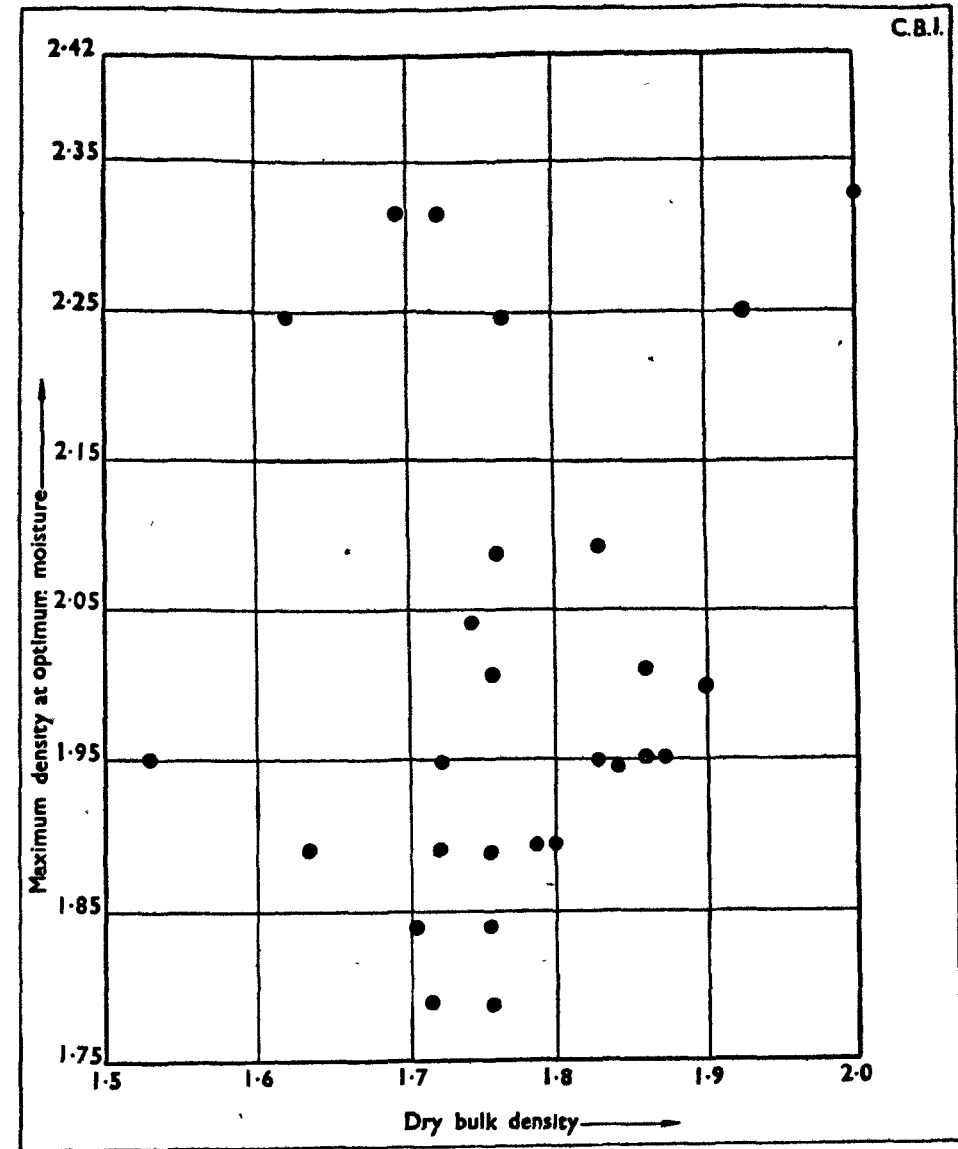
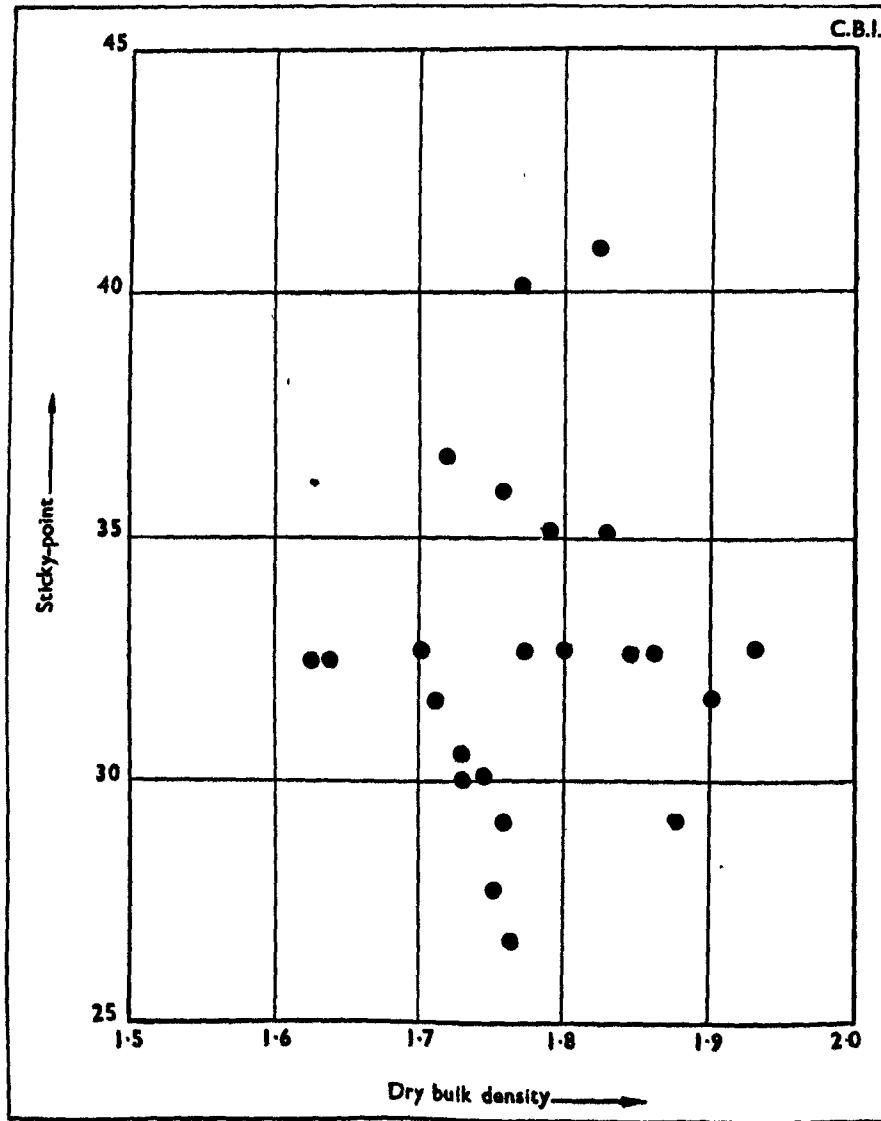


Figure 1E.5:-Showing relation between maximum density at optimum moisture and dry-bulk density



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Figure I.E.6:- Showing relation between dry-bulk density and sticky-point

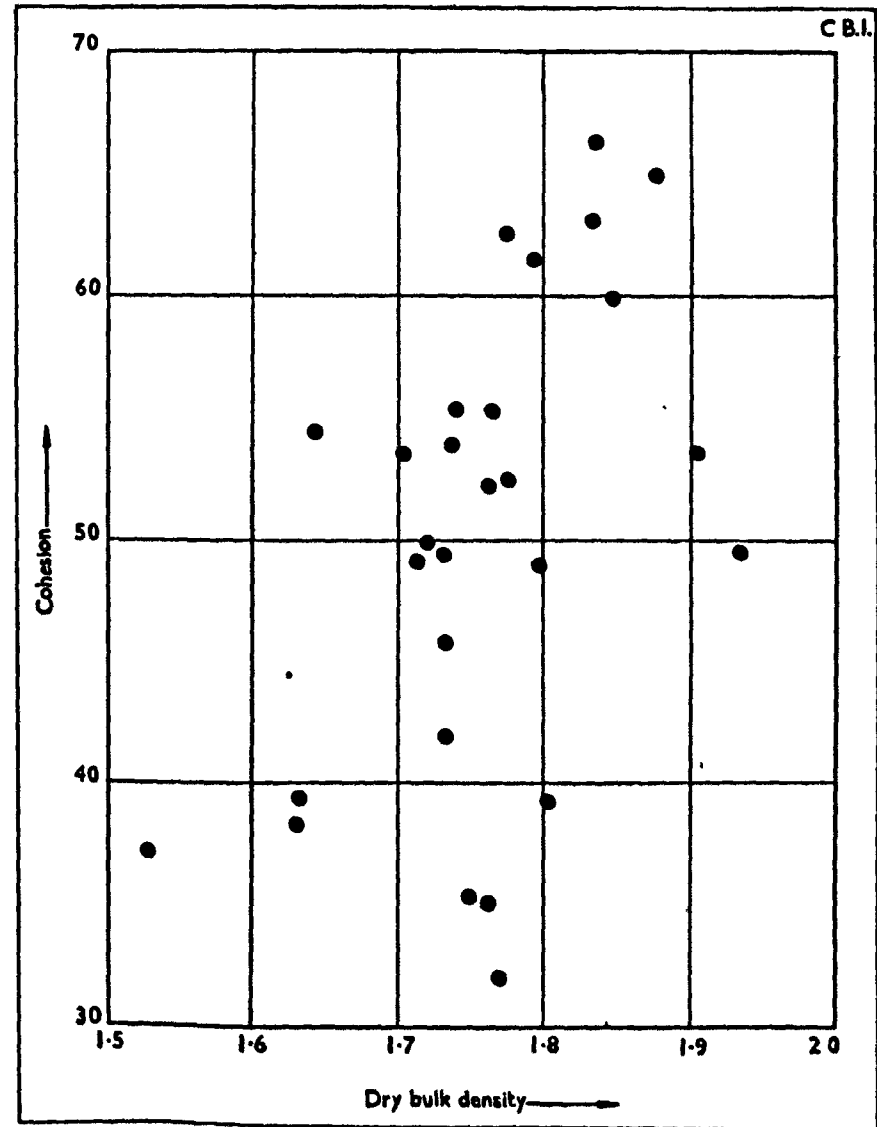


Figure I.E.7:- Showing relation between dry-bulk density and cohesion

(4) HARDNESS OF THE SOIL CRUST (4)

It is well known that each soil has a particular hardness as indicated by the dry bulk density. The results of field measurements conducted upon soils *in situ* reflect significant physical effects as manifested by other physical properties. It was considered of interest to investigate whether any correlation existed between the dry bulk density and other physical constants.

Soil samples were taken from various drains to an average depth of 1.5 feet. The dry bulk densities and the original moisture content of the soils were determined at site, and the other constants were examined in the laboratory.

To facilitate comparison the results of analysis have been represented graphically. The values of moisture content, maximum density at optimum moisture content, sticky point and cohesion have been plotted against the dry bulk density figures separately in Figures 1E.4 to 1E.7.

The results of the statistical analysis are given in Table IE. II.

TABLE IE.II

Correlations between dry bulk density and certain soil characteristics

| Serial No. | Soil Characteristic | No. of observations | Correlation coefficient with dry bulk Density |
|------------|--|---------------------|---|
| 1 | Maximum density at optimum moisture content. | 28 | +0.2748 (insignificant). |
| 2 | Original moisture content | 28 | +0.2601 (Insignificant). |
| 3 | Sticky Point | 28 | +0.4781 (Significant). |
| 4 | Cohesion | 28 | +0.6195 (Significant). |

The following conclusions were obtained from this study :—

(1) The correlations of dry bulk density with maximum density at optimum moisture content and original moisture content though insignificant were positive, *i.e.* the greater the dry bulk density the greater the maximum density at optimum moisture content and the original moisture content of the soil.

(2) There were significant and positive correlations between the dry bulk density and sticky point and cohesion. This showed that high dry bulk density was associated with high sticky point and cohesion.

(4) East Punjab Irrigation Research Institute, Amritsar, Annual Report 1947, page 64.

(5) COMPARATIVE STUDY OF SOIL SAMPLES FROM (i) SANTA CRUZ AIR FIELD (KONKAN ZONE WEST OF GHATS) NEAR BOMBAY, AND (ii) GANGAPUR STORAGE (TRANSITION ZONE EAST OF GHATS) NEAR NASIK (5)

Properties of the two sets of samples from Nasik and Santa Cruz are compared and distinctive features from soil mechanics tests are out lined.

(6) ECONOMICAL LIMIT OF ROLLING BY SHEEP'S FOOT ROLLERS (6)

Soil compaction is controlled first by determining the optimum moisture necessary for the maximum compaction. It has then to be consolidated in layers. Experiments were conducted to find out how the compacted depth of soil decreases with the number of rollings. For this purpose a concrete channel 8 inches wide and 6 inches depth was cast. Soil with optimum moisture content was placed on it to a depth of $2\frac{5}{8}$ inches. Sheep's foot roller 8 inches in length and 4 inches in diameter with frogs 1 inch by 1 inch by $\frac{1}{8}$ inch cast on it was rolled without applying any pressure on it. By its own weight it exerted a pressure of 3.6 lb. per square inch.

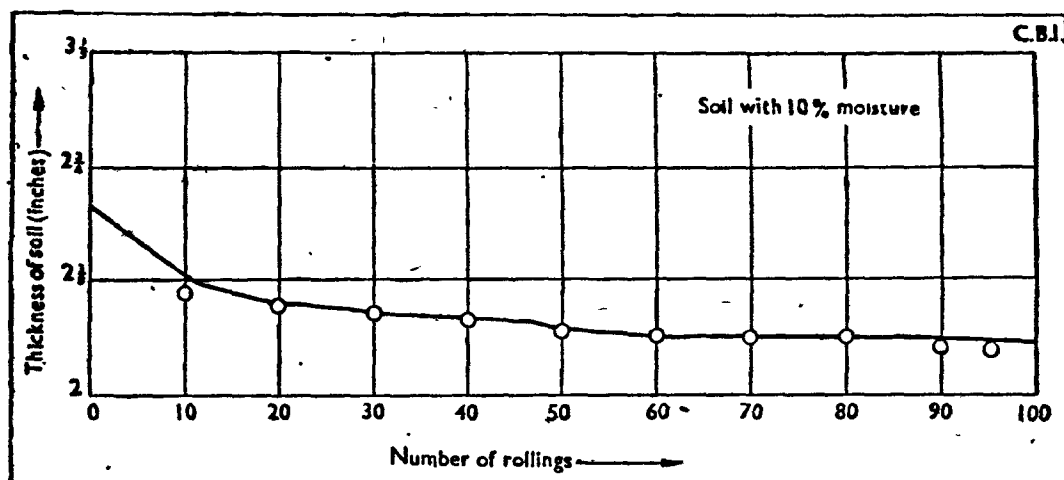


Figure 1 E. 8: Graph showing consolidation test with Sheep's Foot Roller.

It is seen from Figure 1E.8 that the first ten rollings will consolidate the soil 50% more than the next eighty five rollings. It is therefore, desirable to determine the economical limit of rolling for a moisture content and insist on the same thickness and number of rollings throughout the consolidation.

(5) Poona Irrigation and Research Division Poona, Public Works Departments Bombay, Annual Report 1947, pages 32-37.

(6) Hyderabad Research Station Krishnarajasagar Annual Report 1947 page 84.

DISCUSSION BY THE RESEARCH COMMITTEE

MR. L. K. MITTAL introduced items (1) and (2).

In the absence of Mr. Hardikar, item (3) was taken as introduced.

DR. C. L. DHAWAN introducing item (4) said that there was a significant and positive correlation between the dry-bulk density and sticky-point and cohesion. On the determination of partial-co-efficient it was concluded that the dry-bulk density was independent of the sticky-point and depended upon cohesion only.

DR. V. K. GOKHALE introducing item (5) gave a short description of the experiments carried out and said that in the case of samples from the Santa Cruz Airfield, the clay content was ten per cent. and in that from Gangapur it was 15 per cent. The most interesting observation was that the range of optimum moisture in case of the Santa Cruz varied from 16 to 24 per cent. only with 25 cracks whereas in the case of Gangapur sample there were numerous cracks with a narrow range at the optimum moisture contents. In the Santa Cruz sample the change in the maximum density was small and thus the danger of shrinkage under the weight even after it got wet, could be avoided with the result that the same could advantageously be used for laying concrete runways.

MR. N. S. GOVINDA RAO introduced item (6).

MR. S. R. MEHRA gave an account of the work done by the permanent committee to review Standardization of Methods for Testing of Soils. He said that the final proof of the 'Directive' was approved and it was expected that printed copies of the same would be available shortly. It had been proposed that the 'Directive' should be given wide publicity and suggestions invited from workers and further that the discussion among members should be carried out by correspondence in-between the meetings. The Committee further felt that as soon as the 'Directive' was issued, there were likely to be a number of enquiries regarding the sources wherefrom the apparatus specified in the 'Directive' was to be obtained. It was, therefore, agreed that the research-organisations should supply names of the firms which manufactured apparatus, to the Central Board of Irrigation and that the information so collected should be sent out to the workers along with printed copies of the 'Directive.'

The Secretary attributed the delay in the printing of the 'Directive' to the difficulties in the press and hoped that the printed copies would be available for distribution by the middle of October.

DR. R. C. HOON drew attention to the work done in the United Provinces on the effect of the addition of Sodium Carbonate to the soil and enquired if the deflocculating action of Sodium Carbonate had been taken into consideration because according to his experience when the soil gets into consideration the sodium soil came into contact with water it completely deflocculated. Dr. Hoon further stated that for the engineering characteristics of Indian soil it might be of advantage to interpret them in terms of the sticky point or plasticity index besides the usual grading and mechanical analysis.

MR. L. K. MITTAL replying to Dr. Hoon said that it was the deflocculating action of the sodium carbonate which was being studied,

DR. V. I. VAIDHIANATHAN said that in his opinion there was no need to deflocculate the soil for compaction, though for the purpose of finding out the sticky point the same might be done.

DR. R.C. HOON said that to compare the properties of soils it was necessary to carry out some tests as the p_H value varied from place to place. Continuing, he said that if p_H value was five to six, the clay content might be of the order of 24 to 25 per cent. In his opinion, it would be absolutely necessary to deflocculate the soil, as without it, it would not be possible to find out the clay content.

MR. L. K. MITTAL drew attention to item (5) and said that clay content by ordinary method of analysis was only 15 per cent. by adding a deflocculating agent to it was 53 per cent. This showed a great difference. So he suggested that only the standard practice should be followed. It was absolutely necessary to add a deflocculating agent if any reliable and accurate results were to be obtained.

RAI BAHADUR KANWAR SAIN said that for mechanical compaction one would like to fix some readily obtainable criterion without depending much on the laboratory. For compaction in the laboratory the exact analysis by deflocculation was beneficial, but from the engineer's point of view a ready method would be more useful.

RAI BAHADUR C. L. HANDA said that in his opinion it was most important, from the practical point of view, to know the moisture content, as engineers were interested to know as quickly as possible what they should do to a soil in order to get the degree of compaction that would be needed for any purpose. He further pointed out that there was a need for such ready gauges as could indicate the treatment that was needed to get the compaction desired.

DR. C. L. DHAWAN explained that the dispersion co-efficient had a direct bearing on the structure of the soil. He laid emphasis on the fact that before adopting any of the American or British practices, it should be found out whether they would suit Indian conditions *i.e.* the particular type of soil and the climate which is met with in India.

SARDAR BAHADUR SARDAR SARUP SINGH said that Dr. Savage had told him about vibrator sets for compaction work which were available in America and that he had placed an order for 4 such machines. They would be better than Sheeps' Foot Rollers.

DR. V. I. VAIDHIANATHAN said that from his experience in the Punjab he had come to the conclusion that a vibrator for compaction was not satisfactory and that a roller could be used as many times as possible for necessary compaction by increasing the number of rollings according to necessity.

DR. K. L. RAO said that he had seen quite a number of American dams being constructed where no vibrators had been used and further pointed out that the cost of a vibrator was easily ten times that of the roller and advised that the view, expressed by Dr. Vaidhianathan should be adopted.

DISCUSSION BY THE BOARD

THE SECRETARY said that six items were discussed at the Research Committee meeting (page 320). There was no resolution. The directive on standards for testing soils as prepared by the Permanent Committee had since been issued and distributed. The resolution passed by the Board at its last meeting was on page 317. In addition to the information given in the Preliminary Note, Bombay Government had instructed the Executive Engineer's (North) to carry out experiments and submit a report on them in due course. Irrigation Research Station, Madras was carrying out experiments and results would be presented next year. Hydraulic Research Station Krishnarajasagar intimated that since stones were available all over the State it was not considered necessary to conduct field experiments on using either concrete or graded soils. U.P. intimated that results had already been reported to the Board as a part of their Annual Report. C.P. stated that in the Province, upstream face of earthen dams was protected by dry stone pitching and there had been no instance where the pitching had not been able to withstand the wave wash and as such no action was taken on the resolution of the Board.

MR. J. C. HARDIKAR said that in Hyderabad State cement concrete revetment for the slopes of earthen tank *bund* had been tried. Unfortunately it had failed due to un-even sinking. He was of opinion that ordinary stone revetment was sufficient to withstand wave-wash.

RAI BAHADUR C. L. HANDA said that his Chief Engineer, Rai Bahadur Garg had approved for experimental purposes, the substitution of soil cement blocks in place of stone for urgent protection works on rivers. On account of the non-availability of stone of suitable size and due to the carriage involved being from 300 or 350 miles, the rate of stone had gone upto 70 or 75 rupees per 100 cubic-feet. Apart from that the East Punjab Railway was so busy with their transportation problem of food and refugees and they had no space for stone.

One problem which required immediate attention was the Beas protection work. There was a system of *bunds* which had stood for many years. But now the Beas showed a tendency of moving towards the main Railway line, about 200 feet from the *bund*. It was almost certain that even if a small flood were to occur this *bund* was likely to breach and likely to interfere with the traffic on main line to Amritsar and the railway line would be threatened. Therefore something had to be done urgently. So experiments were carried out with five per cent. cement soil which was found to have necessary resistance capacity and it was able to give the necessary weight for the aprons as well as the pitching. They did some experiments for the last four or five weeks and felt fairly reassured about these blocks. These blocks could stand a velocity of even 12 feet per second. The economics were also studied and they were able to do this job with 44 to 45 rupees per 100 cubic-feet in place of 75 rupees for stone.

DR. R. C. HOON asked what was the clay content of the soil.

RAI BAHADUR C. L. HANDA said that he was not in a position to say definitely the clay content of soil. They had yet to undertake the tests. But the results of experiments conducted by Mr. Mehra indicated that even 2½ per cent. blocks did not disintegrate in the course of 5 to 10 years. He suggested that a small sub-committee be formed to guide research.

THE SECRETARY asked what was the weight of the proposed blocks.

RAI BAHADUR C. L. HANDA said that the volume of the block was 1.5 cubic feet and the weight would be about 140 lbs.

DR. R. C. HOON recapitulated some work that he did when he was on deputation in the Army. Broadly speaking he divided the alluvial soils on the basis of clay content in three groups—one with clay content below 15 per cent. second 15 to 30 per cent. and the third above 30 per cent. The soils of the first group gave rather good results only with cement above 10 per cent. The next group containing 15 to 30 per cent clay content afforded best stabilization with 10 per cent. cement. In the third group containing 30 per cent. clay it was not economical to use cement for stabilisation. In the case of black cotton soil it was no use mixing cement, while very good stabilisation with water alone was possible with latrite soils. He wished that some further work was done by East Punjab Institute before the limit of cement was finally fixed for soil-cement blocks with soil of the alluvial type. He suggested the carrying out of wetting and drying tests and freezing and thawing tests with stabilized soil-cement blocks because the surface conditions of those blocks alone were not truly indicative of their strength and future behaviour. He showed photographs of briquettes made with soils of different clay content and varying cement contents which showed how those cement soil briquettes behaved, the best were those where the clay content was between 10 to 30 per cent. and when the cement content was 10 per cent. This classification of soil cement stabilisation for roads the Americans had suggested that 10 per cent. cement should be taken for stabilisation. Therefore he thought it worth-while to try that proportion. He also added that good results may be obtained if the sides of the blocks were given a sodium silicate wash. The sodium silicate solution should be of brushing consistency.

MR. S. N. GUPTA said his experience in United Provinces was somewhat different. Soils with 10 per cent. of clay worked very satisfactorily.

DR. N. K. BOSE was of opinion that the difference might be due to difference due to grading. Regular graded soils give very good results. He said that it was important that grading should be taken into account before the soil and cement contents were fixed.

DR. DHAWAN said that he had carried out wetting and drying experiments with these blocks for 12 cycles and they had passed the test. He was of opinion that the Sodium Silicate being alkaline might not be suitable for Punjab soil with 9.5 p_H. The cement and the alkaline chemical would react. He had been doing some experiments to find out a better organic binder. Grading

was a very simple thing. But he asked which was the right grading. Each soil had a different grading. They had to consider not only its physical properties but also its chemical properties. During Research Committee meeting Dr. Ramdas said that he could stabilise black cotton soils with 3 per cent. sodium carbonate, which is in fact the conversion of calcium soil into sodium one.

Replying to Mr. Guha, DR. DHAWAN said that cement stabilisation worked well with *murram* soils.

DR. R. C. HOON agreed with Dr. Bose's remarks that grading had very much to do with the ultimate density of the soil mass. But the pity was that in the Punjab alluvium it was very difficult to have graded soil. That was why he was feeling a bit worried when Rai Bahadur Handa said that they were trying to incorporate boulders in the soil. It might make up for good density but it had a weak point. There was a limit to the size of boulders and one should also see that the grading of the soil mass was maintained.

Regarding Dr. Dhawan's remarks about sodium silicate he only suggested that it was to be a sort of wash just from outside and not actual mixing with the cement. The effect was that sodium silicate would react with the cement layer to form calcium silicate and it would give a hard surface.

He was of the opinion that more than the wetting and drying tests they should carry out freezing and flowing tests because unfortunately in the Punjab the soils contain sodium sulphate and that behaved very badly when the humidity was high and the temperature low. It would be worth while to conduct these tests before the final election.

DR. UPPAL said that regarding providing cover to these blocks for protection he had found that the smallest quantity of cement which would enable the cement plaster to adhere on the blocks was 2.5 per cent.

A sub-committee comprising Rai Bahadur Gita Ram Garg, Rai Bahadur C.L. Handa, Dr. N. K. Bose and Dr. R. C. Hoon was formed to go into the problem.

(ii) Earth Dams and Embankments

PRELIMINARY NOTE

There was no contribution and no discussion under this sub-head at the 1947 Research Committee Meeting.

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The Year's Work.

The following items were discussed at the 1948 Research Committee Meeting —

- (1) Usehat bund.
- (2) Effect of changes in profile of dams founded on pervious foundations^{*}
- (3) Testing of soil samples from Messenjore Dam site.
- (4) Testing of soil samples for Afflux Bund at Tilpara Ghat.
- (5) Testing for earthen dams.
- (6) Experiments with soil samples of Nelligudda reservoir.
- (7) Hydraulic gradients through earth *bunds*.

(1) THE USEHAT BUND (⁷)

Last year stabilised soil blocks 1 foot × 1 foot × 2 inches with cement soil ratios ranging from 1 : 6 to 1 : 14 were placed along the banks below a distributory fall, where the wave action was very pronounced, to test the effect of waves on them. The slabs have been in place more than a year now and have not shown any sign of deterioration.

(2) EFFECT OF CHANGES IN PROFILE OF DAMS FOUNDED ON PREVIOUS FOUNDATION (⁸).

Last year experiments were conducted to study the effect of changes in profile of an earth dam, founded on impervious base, on the position of the line of saturation. This year the experiments have been extended to dams founded on previous foundations. The study has been carried out under the following heads :—

- (a) Effect of flattening of downstream slope,
- (b) Effect of flattening of upstream slope,
- (c) Effect of top width,
- (d) Effect of berms on the downstream slope.

⁽⁷⁾ United Provinces Irrigation Research Station Report on Research Progress during 1947 pages 107-108.

⁽⁸⁾ *Ibid*, pages 108—110.

(A) EFFECT OF FLATTENING DOWNSTREAM SLOPE

Models of dams with different downstream slopes and constant upstream slopes of 3 : 1 were constructed in a chamber with glass face as usual. Figure 1E.9 shows that the line of saturation gets lowered and flattened with flattening of downstream slopes. Curve A of Figure 1E.10 shows the lowering of the discharge point with respect to the percentage increase in earth work.

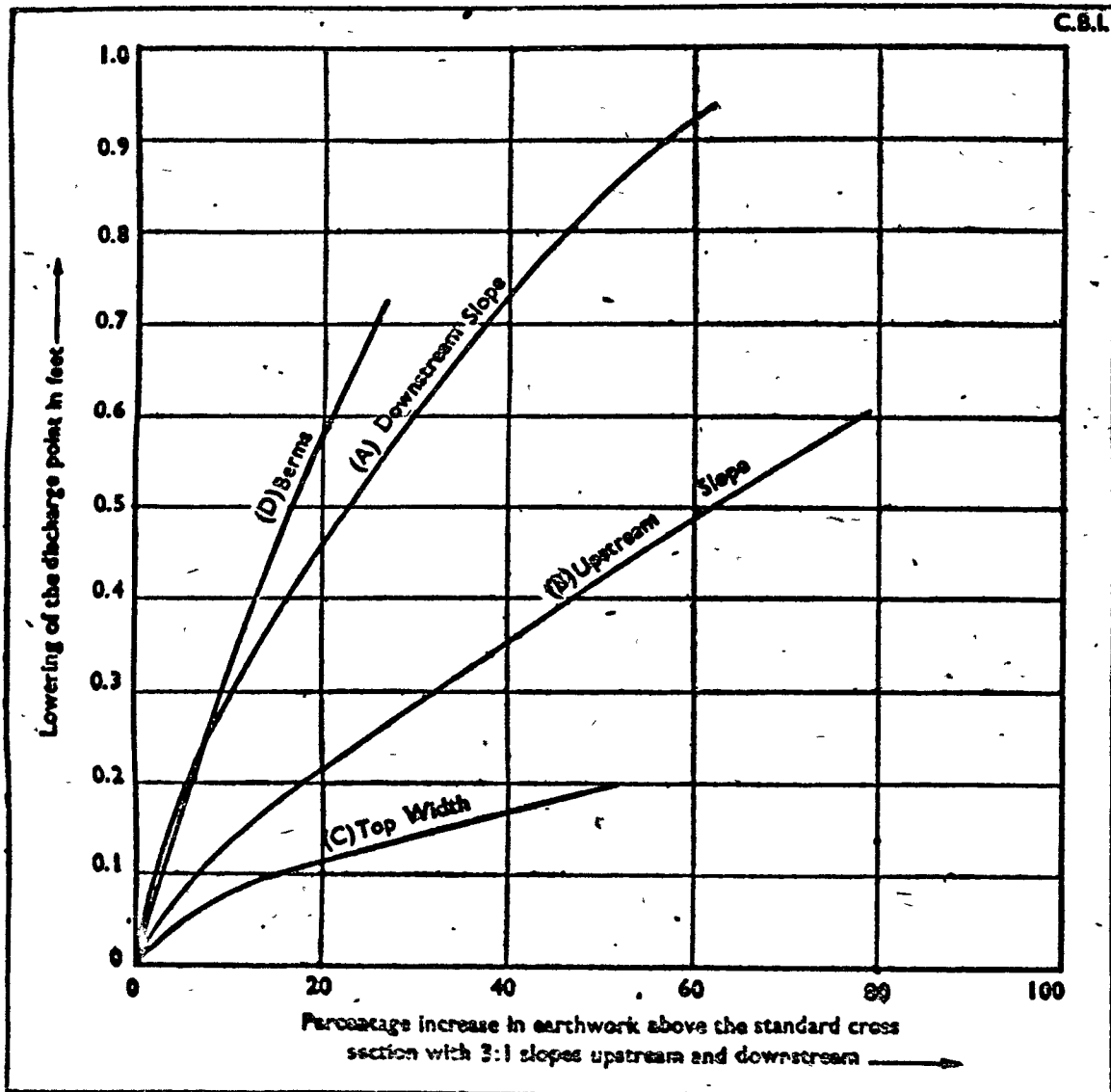


Figure 1E.10: Showing relation between earth work of the dam and lowering of the discharge point under the effect of (A) downstream slope (B) flattening of the upstream slope (C) top width and (D) berms on the downstream slope.

(B) EFFECT OF FLATTENING UPSTREAM SLOPE

Figure 1E.11 shows the lowering in the line of saturation with flattening of downstream slope. Curve B of Figure 1E.12 shows lowering of the discharge point with respect to the percentage increase in earth work.

(C) EFFECT OF TOP WIDTH

Figure 1E.12 shows the lowering of the line of saturation due to increase in top width. Curve C of Figure 1E-10 shows the lowering of the discharge point with respect to the percentage increase in earth work.

(D) EFFECT OF BERMS DOWNSTREAM

Experiments have been conducted with no berms and with one, two and three berms on the downstream side using the standard section with 3:1, both upstream and downstream slopes *vide* Figure 1E.13.

Curve D of Figure 1E.10 shows the lowering of the discharge point with respect to the percentage increase in earth work.

CONCLUSIONS

1. Results on the measures to be adopted for lowering the discharge point downstream with respect to earth work involved with permeable and impermeable base are fairly similar.
2. The most economical device for lowering the saturation line is again the addition of berms to the downstream slopes.
3. Flattening of downstream slopes is the next most economical device.

RELATION BETWEEN THE SIZE OF THE GRAVEL TOE AND ELEMENTS OF PROFILE

In order to find a suitable size of the filter toe which will prevent the line of saturation from appearing on downstream slope, above the toe, for a particular dam section founded on impermeable base, experiments were conducted with:—

- (1) Different downstream Slopes,
- (2) Different upstream Slopes,
- (3) Different Top Widths

1. *Effect of downstream slopes*—Slopes 1 : 1, 2 : 1, 3 : 1, 4 : 1 and 5 : 1 were tried and the minimum size of the gravel toe of shape, having its one slope the same as the downstream slope of the

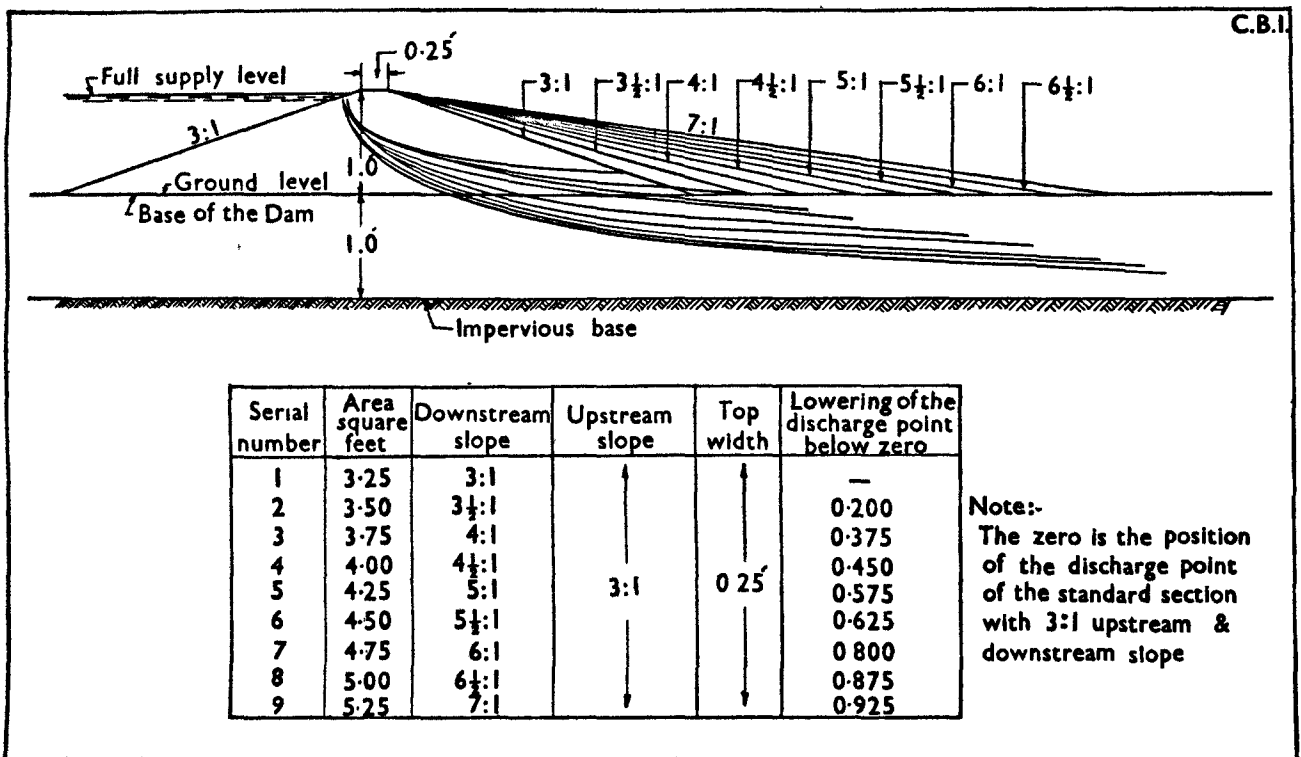


Figure I.E.9:-Effect of downstream slope on the line of saturation (Earth Dam with porous base)

Scale 1 5 0 1 2 3 4 Feet

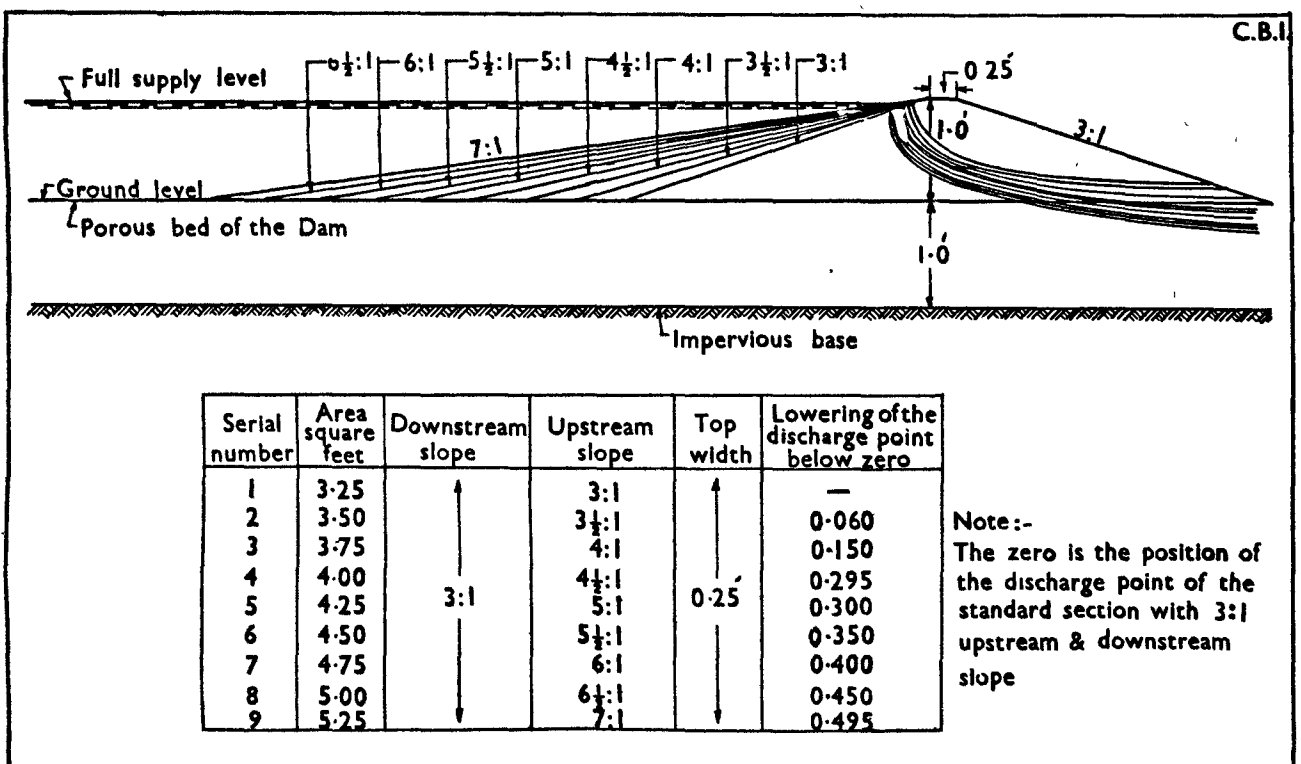


Figure I.E.11:-Effect of upstream slope on the line of saturation (Earth Dam with porous bed)

Scale 1 5 0 1 2 3 4 Feet

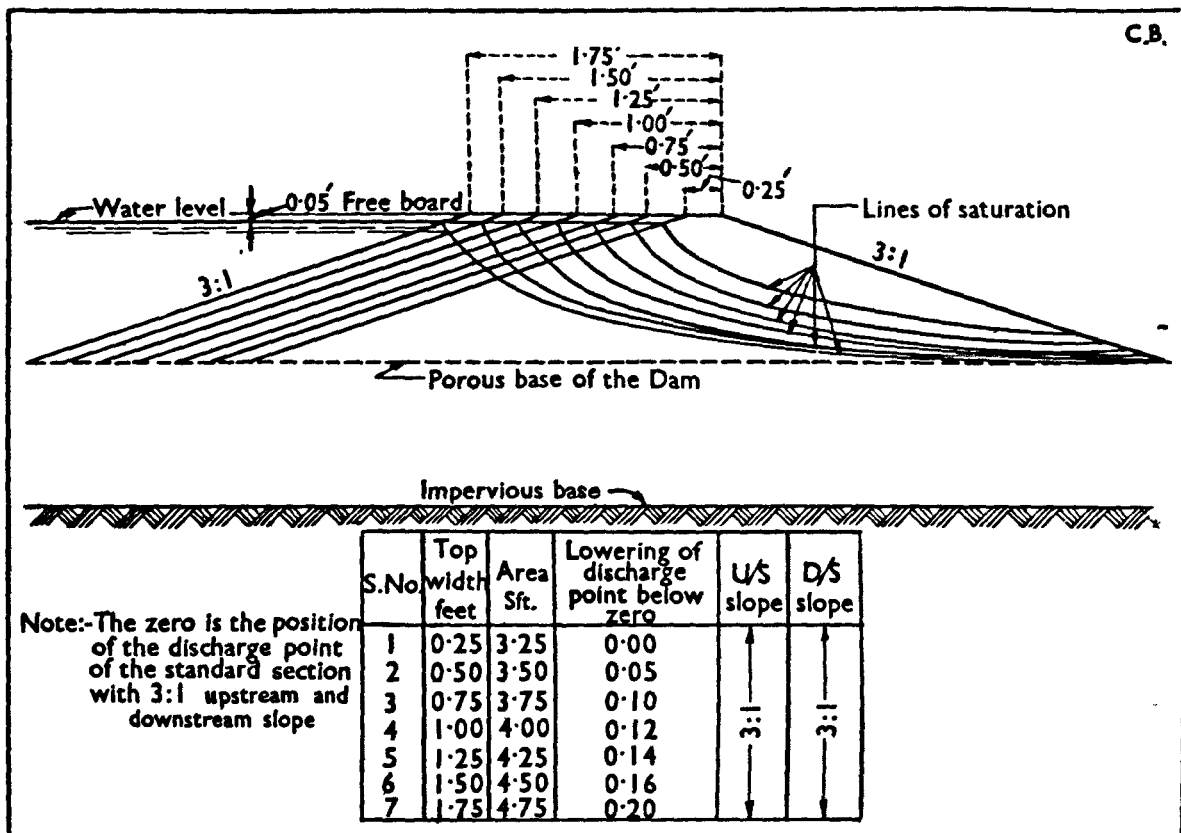


Figure 1E.12:- Showing effect of top width on the line of saturation (Earth dam with porous base)

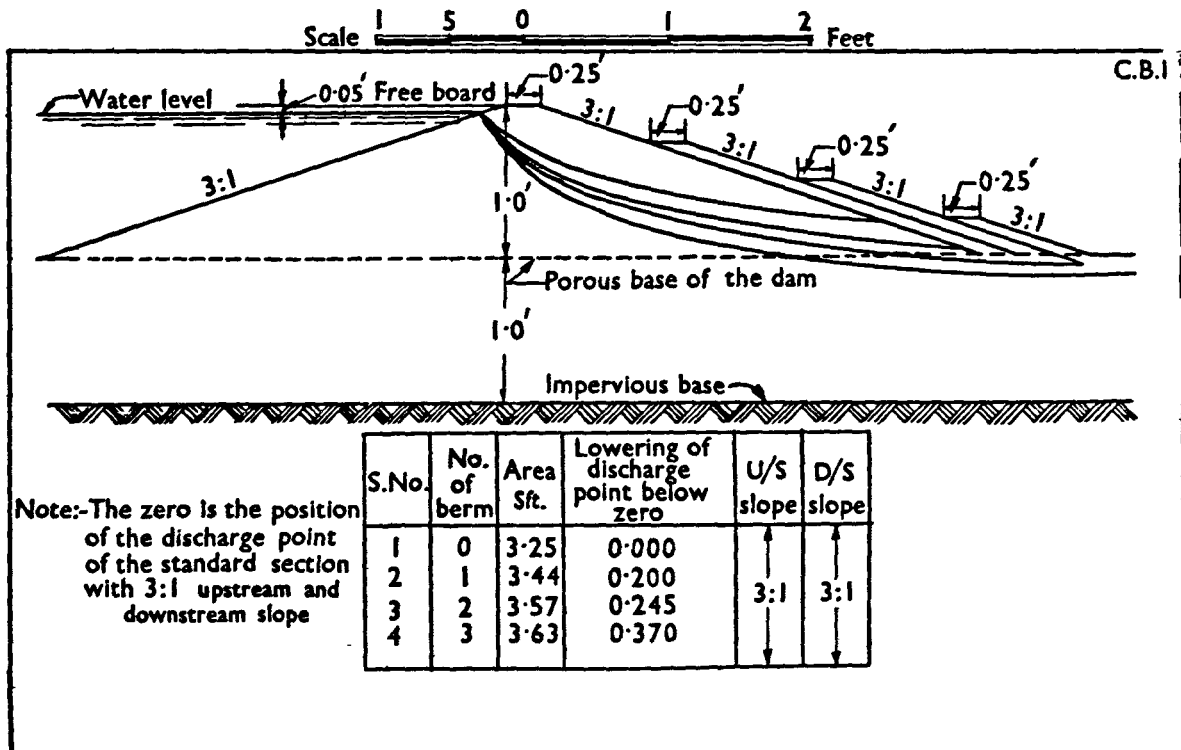


Figure 1E.13:- Showing effect of berm on the line of saturation (Earth dam with porous base)

dam and the other at 1 : 1, was determined by model experiments. The results are shown in Figure 1E.14. The ratio $\frac{h}{H}$ as shown on the curve gives us the size of the gravel toe in terms of the height of the dam.

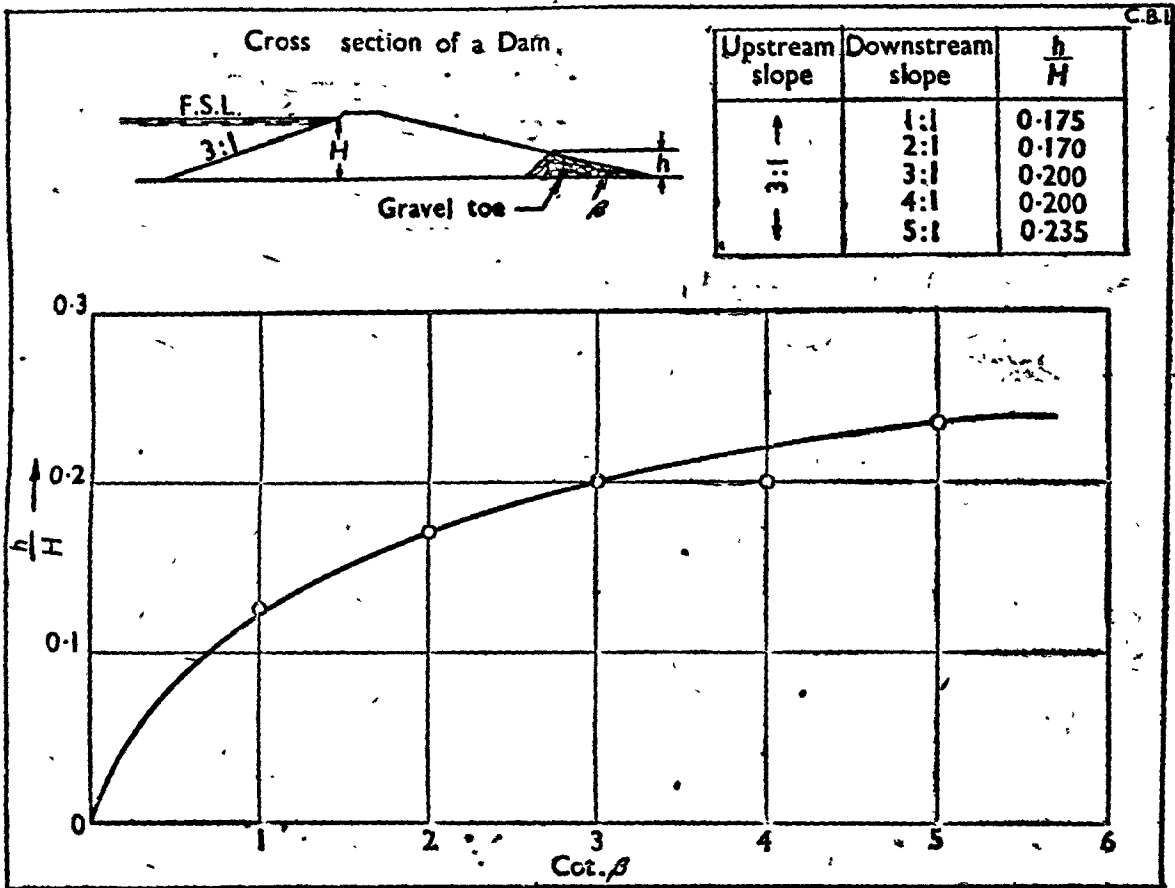


Figure 1E.14 : Showing relation between the size of the gravels and downstream slope.

2. *Effect of upstream Slope.*—By changing upstream slope, there was no significant effect on the size of the toe. The reason is clear from the fact that upstream slope has a much smaller effect on the line of saturation.

3. *Effect of top width.*—In this case also, there is no effect for the same reason that a change in the top width does not affect the line of saturation to a very great extent.

CONCLUSION

The requirement of a gravel toe is guided by the downstream slope of the dam only, and its size can be known from the curve of Figure 1-E 14 which of course applies to this type of toe only, and curves will have to be drawn for other types of toes.

(3) TESTING OF SOIL SAMPLES FROM MESSENGORE DAM SITE (9)

In connection with the Mor Project a dam was proposed to be constructed on the river Mor at Messenjore near Dumka in Santal Perganas, Bihar. Disturbed samples of soil were collected from the locality of the proposed dam to test the suitability of the soil for the construction of an earthen dam. These samples were sent to the Soil Mechanics Laboratory of this Institute for tests. 102 samples were received last year (1946) and were tested. During this year another 300 samples were collected and sent for examination. These samples were dug from pits in successive depths of the profile and were collected separately in gunny bags and transported to this laboratory. The following exploratory tests on each sample were carried out : (1) Mechanical Analysis (2) Specific Gravity and Apparent Density, (3) Porosity and Void Ratio (4) Compaction and Penetration Resistance and (5) Shear.

(4) TESTING OF SOIL SAMPLES FOR AFFLUX BUND AT TILPARA GHAT (10)

At Tilparaghat where the Mor Barrage is being constructed the afflux *bund* was proposed to be put up. Samples from this afflux *bund* were sent from More Construction Division No. III for Mechanical Analysis, Compaction and Penetration resistance, Porosity and Void Ratio, Specific Gravity, Apparent Density and Shear Tests.

(5) TESTING FOR EARTHEN DAMS (11)**WOHAR EARTHEN DAM**

Some sixteen selected samples of soils were received for recommendation of suitable material for the construction of Wohar Earthen Dam near Aurangabad. Grading of the sixteen samples was determined by mechanical analysis.

ARJANPATLA EARTHEN DAM

Eight samples from soils available for breach filling of Arjanpatla earthen dam were sent for analysis. Soils 1 to 6 were of gravelly character called "*Morum*" locally, soil 7 was clayey meant for admixture with "*Morum*" or for use as a hearting material Mechanical. Analysis of the samples sent was conducted.

GAGILLAPUR EARTHEN DAM

Seven samples of soils to be used for restoration of Gagillapur tank were sent for the necessary recommendations. Mechanical Analysis for the samples sent was carried out.

MADIRAM EARTHEN DAM

Six samples from soils to be used for Madiram tank were received for analysis. The grading of these samples was obtained.

(9) River Research Institute West Bengal, Annual Report 1947, pages 105-143.

(10) River Research Institute West Bengal, Annual Report 1947, page 144.

(11) Hyderabad Engineerin Research Laboratories, Annual Report 1947 pages 30.

(6) EXPERIMENTS WITH SOIL SAMPLES OF NELLIGUDDA RESERVOIR (12)

Nelligudda is situated about a mile away from the 9th mile of Bangalore—Mysore Road, near Bidadi.

Good gravelly earth and puddle clay are available in plenty in the locality. A small tank with an earthen bund is proposed to be constructed here.

The soil samples from the borrow pits were sent to the Hydraulic Research Station, Krishnarajasagar for determining their properties and conducting certain tests.

The following tests were conducted (i) Mechanical analysis, (ii) Specific gravity (iii) Liquid limit, (iv) Plastic limit and plasticity index, (v) Optimum moisture content, and maximum dry density and (vi) Compaction tests.

(7) HYDRAULIC GRADIENTS THROUGH EARTH BUNDS (13)

A glass flume 12 feet by 2 feet by $1\frac{1}{2}$ feet was constructed on an impervious platform. Models of earth bunds of various designs and sections were put up and their lines of saturation were traced. The bunds were 16 inches to 18 inches high with a top width of 6 inches. Potassium permanagnate solution was used to trace the line of saturation. Water level upstream was maintained at a constant level by having an overflow weir and a small auxiliary tank with a tube and a stopcock. A burette was used to feet the solution drop by drop to get a uniform line indicating the hydraulic gradient.

It may be interesting to note here that the hydraulic gradient in a homogeneous earth dam is dependent of the material. It is the quantity of seepage per unit width that varies with the material which in turn depends upon the co-efficient of permeability, K . The value of this is dependent upon the size and grading of the particles, density of the material, temperature of water, and the presence of organic and colloidal matter.

Experiments were conducted to determine (1) the effect of berms and (2) the position and the size of jelly drains on the hydraulic gradient in an earthen bund.

Figures 1.E 15 to 1.E 19 show the sections experimented upon and the results obtained.

It will be seen therefrom, that

(1) The effect of adding berms is to depress the saturation gradient in a bund. It is better to add a number of berms of small widths in preference to a few of large widths.

(2) The effect of jelly drains is to lower the saturation gradient considerably, providing a safe exit for the seepage water. In locating its position, care should be taken to ensure that the velocity of the seepage is not too large to carry away articles of earth with it.

(3) Experiments conducted to determine whether the stone revetment on the front face of the bund creates any loss of head to the entry of the seepage water into the bund indicated that there was not any appreciable loss.

(12) Hydraulic Research Station Krishnarajasagar, Annual Report, 1947, page 69.

(13) Hydraulic Research Station Krishnarajasagar, Annual Report 1947 pages 78-85.

DISCUSSION BY THE RESEARCH COMMITTEE

MR. L. K. MITTAL introduced items (1) and (2). Regarding item (2) he said that the addition of berms and the flattening of the down-stream slope had the maximum effect in lowering the line of saturation.

DR. N. K. BOSE introduced items (3) and (4).

THE PRESIDENT said that item (5) of the Hyderabad Laboratories might be taken as introduced.

MR. GOVINDA RAO introduced items (6) and (7). Regarding item (7) he said that they had very interesting results *i.e.*, the hydraulic gradient in a homogeneous earth dam was independent of material. He further added that the experiment conducted by them had led to the same conclusion as those in U.P. *i. e.* the addition of berm had lowered the line of saturation.

DR. K. L. RAO said that it was very interesting and curious to note that the graphs of the saturation lines of three different provinces were different from each other. For example the U. P. graphs on page 108 were convex ; the Mysore research station had shown them as concave and the Poona Station had shown them both ways. The saturation line was one of the determining factors in engineering and could not be obtained by a model test in the laboratory. The time of test was a very important factor in the determination of saturation lines. According to him the saturation line in an earthen embankment should be concave to start with but after say ten years the saturation line could become convex. Dr. Rao then described diagrammatically the way in which the saturation line affected the various dams in America. Continuing he said that it had been observed in American Dams that the line of saturation was higher than the height of water in the reservoir and that this was of considerable importance.

He further said that the shearing strength of the soil was the most important criterion connected with the slope and the safety of the embankments and that the upstream slope in his opinion should be flatter and not the downstream one. He said that the Bureau of Reclamation had devised a method of analysing the soil which should be adopted in India.

Regarding clay puddling inside the embankment, Dr. Rao said that it was not very suitable because in America they had been using sand-shingle combine for this purpose. He further explained that there was a lot of latitude in the selection of soil for earthen embankments because it was the strength of the material in the shearing that mattered. He was of the opinion that most of the tests which had been carried out in various laboratories were not necessary for the practical engineer. Referring to the investigations carried out in the case of Ramapadasagar he said that Prof. Terzaghi who had gone to Madras in this connection was opposed to the type of investigations which had been carried out. Giving his impressions of the two highest earthen dams 426 feet and 460 feet in height built in America, he said that in both of these the desired density was obtained by proper selection, and by studying the shearing strength, of the material. He concluded by saying that the Central Board of Irrigation should collect all data and literature regarding earthen dams.

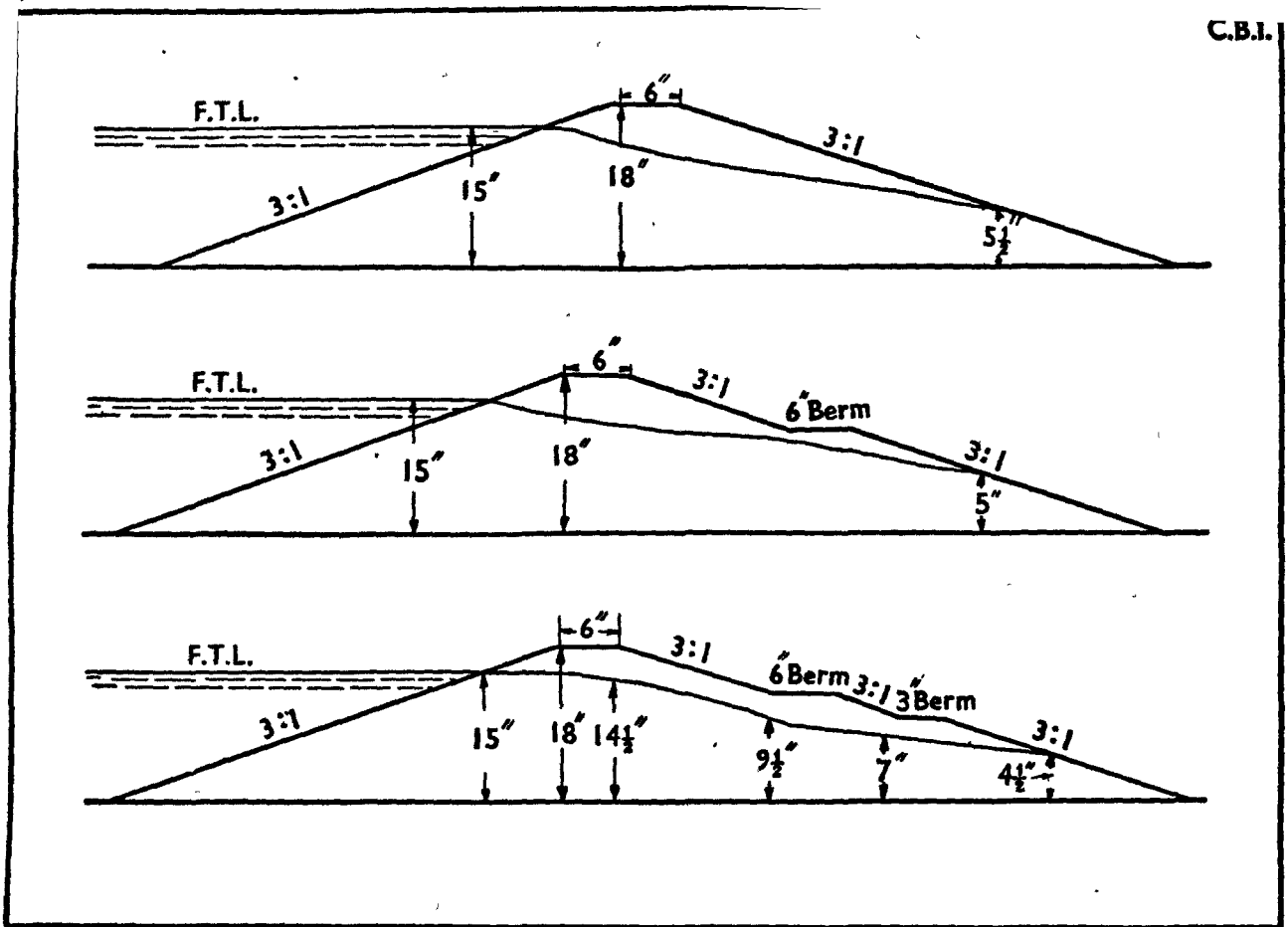


Figure I.E.15:- Showing seepage through earthen bunds

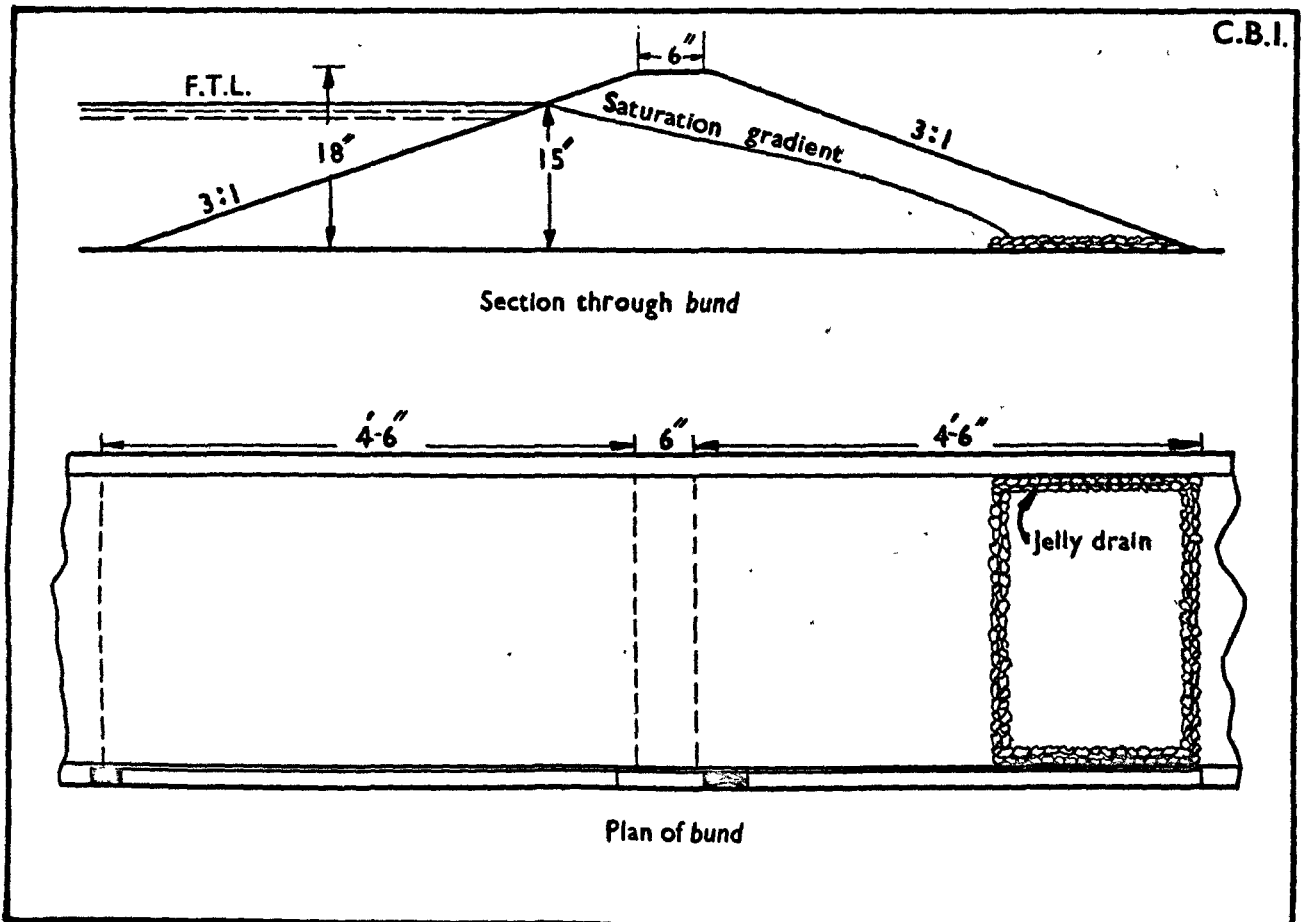


Figure I.E.16:- Showing seepage through earthen bunds

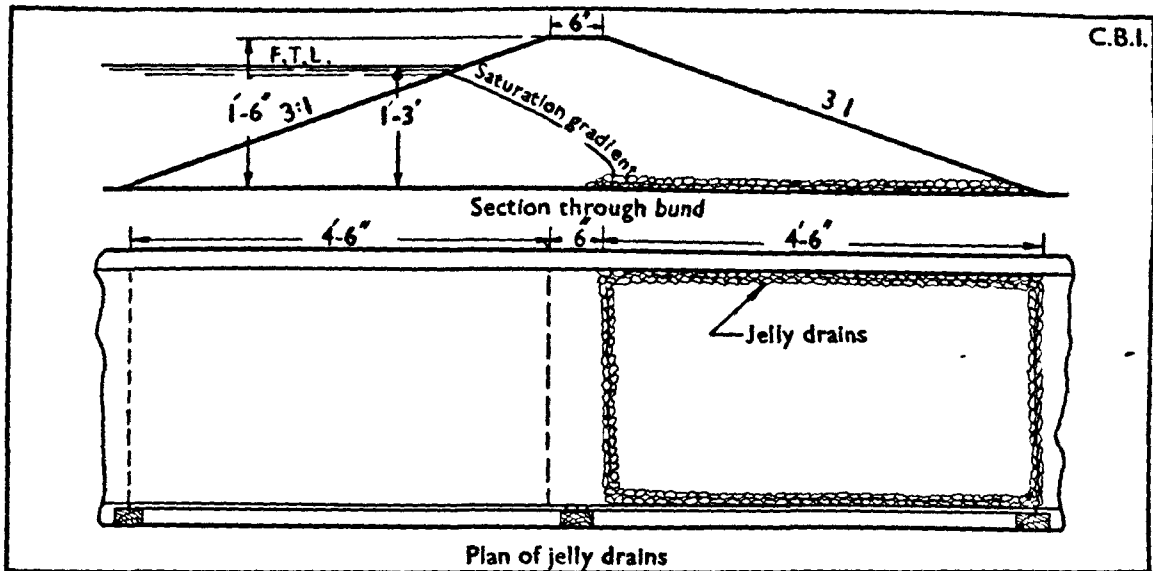


Figure E.17:- Showing seepage through earthen bunds

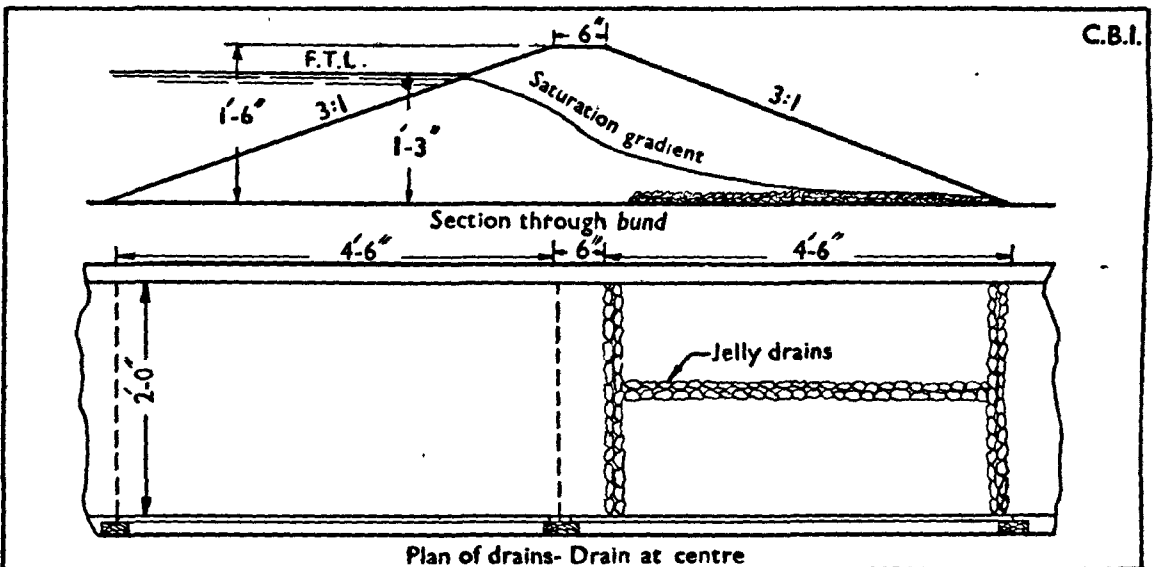


Figure E.18:- Showing seepage through earthen bunds

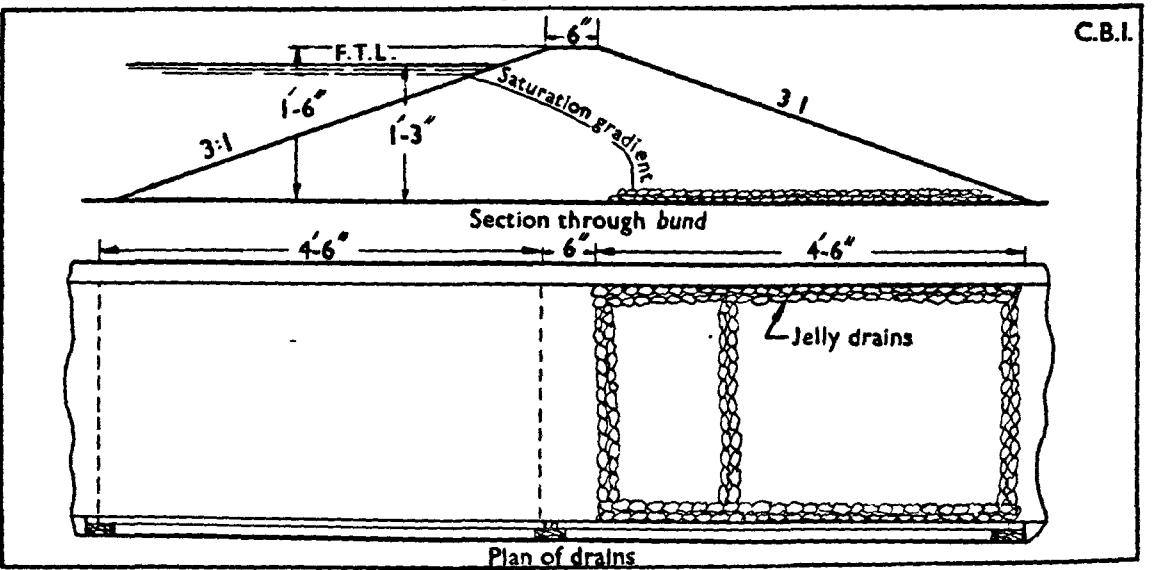


Figure E.19:- Showing seepage through earthen bunds

RAO BAHADUR A.R. VENKATACHARYA said that he had a problem in hand in connection with the construction of Bhawani Project. The dam was $1\frac{1}{2}$ to 2 miles in length. On preliminary investigations they had found that the soil was not suitable for the earthen embankment. On further investigation they had come to the conclusion that the soil round about would make an ideal embankment and was most effective from the point of view of percolation.

Referring to the Bhawani Project MR. KUTTIAMMU said that he had carried out experiments on the soil which were not yet concluded. He said that the basis of these experiments was to start with a fully pervious bank and by trying different materials on the sides of the channel in each case the quantity of water seeping through the bank was noted. A curve showing the percolation of material was drawn and they were then in a position to understand the optimum moisture required.

DR. V.I. VAIDHIANATHAN said that earthen dams had been constructed in India for the last thousand years.

The facts regarding the saturation line were discussed at the Research Committee about three years ago and it was then pointed out that what they were doing in this respect was not very correct from the point of view of measuring capillary pressures. However he did not agree with Dr. Rao's contention that all that was wanted in the soil was the sheer strength test alone. In his opinion experiments carried out for finding the sheer strength and sheer compaction would no doubt give good results which could be useful in the construction of dams, but they had to be supplemented with other tests.

MR. GOVINDA RAO said that he had carried out basic experiments to study the effect of hydraulic gradient, on permeable foundation. The foundations were all concrete, and the soil chosen was pure sand. The hydraulic gradient was found to be independent of the material. There was a certain relation between the dissipation and the hydraulic gradient. He held out that the fact that capillary pressure had not been taken into account should not matter much. Regarding remarks of Dr. Rao that the Indian practice of soil tests was wrong and the American practice was right, he differed from him. In India there were also earthen dams, one 180 feet in Bombay and another 120 feet high in Mysore and about 2,000 earthen tanks which had been constructed for the last 1,000 years. He said that one should be cautious before taking up the American practice and diverting from the practice which had been followed so far.

MR. T. P. KUTTIAMMU said that in the U. P. experiments it had been stated that they had permeable foundations, whereas in Mysore for the same experiments, they had used an impermeable base. There was no indication of any control of water level downstream. It was unfortunate omission. He suggested that some of the experiments might be repeated with proper controls.

DR. V. K. GOKHALE referring to the question of curves which he had drawn for a number of dams constructed of black cotton soil in the Deccan said that the saturation line had a tendency to be concave after the dam had been in operation for a number of years.

MR. S. L. MALHOTRA said that on almost all the canal embankments in the Punjab they had been using clay puddle and it had been found that clay puddle

core was really very effective and the seepage from the canals was stopped. In the Punjab a slope of 3 to 1 towards the water side and 2 to 1 on the outside had been adopted in embankments. As regards the use of vibrator for compaction, he said that due to labour trouble their use would be useful and economical.

MR. R. R. HANDA suggested that those engineers who were to go abroad for training should be asked first to go round the works in India for a certain period to see what had been done and what was being done in regard to engineering works at home.

THE PRESIDENT remarked that the discussion had been very interesting and that the truth was neither with Dr. Rao nor with Mr. Malhotra but was somewhere mid-way. He stressed that traditions should not be followed blindly but that advance should be made as a result of experience gained. As large works had been carried out both in America and elsewhere, one had, no doubt, to learn a lot from them, but he sounded a note of warning against always seeking inspiration from abroad when this could more profitably be done from the large scale enterprises in India. He was painfully conscious of the general tendency on the part of engineers, scientists, administrators and other workers in India to quote foreign names for references in the sub-conscious belief that in that way their ideas would sell better. They felt shy of acknowledging the work of their own countrymen thus attaching to them by implication, a stigma of inferiority. That resulted in two fold damage, firstly in keeping from the world a true appreciation of the knowledge and practice developed in India and secondly in engendering a recurring sense of inferiority. He emphasised that it was high time for them to throw off that slavish mentality.

The President stressed the need for original thinking and deprecated the practice of blind adherence to certain utterances and theories propounded by some one, who, in the estimation of a group or groups, may, for the time being, be designated as a genius. They should scrupulously guard against the habit of edifying the unknown and the foreign, otherwise their own intellectual growth would permanently remain stunted and their achievements would be but a pale reflection of those whom they meant blindly to follow. He wanted them to take the maximum advantage of latest developments in theory research and practice of other countries, but at the same time to take the most vigorous steps to work on original lines so as to be able to contribute their share towards knowledge. There should be two-way traffic of knowledge and experience and their aim should be to give at least as much to the outside world as they took from them.

He next referred to the high earth dams in America, particularly the Anderson Ranch Dam and stated that earth dams had a great future for them in India.

The President said that observations made on saturation lines required very careful examination. The observations in the laboratory, no doubt, were of utmost importance but he stressed the necessity of checking them against field condition. The real purpose of the laboratory research was to give something simple to understand and simple to apply with certainly as to results.

DISCUSSION BY THE BOARD

THE SECRETARY said that seven items were discussed at the Research Committee meeting (page 323). There was no resolution.

MR. MITRA said that he wanted to get a certain problem solved with the help of the assembly. He had to raise the water level in a canal by about 10 feet and consequently the bank had to be raised by the same amount. There was an existing spoil bank nearly 100 years old of the requisite height. He wanted to know whether he could use the spoil bank as it was or should strengthen it, or cut it and build a pucca bund.

DR. N. K. BOSE said that a similar thing was done in Ceylon and it had stood well.

MR. T. MYLVAGANAM said that they took out undisturbed soil samples from the old bank and tested for compaction *etc.*

RAI BAHADUR S. K. GUHA suggested putting a two to three feet puddle core in the middle of the spoil bank.

THE SECRETARY suggested building an additional bank in front.

(iii) Roads and runways-

PRELIMINARY NOTE

There was no contribution and no discussion under this sub-head at the 1947 meeting of the Research Committee.

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THE YEAR'S WORK

The following items were discussed at the 1948 Research Committee Meeting:—

- (1) Soil stabilisation of proposed second runway at Calcutta Air Port.
- (2) Stabilised soil roads.
- (3) Standardisation of specifications of earth roads under Punjab conditions.

(1) SOIL STABILISATION OF PROPOSED SECOND RUNWAY AT CALCUTTA AIR PORT ⁽¹⁴⁾

The modern technique of processing naturally occurring soils which would stand air traffic load without any yield or settlement has been the subject matter of investigation by the soil investigation and survey section of this Institute. A runway other than the existing one has been proposed to be constructed at the Dum Dum Air Port, Calcutta, utilising soil stabilisation method. With this end in view attempts have been made to find out by laboratory and field experiments on scientific lines, if soil stabilisation can lead to desired ends namely, attainment of both mechanical and moisture stability of local soil material at a comparatively low cost, which in its turn would be strong enough to stand the applied loading without detrimental deformations or actual failures.

⁽¹⁴⁾ River Research Institute West Bengal, Annual Report, 1947, pages, 1451—56.

(2) STABILISED SOIL ROADS ⁽¹⁵⁾

A preliminary experiment for the improvement of road berms was conducted on a 100 feet long and a 10 feet wide strip of a berm on Habeebnagar cement concrete road in the Hyderabad City. Berm of a busy road in city area with an approximate traffic of 750 tons per day (over the berm) was selected to get quick results by an accelerated effect of traffic.

The subgrade soil was tested for determining its suitability as a base material and it was found to have a grading conforming to the specifications for stabilised base course (A. S. T. M. type C.) with liquid limit of 21.0 and plasticity index of 3.6. As this subgrade soil was found to be suitable for use as a stabilised base course a six inches base of this soil was constructed by rolling the soil in two layers by a six ton tandem roller for getting a density of 126 lb. per cubic foot at O. M. C. of 9.0.

A gravelly soil in the vicinity with high percentage of coarser particles and with a liquid limit of 21.8 and a plasticity index of 6.4 was selected for use as a stabilised wearing course. The selected soil was found suitable for mechanical stabilisation and could be compacted at a density of 136 lbs. per cubic foot at O. M. C. of 10.2, but as it was desirable to study also the effect of cement on this soil 75 feet out of the proposed 100 feet length of stabilised two inches wearing course was cement stabilised with an admixture of 8 per cent. cement.

The work was conducted with modern earth moving machinery as far as possible. Excavation of eight inches deep foundations were made by a motor grader with roter attachment. Uniform mixture of water needed and breaking of soil was done by shoring and spreading of soils by suitable tilts of the motor grader. The cement mixing for the wearing course was done by a concrete mixer. Compaction was made by a six ton tandem roller (as sheep's foot rollers were not available and the compaction control was made by burning the wet soil with alcohol and by the sand bottle method.

The work was carried out in July 1947 and since then nearly 750 tons of traffic per day has been estimated on the berm by a census taken for about a week. The base is quite intact but the wearing course of the experimental bit has worn out after about 8 months of traffic of the above intensity. A monthly record of the behaviour of the road under traffic was maintained and the following conclusions have been drawn from the experiment.

1. The gravel percentage (16 per cent.) in the selected soil for the wearing course is not enough for providing sufficient abrasive resistance and unless a higher percentage of gravel is added the wearing course with or without cement will not possess sufficient abrasive resistance against traffic.

2. As the road behaved well in the rainy season but became dusty in the dry weather, the selected plasticity index of 6.4 (which is well within the limit of four to nine as recommended by U. S. Public Roads Administration for American climate) is not sufficient for retaining moisture adhesive films in the dry weather of Hyderabad. A higher plasticity index of say nine or above is proposed to be used in future experiments.

⁽¹⁵⁾ Hyderabad Engineering Research Laboratories, Annual Report 1947, pages 45-46.

3. The use of cement as stabiliser with soils of a low plasticity index or with low clay content disintegrates readily under traffic, forming dust in dry weather. This is probably, because, due to lack of necessary clay percentage, adhesive moisture films for the necessary stability in dry weather are not formed. The plasticity of the soil used (P. I. = 6.4) for cement admixture was not sufficient for the dry climate of Hyderabad and hence the soil cement wearing course failed under traffic forming dust in the dry weather. This observation conforms to the results arrived at by the Military Soils Engineering Station of the Indian Army from their experience of Soil-cement constructions in the Indian climate during the last war (*vide* notes on Soil Engineering Testing by O. C. Soils Engineering Station 1945. Page 21). Future experiments on soil cement wearing course are proposed to be carried out on soils with a higher plasticity index.

4. Stabilised Soil open wearing course (with or without cement) may not be suitable for the intensity of traffic of the experiment (750 tons per day) unless a flexible surface protective carpet is provided.

(3) STANDARDISATION OF SPECIFICATIONS OF EARTH ROADS UNDER PUNJAB CONDITIONS⁽¹⁶⁾

The study concerned itself with the investigations of the specifications for surface course of the earth roads under Punjab conditions.

Soil samples were taken from the good, poor and bad roads and analysed for the different soil constants.

A perusal of the actual data revealed that the standard American specifications for materials for stabilized surface course could not apply to our conditions. The standard specifications for materials for stabilized surface course M 61-38, of the A.A.S.H.O., require that the dust ratio shall not exceed 2/3 and that the fractions passing the No. 40 sieve shall have a liquid limit not greater than 35 and a plasticity index not less than four and not greater than nine.

The result of the investigations brought out the standard specifications for the earth roads under Punjab conditions, given in Table IE III.

TABLE IE. III

| Serial No. | Name of the characteristic | Limit |
|------------|----------------------------|-----------------|
| 1 | Dust ratio | No relation. |
| 2 | Clay | Greater than 15 |
| 3 | Cohesion | Greater than 20 |
| 4 | Liquid limit | Greater than 30 |
| 5 | Plasticity index | Greater than 10 |
| 6 | Base exchange | Greater than 7 |
| 7 | Degree of alkalisation | Greater than 30 |

⁽¹⁶⁾ East Punjab Irrigation Research Institute, Amritsar, Annual Report 1947, page 64.
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One of the most important conclusions drawn was that all soils could not be adequately classified for road building purposes by physical tests alone, and the chemistry of the soil should be considered in such cases.

DISCUSSION BY THE RESEARCH COMMITTEE

DR. N. K. BOSE introduced item (1).

THE PRESIDENT said that item (2) was from Hyderabad Laboratories and the same should be taken as introduced.

DR. C. L. DHAWAN introduced item (3) and said that one of the most important conclusions drawn was that all soils could not be classified adequately for road building purposes by physical tests alone, and that the chemistry of soils should be considered in such cases. He further added that a systematic study had been started to find out the various details concerning specification in the case of soil stabilisation and their inter-relations.

MR. S. R. MEHRA said that they had done research in this connection in the Punjab for some years and had followed the standard methods. He described how far the main roads, gravel could be replaced by a mixture of light aggregate and soil. He went on to describe the stabilisation of soil with soft aggregates, where gravel was not available. The proportions were 40 per cent. aggregate and 60 per cent. graded soil, according to local conditions; sand content in bearing course was to be not less than 30 per cent. and the base course was to have a plasticity index higher than six.

He gave figures of costs for central Punjab: 25 per cent. of conventional type of not surfaced and 50 per cent. of surfaced.

DISCUSSION BY THE BOARD

THE SECRETARY said that three items were discussed at the Research Committee meeting. There was no resolution.

(iv) Foundations

PRELIMINARY NOTE

There was no contribution and no discussion under this sub-head at the 1947 Research Committee Meeting.

Recent Literature

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(14) Meyerhof, G. G., M.Sc. (Eng.), A.M.I.C.E., A. M. I. Struct. E. Department of Scientific and Industrial Research Building Research Station.—An investigation of the bearing capacity of shallow footings on dry sand. International Conference on Soil Mechanics and Foundation Engineering, Rotterdam, 1948, Vol. I.

(15) Beer, E. DE. Ghent (Belgium).—Settlement records on bridges founded on sand. International Conference on Soil Mechanics and Foundation Engineering, Rotterdam, 1948, Vol. II.

(16) Geers, F. J. B. G. Ir., Chief Engineer of the Zuiderzee works and Mierlo, W. C. Van Ir. Head of the consulting Department of the Delft Soil Mechanics Laboratory.—Estimation of future settlements of the dikes of the north-east polder based on observation of past settlements. International Conference on Soil Mechanics and Foundation Engineering Rotterdam, 1948, Vol. II.

(17) Merlo, W. C. Van, Ir., Head of the Consulting Department of the Delft Soil Mechanics Laboratory and Breeje, H. I. Den, Ir., Engineer of the Waterstaat of the Province Zuid Holland, Formerly of the Delft Soil Mechanics Laboratory.—Determination of expected settlements of Hydraulic fills in the Spangen Polder near Rotterdam. International Conference of Soil Mechanics and Foundation Engineering, Rotterdam, 1948, Vol. II.

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(25) Fischer, K., Dipl. Ing.—The foundation of the Rotunda bridge in Vienna. International Conference on Soil Mechanics and Foundation Engineering, Rotterdam, 1948, Vol. IV.

(26) Glick, George W., Consulting Engineer New York, N.Y.—Influence of soft ground on the design of long piles. International Conference on Soil Mechanics and Foundation Engineering, Rotterdam, 1948, Vol. IV.

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(31) Geuze, E.C.W.A. Ir., Head of the Research Department of the Delft Soil Mechanics Laboratory.—Horizontal earth pressure against a row of piles International Conference on Soil Mechanics and Foundation Engineering Rotterdam, 1948, Vol. IV.

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THE YEAR'S WORK

There was no contribution under this sub-head.

DISCUSSION BY THE RESEARCH COMMITTEE

DR. K. L. RAO said that in India, foundation problems had received very little attention. Considerable expenditure was being incurred on buildings and other structures but not a single investigation had been carried out in connection with foundation work. He said that there were many things which required investigation, for example, relative compaction of soil and its bearing capacity. He stressed that the loading tests on different soils should be carried out before constructing any structure and that the design of foundations should be based on the scientific data thus collected. He suggested that the best plan would be to carry out tests of different soils all over the country and to specify them in some order. He further suggested that the Central Board of Irrigation should ask all the Provinces and States to carry out investigations on the cracks

which had occurred in structures in their respective administrations and a survey of the properties of the soils. He concluded by saying that in the light of the information thus collected further works should be planned.

THE SECRETARY said that at the last meeting of the International Commission on Large Dams a suggestion was made to carry out the crack survey of all dams and that he had promised, by next year, to do some sort of survey of the cracks in dams in India. He requested that the Provinces and States who had dams in their respective administrations should give him information regarding cracks for presenting the same at the next meeting of the International Commission. Referring to cracks in general he said that he entirely agreed with what Dr. Rao had said about a systematic survey but felt that before any Province was asked to carry out such a survey it would be advisable if Dr. Rao were to carry out a sample survey in a small area and indicate the nature of soils, the intensity, and other factors pertaining to a particular locality. On receipt of a note on such studies to be made by Dr. Rao, other administrations would be asked to extend their studies on the same lines.

RAO BAHADUR KANWAR SAIN said that most of the cracks were due to unequal settlement and this should be avoided by the designer.

MR. H. H. BANERJI said that he wanted to know the technicalities of the black cotton soil and further whether any experiment had been carried out in the Punjab about this.

DR. R. C. HOON replying to Mr. Banerji said that as a result of the investigations which he had carried out a few years ago, he found that the cracking manifested by cotton soils on drying a few years ago, could not be overcome by the addition of economic quantities of various chemicals. The admixture of sand in suitable quantities, however, proved successful.

DR. V. I. VAIDHIANATHAN said that settlement and contraction of soil was certainly a very important factor in the occurrence of cracks and that it also depended on the pressures put on it. He added that the expansion in the black cotton soil under pressure would not be more than two to three per cent. otherwise every structure in South India would have collapsed by now.

RAI BAHADUR C. L. HANDA said that in the Punjab, treatment of soils was specially studied at the time of construction of the Thal canals. The soil used was a black cotton soil and it was found that after the first rainy season cracks developed. Some investigations were carried out and a certain amount of scientific analysis was also made and it was revealed that the water content of the soil was the determining factor in the development of cracks.

DR. K. L. RAO said that volume changes in the black cotton soil occurred only upto three to four feet from the ground level and if greater safety was to be secured, foundations should be taken deeper.

DISCUSSION BY THE BOARD

THE SECRETARY said that there was no contribution under this sub-head. There was no resolution. In connection with crack surveys of dams in India, some suggestions had been made on pages 349 and 350. The Board might like to consider them and pass a resolution for collecting the data. The Board adopted the following resolution :

“It was decided that the provinces and states who have dams in their respective Administrations may be requested to carry out crack surveys of all dams and supply the requisite information to the Secretary, Central Board of Irrigation who should compile it for presenting a note to the International Congress on Large Dams as early as possible.

“Further it was decided that before various administrations in India be asked to carry out a systematic survey of cracks in all hydraulic and other structures it would be better if Dr. Rao of Madras could carry out a sample survey in a small area indicating the nature of soils, the intensity, and other factors pertaining to a particular locality and the results obtained and supply a note on such studies to form the basis for carrying out similar surveys in other parts of the country”.

(v) Retaining walls, Revetments and Trenches

PRELIMINARY NOTE

There was no contribution and no discussion under the sub-head at the 1947 Research Committee Meeting.

Recent Literature

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- (3) Scott-Wilson, W.—Data for concrete retaining Walls. Civil Engineering and Public Works Review, Vol. 42, No. 488, February 1947.
- (4) Haefeli, R. Laboratory for Hydraulic Research and Soil Mechanics, of the Swiss Federal Institute of Technology, Zurich.—The stability of slopes acted upon by parallel seepage.—International Conference on Soil Mechanics and Foundation Engineering, Rotterdam, 1948, Vol. I.
- (5) Skempton, A. W., M.S.C., A.M.I.C.E., F.G.S. University Reader in Soil Mechanics and Assistant Professor at Imperial College, University of London.—The $\phi=0$ analysis of stability and its theoretical basis. International Conference on Soil Mechanics and Foundation Engineering Rotterdam, 1948, Vol. I.
- (6) Jaky. Dr. J. Prof.—Pressure in soils. International Conference on Soil Mechanics and Foundation Engineering, Rotterdam, 1948, Vol. I.

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- (12) Golder, Hugh Q., M. Eng., A.M. Inst. C.E.—Measurement of pressure in timbering of a trench in clay. International Conference on Soil Mechanics and Foundation Engineering, Rotterdam, 1948, Vol. II.
- (13) Packshaw, S., B. Sc.—Earth pressure on flexible walls. International Conference on Soil Mechanics and Foundation Engineering Rotterdam, 1948, Vol. II.
- (14) Bendel, Dr. L., Ing. Privatdozent an der Ecole Polytechnique de 'Universite de Lausanne Luzern.—Protracted sliding surface. International Conference on Soil Mechanics and Foundation Engineering, Rotterdam, 1948, Vol. III.
- (15) Jaky, Prof. Dr. Jozsef.—Minimum value of earth pressure. International Conference on Soil Mechanics and Foundation Engineering, Rotterdam, 1948, Vol. III.
- (16) Jaky, Prof. Dr. Jozsef.—Novel theory of earth pressure. International Conference on Soil Mechanics and Foundation Engineering, Rotterdam 1948, Vol. III.
- (17) Wolf, William H., Engineer, U.S. Bureau of Reclamation, Denver, Colorado and Holtz, W.G., Head, Earth Materials Laboratory, U.S. Bureau of Reclamation, Denver, Colorado.—Slope stability studies for the Delta-Mendota intake canal. International Conference on Soil Mechanics and Foundation Engineering, Rotterdam, 1948, Vol. III.

(18) Epstein, Harris, Head Designing Engineer, Waterfront Structures Bureau of Yards and Docks, U.S. Navy Department, Washington, D.C.—Reduction of lateral cohesive soil pressure on quaywalls by use of sand dikes. International Conference on Soil Mechanics and Foundation Engineering, Rotterdam, 1948, Vol. III.

(19) Browzin, Boris S., Dipl. Ing. Leningrad, Polytechn. Inst. France.—Upon the deflection and strength of anchored bulkheads. International Conference on Soil Mechanics and Foundation Engineering, Rotterdam, 1948, Vol. III.

(20) Toms, A. H., B.Sc., A.M.I.C.E., Southern Rly. Company.—The present scope and possible future development of soil mechanics in British railway civil engineering construction and maintenance. International Conference on Soil Mechanics and Foundation Engineering, Rotterdam, 1948, Vol. IV.

THE YEAR'S WORK

There was no contribution under this sub-head.

DISCUSSION BY THE RESEARCH COMMITTEE

Dr. L. K. Rao said that coarse-grained material should be put behind retaining walls instead of clay. He advocated a revision of Rankine's theory and the observation of pressures on actual structures.

RAI BAHADUR C. L. HANDA said that due to seasonal changes, records of pressures behind retaining walls should be kept and that the Central Board of Irrigation should indicate the type of surveys that should be carried out in this connection.

DISCUSSION BY THE BOARD

THE SECRETARY said that there was no contribution under this sub-head. The discussion by the Research Committee was given above. There was no resolution.

(vi) Buildings Research

THE YEAR'S WORK

DISCUSSION BY THE RESEARCH COMMITTEE

THE PRESIDENT said that this was a new sub-head which had been introduced by the Secretary. He requested Mr. Mehra to describe the work which he had carried out on the use of soils for buildings.

MR. S. R. MEHRA said that shortage of coal was being felt all over the country and bricks had become very expensive and were not available in large quantities. Research might, therefore, be started on the use of a substitute in the form of soil. All attention was directed towards getting the highest possible compressive resistance in any particular soil by using a small quantity

of cement. He added that by experiments it had been found possible to bring down the quantity of cement to $2\frac{1}{2}$ percent. Blocks of soil with a mixture of $2\frac{1}{2}$ percent. cement were made and had been tried for the last $4\frac{1}{2}$ months and they seemed to have stood well. These specifications were prepared for the project in East Punjab in connection with the construction of 4,000 houses for refugees. The sand content of the soil used was not less than 35 percent. and the success of the method depended on proper planning. He drew attention to the fact that it was not only the saving of coal that would result from the use of this type of specification for construction but that the construction cost would be much cheaper as the price of stabilised soil was about 55 percent. of the cost of brick work in mud and 45 percent. of brick in cement. He concluded by remarking that their progress in this connection had been satisfactory.

SARDAR BAHADUR SARDAR SARUP SINGH said that he had heard that experiments had not been successful.

MR. S. R. MEHRA replying said that that was incorrect as 200 house at Karnal and another 200 at Panipat and Rupar had been completed successfully.

THE PRESIDENT remarked that the use of stabilised soil for construction purposes was indeed an interesting innovation which would save a lot of money.

MR. S.R. MEHRA said that 24 laboratories had been set up and were working with full speed in connection with the construction of 4,000 houses.

MR. H. H. BANERJI said that the experiments mentioned by Mr. Mehra were interesting. The Railway Board had a nucleus laboratory where some 100 soils from different railway embankments and sidings were being tested. Thirty samples had been tested so far and it had been found that the addition of cement varied from three to six and even seven per cent. depending upon the basic nature of the soil. Referring to the buildings which had been constructed in East Punjab, he said that he had seen some of them and had found that the process followed was not very successful because some of the buildings near Dr. Uppal's laboratory had cracked.

MR. S.R. MEHRA said that the house to which Mr. Banerji had referred was one of the first to be constructed and since then they had gone ahead and made improvements. They had tried 10 different processes and the one which had been adopted finally had proved very successful.

MR. H. H. BANERJI enquired whether the cost was based on Rs. 60 or Rs. 35 per hundred cubic feet.

MR. S. R. MEHRA replying said that the basic rate was Rs. 35 per hundred cubic feet and Rs. 11/8/0 for cement plaster.

MR. H. H. BANERJI said that they had been using cinder plaster in the ratio of 1 of cement, 8 of lime and 32 of cinder and that the tare had worked out at Rs. 10 per hundred square feet.

RAO BAHADUR A. R. VENKATACHARYA said that they had done a number of experiments in the Bhavani Project with the red loam soil. The percentage of cement was found to be eight per cent. and it was very suitable. The experiments had not been finalised yet, and they were also trying to do some cement soil plasters.

DR. O. VAIDHIANATHAN said that in connection with the canal lining in the Punjab he had carried out some soil surveys a few years back. Slabs of different soils with various percentage of soil and sand were made and it was found that most of them cracked invariably and were, therefore, given up. *Pacca* bricks were tried under varying conditions and it was found that the variety of bricks the use of which was being advocated were not very satisfactory. Some of the soils were alkaline and, therefore, bricks made of them began disintegrating after some time. Continuing he said, that in America soil-cement combination had been tried for small canals and had been found successful and concluded by saying that it would be worthwhile looking into the details of the American experiments.

It was decided that the subject should remain on the agenda.

DISCUSSION BY THE BOARD

THE SECRETARY said that this was a new sub-head introduced this year. There was no contribution. There was no resolution. The Board would be visiting the soil stabilised buildings on Sunday.

2E. Movement of Moisture in Saturated and Unsaturated Soils

PRELIMINARY NOTE

This subject was introduced on the agenda in 1947. A sub-committee comprising Dr. Bose (Convener), Dr. Asghar, Dr. Hoon, Mr. Bhatia, Rao Bahadur Maydeo and Dr. Vaidhianathan was constituted in 1946 to write up a book on the 'Fundamentals of Soil Research'. The first meeting of the sub-committee was held in July 1947 at the time of the last Research Committee Meeting. A note on 'Fundamentals of experiments on Soil Research', prepared by the Sub-Committee was circulated to the Directors of Research Organisations in India and Ceylon for further suggestions and comments. Comments were received from the Director, Central Waterways, Irrigation and Navigation Research Station, Poona and the Executive Engineer, Irrigation Research Station Madras. Remarks of the Director, Central Waterways, Irrigation and Navigation Research Station, were circulated further to all the Directors for furnishing necessary replies to the points raised in the remarks. Reply has since been received from the Executive Engineer, Irrigation Research Station, Madras.

The Sub-Committee also held its second meeting in December 1947 at the time of the last Board Meeting. No final draft for the book has so far been produced by the Sub-Committee.

The following items were discussed at the 1947 meeting of the Research Committee:—

- (1) Soil moisture and evaporation—investigations being conducted by the Agricultural Meteorological Section at Poona by Dr. L. A. Ramdas.
- (2) Experiments on transmission co-efficients of sand in Sind.
- (3) Seepage into the foundation trench of the Ramapadasagar Dam.
- (4) Lysimeter experiments.
- (5) Moisture movements.

Recent Literature

(1) Christiansen, J.E.—Some permeability characteristics of saline and alkaline soils. *Agricultural Engineering*, Vol. 28, No. 4, April 1947.

(2) Report on soil moisture and evaporation investigations being conducted by the Agricultural Meteorological Section at Poona (stencilled 1947).

(3) Asghar, A. G.—Movement of moisture in soils. Proceedings of Punjab Engineering Congress, Vol. 35, Paper No. 285, 1947.

(4) Dolgov, S. I.—Forms and states of soil moisture. Pedology, Vol. 7, 1946.

(5) Bolshakov, A. F.—Forms of the movement of moisture in soils of the steppe type. Pedology, Vol. 7, 1947.

(6) Myslivec, Alois, Docteur, Professeur a l'Institut d'Hydraulique Prague Podaba Techcosl.—Infiltrations a travers les digues en terre employees pour les barrages reservoirs et terres propres a leur tanchement (Seepage through earth dams of water reservoirs and soils suitable for the watertight layer). International Commission on Large Dams, Third Congress, Stockholm, 1948, R7.

(7) Yang, Shih, Te., On the permeability of Homogeneous Anisotropic Soils—International Conference on Soil Mechanics and Foundation Engineering, Rotterdam, 1948, Vol. II.

(8) Schofield R. K. and Penman H. L.—The concept of soil moisture deficit—International Conference on Soil Mechanics and Foundation Engineering, Rotterdam, 1948, Vol. I.

THE YEAR'S WORK

The following items were discussed at the 1948 Research Committee Meeting :—

- (1) Locomotive Project Survey.
- (2) Effect of various soil factors on the field capacity in soils.
- (3) Hydraulic gradients in soils (model experiments).
- (4) Hydraulic gradients in soils (laboratory experiments).
- (5) Hydraulic gradients in canal banks.
- (6) Movement of sub-soil water table and flow gradients.

(1) LOCOMOTIVE PROJECT SURVEY (1)

ABSTRACT

It is proposed by the Railway Board of the Indian Union to put up a locomotive Workshop and shed for the East Indian Railway. A site near Rupnarayanpur on the Bengal-Bihar border was tentatively selected by the railway authority for the location of this workshop. It was expected that a railway colony will grow up round this workshop that will accommodate about 10,000 people. The water-supply to this big colony was the problem. There were two sources of supply near about this site. One was the river Adjai and another the Barakar. The river Barakar has this advantage that the lake of the

(1) River Research Institute West Bengal, Annual Report, 1947, pages 157—162.

dam that is going to be put up near Maithon on this river will extend quite close to this site and it will be possible to have any amount of water supply from the lake. But the construction of the reservoir may take a few years and as the workshop had to be put up immediately, the site nearer Adjai was tentatively selected. The Institute was approached by the East Indian Railway Authorities to carry out certain laboratory tests and find out if a minimum supply of six to seven cusecs could be assured from the river Adjai. The Senior Superintendent, Way and Works, Asansol, was asked to secure some bed sand samples from the river at three cross sections near about the site selected by the Railway Authorities for drawing the supply. Bed sand samples from these cross sections of the river near the point were collected and sent to this laboratory for examination. These samples were tested for mechanical analysis and transmission constants.

Description of the transmission constant determination apparatus.—The apparatus consists of a hard glass tube 50 cm. in length and of external diameter 3.5 cm. On this tube are fixed five vertical narrow glass tubes each of 30 cm. in length with strainer of fine wire-netting at the bottom. These tubes are used as manometer. The apparatus is fitted at both its ends with two brass sockets and sealed by sealing wax to prevent leakage. Each of the brass sockets has a fine wire-netting inside it, which acts as strainer. There was also a small hole in both the sockets for inserting thermometer to register temperature of the inlet and outlet water. Through one of these sockets water from a constant pressure head tank enters and flows through the tube uniformly packed with sand whose transmission constant is to be determined and was discharged through the other brass sockets and collected and measured in a measuring cylinder, *vide* Figure 2E. 1.

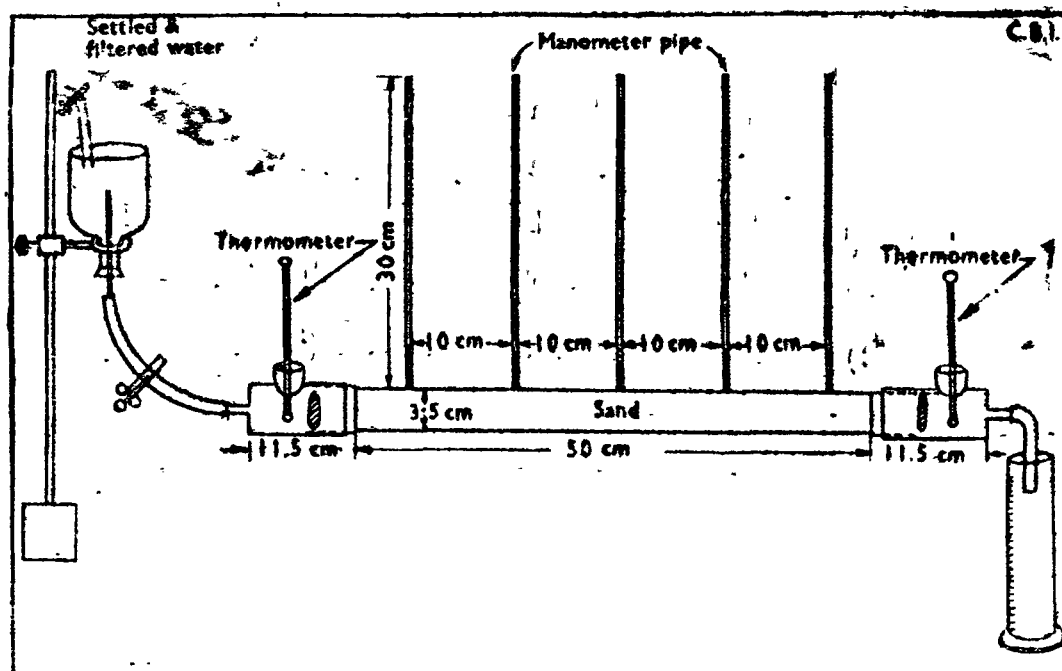


Figure 2E.1 :—Showing transmission constant determination apparatus.

Technical difficulties.—In the determination of transmission constant of sand with this apparatus it was found that if the experiments were carried out with dry sand a considerable time takes place to chase all the entrapped air and consequently there is a constant flickering of pressure levels in the manometric tubes. This difficulty was got rid of by pouring sand into water and stirring the sand with a glass rod to drive all air out and then pouring out the surplus water; the moist sand is then packed uniformly in the tube.

The water flowing through the sand must be free from fine suspended matter else, they clog the sand causing a continual decrease in the flow of water. For this purpose, water was filtered through glass wool.

Again the water should not be taken directly from the tap. The tap water contains dissolved air and interlocked air bubbles. Apart of this air would be released when flowing through the sand. This was removed by using water, which was allowed to stand in a reservoir for a day or two.

The essential factor on which the correctness of the result depends is the packing. The packing must be uniform, otherwise a constant result is difficult to get.

It was also necessary to maintain the temperature steady during the experiment. In those cases where it was not possible, temperature corrections were made according to the formula :—

$$K_{20} = \frac{Q}{A.T.J.} \times \frac{\eta_1}{\eta_{20}}$$

where Q = Quantity of water collected.

A = Area of cross section of the tube.

T = Time interval in seconds.

J = Hydraulic gradient.

η_1 = Viscosity of water at the observed temperature.

η_{20} = Viscosity of water at 20°C.

The results of the experiments are given in Tables 2E. I, 2E. II and 2E. III.

The average value of the transmission constant of "up" sample gave the highest value 0.00605 foot per second while that of "centre" gave the lowest value of 0.00270 foot per second and the transmission constant of "down" was 0.00366 foot per second. These results are consistent with the results obtained by the siltometer analysis. The mean diameter as found by the siltometer analysis of the sand particles of "up" sample was 0.9 mm., while the mean diameter of the "centre" sample was 0.642 mm. and the mean diameter of the "down" sample was 0.884 mm. The "up" sample consisted of coarse and with small stones and gravels and was slightly reddish in colour. The "centre" sample consisted mainly of coarse sand and was uniformly distributed. The "down" sample consisted of coarse and with some small stones and gravel. Both the "up" and "down" are non-uniform in their distribution. A cross section of the river bed at the centre site was taken. A number of borings was also carried out at the same cross sections. Assuming that the sand all throughout in the cross section was of the same texture and water was flowing through the whole section, the average discharge was found to be 16.35 cusecs and the minimum discharge 10.76 cusecs. These discharges were calculated on the assumption that the whole volume of sand on the river bed was tapped. But as this was not possible it was not expected to get more than five or six cusecs during the dry part of the year.

TABLE 2E. I

Screen Analysis in per cent.

| Sample No. | Stones and gravel | Fine gravel | Coarse sand | Fine sand |
|------------|-------------------|-------------|-------------|-----------|
| Up | 1.4 | 5.4 | 83.8 | 9.4 |
| Centre | 1.0 | 2.2 | 82.8 | 14.0 |
| Down | 2.8 | 6.8 | 73.4 | 17.0 |

TABLE 2E.II

Experimental Results

| Sample No. | Date of sampling | Description of sand samples | Mean diameter in mm. | Per cent. above 0.6 mm. | $K_{1.0}$ (foot per second) | Q. (cusecs) | Q.min (cusecs) | Remarks |
|------------|------------------|--|----------------------|-------------------------|-----------------------------|-------------|----------------|---|
| Up | Nil | Coarse sand with small stones and gravels and is slightly reddish in colour. | 0.90 | 76.58 | 0.00605 | 16.35 | 17.6 | 58 per cent. of the samples lie between 0.6—1.0 mm. Non-uniform sample. |
| Centre | Nil | Mainly coarse sand | 0.642 | 56.48 | 0.00270 | .. | .. | 53.8 per cent. of the samples lie between 0.6—1.0 mm. Non-uniform sample. |
| Down | Nil | Coarse sand with some stones and gravel. | 0.884 | 66.94 | 0.00366 | .. | .. | 49.4 per cent. of the samples lie between 0.6—1.0 mm. Non-uniform sample. |

Area of cross-section of the river bed—3,988 s q. ft.

TABLE 2E. III

Observational Data for determining "K" from Bed Sand Sample

| Sample No. | Time t. (minutes) | Quantity collected Q. (c.c.) | Temperature | | Hydraulic gradient $\frac{e}{L}$ | K (cusecs) | Temperature correction. | K ₂₀ (cusecs) |
|------------|-------------------|------------------------------|-------------|---------|----------------------------------|------------|-------------------------|--------------------------|
| | | | t°C In | t°C Out | | | | |
| Up | 5 | 182 | 27 | 28 | 2.15 | 0.161 | 1.19 | 0.1915 |
| | 5 | 181 | 27 | 28 | 2.15 | 0.161 | 1.19 | 0.1915 |
| | 5 | 190 | 27 | 28 | 2.03 | 0.159 | 1.19 | 0.1892 |
| | 5 | 188 | 27 | 28 | 2.05 | 0.159 | 1.19 | 0.1892 |
| | 5 | 188 | 27 | 28 | 2.05 | 0.159 | 1.19 | 0.1892 |
| | 5 | 180 | 27 | 28 | 2.12 | 0.157 | 1.19 | 0.1868 |
| | 5 | 180 | 27 | 28 | 2.12 | 0.157 | 1.19 | 0.1868 |
| | 5 | 174 | 27 | 28 | 2.19 | 0.157 | 1.19 | 0.1868 |
| | 5 | 170 | 27 | 28 | 2.22 | 0.155 | 1.19 | 0.1844 |
| | 5 | 171 | 27 | 28 | 2.22 | 0.155 | 1.19 | 0.1844 |
| | 5 | 171 | 27 | 28 | 2.22 | 0.155 | 1.19 | 0.1844 |
| | 5 | 167 | 27 | 28 | 2.26 | 0.155 | 1.19 | 0.1844 |
| | 5 | 167 | 27 | 28 | 2.26 | 0.155 | 1.19 | 0.1844 |

K₂₀ = 0.1844 cusec.

TABLE 2E. III—*contd.*

| Sample No. | Time t (Minutes) | Quantity collected Q (c.c.) | Temperature | | Hydraulic gradient $\frac{e}{L}$ | K (cusec) | Temperature correction | K_{20} (cusec) |
|------------|--------------------|-------------------------------|------------------------|-------------------------|----------------------------------|-------------|------------------------|------------------|
| | | | $t^{\circ}\text{C}$ In | $t^{\circ}\text{C}$ Out | | | | |
| Centre | 5 | 127 | 28 | 29 | 1.31 | 0.0689 | 1.22 | 0.0841 |
| | 5 | 120 | 28 | 29 | 1.38 | 0.0685 | 1.22 | 0.0836 |
| | 5 | 114 | 28 | 29 | 1.38 | 0.0685 | 1.22 | 0.0832 |
| | 5 | 121 | 28 | 29 | 1.36 | 0.0680 | 1.22 | 0.0830 |
| | 5 | 120 | 28 | 29 | 1.36 | 0.0675 | 1.22 | 0.0823 |
| | 5 | 120 | | | 1.36 | 0.0675 | 1.22 | 0.0823 |
| | 5 | 120 | 28 | 29 | 1.36 | 0.0675 | 1.22 | 0.0823 |
| | 5 | 120 | 28 | 29 | 1.36 | 0.0675 | 1.22 | 0.0823 |
| | 5 | 120 | 28 | 29 | 1.36 | 0.0675 | 1.22 | 0.0823 |
| | 5 | 120 | 28 | 29 | 1.36 | 0.0675 | 1.22 | 0.0823 |
| | 5 | 120 | 28 | 29 | 1.36 | 0.0675 | 1.22 | 0.0823 |
| | 5 | 120 | 28 | 29 | 1.36 | 0.0675 | 1.22 | 0.0823 |
| | 5 | 120 | 28 | 29 | 1.36 | 0.0675 | 1.22 | 0.0823 |

$K_{20} = 0.0823$ cusec

TABLE 2E. III—contd.

| Sample No. | Time t (minutes) | Quantity collected Q (c.c.) | Temperature | | Hydraulic gradient $\frac{e}{L}$ | K (cusec) | Temperature correction | K_{10} (cusec) |
|------------|--------------------|-------------------------------|------------------------|-------------------------|----------------------------------|-------------|------------------------|------------------|
| | | | $^{\circ}\text{C.}$ In | $^{\circ}\text{C.}$ Out | | | | |
| Down .. | 5 | 161 | 27 | 28 | 1.42 | 0.0959 | 1.19 | 0.1141 |
| | 5 | 161 | 27 | 28 | 1.43 | 0.0959 | 1.19 | 0.1141 |
| | 5 | 150 | 27 | 28 | 1.52 | 0.0948 | 1.19 | 0.1128 |
| | 5 | 153 | 27 | 28 | 1.49 | 0.0943 | 1.19 | 0.1122 |
| | 5 | 153 | 27 | 28 | 1.49 | 0.0943 | 1.19 | 0.1122 |
| | 5 | 153 | 27 | 28 | 1.48 | 0.0937 | 1.19 | 0.1115 |
| | 5 | 152 | 27 | 28 | 1.50 | 0.0937 | 1.19 | 0.1115 |
| | 5 | 154 | 27 | 28 | 1.52 | 0.0937 | 1.19 | 0.1115 |
| | 5 | 152 | 27 | 28 | 1.50 | 0.0937 | 1.19 | 0.1115 |
| | 5 | 152 | 27 | 28 | 1.50 | 0.0937 | 1.19 | 0.1115 |
| | 5 | 152 | 27 | 28 | 1.50 | 0.0937 | 1.19 | 0.1115 |

$K_{10} = 0.1115$ cusec.

(2) EFFECT OF VARIOUS SOIL FACTORS ON THE FIELD CAPACITY IN SOILS (2)

Field capacity has been described as the upper limit of soil moisture content found under field conditions in a soil having unobstructed sub-drainage. Each layer of the soil would retain as much of moisture as it could hold against gravity and any excess of it would move further down to lower strata. It is, therefore, an important soil characteristic in a soil moisture system.

The technique developed for the determination of the field capacity of soils and the effect of clay and initial moisture content were described in the Annual Report of the Lahore Institute for 1946.

The results showed that :—

- (1) The other factors remaining the same, there is a gradual decrease in the field capacity with a decrease in clay content.
- (2) The value of the field capacity is independent of the moisture content.

Further work in this connection was carried out to study the effect of the salts and humus.

EFFECT OF THE NATURE OF SALT ON THE FIELD CAPACITY IN SOILS.

The same typical Punjab soil containing about 16% clay was used in all these experiments. It was compacted at 1.5 dry bulk density.

The effect of increasing the amounts of Sodium Chloride, Sodium Sulphate and Calcium Sulphate was investigated. The results are presented in Table 2 E. IV.

TABLE 2E. IV

| Serial No. | Salt percentage | Field capacity |
|---------------------------------------|-----------------|----------------|
| (a) Effect of Sodium Chloride | | |
| 1 | 0.0 | 21.0 |
| 2 | 0.5 | 20.3 |
| 3 | 2.5 | 19.6 |
| 4 | 5.0 | 15.9 |
| 5 | 10.0 | 16.7 |
| (b) Effect of Sodium Sulphate | | |
| 6 | 1.0 | 21.7 |
| 7 | 2.5 | 21.2 |
| 8 | 5.0 | 20.6 |
| 9 | 10.0 | 20.3 |
| (c) Effect of Calcium Sulphate | | |
| 10 | 0.5 | 21.0 |
| 11 | 1.25 | 22.2 |
| 12 | 2.5 | 22.4 |

This shows that there was an appreciable decrease in the field capacity of soils by the addition of Sodium Chloride, while Sodium Sulphate did not effect it very much. Calcium Sulphate increased the field capacity to a very small degree.

(2) East Punjab Irrigation Research Institute, Annual Report, 1947, p. 33, 34.

EFFECT OF HUMUS ON THE FIELD CAPACITY IN SOILS

Experiments were next undertaken to determine the effect of the humus on the field capacity in soils. The results are given in Table 2E, V.

TABLE 2E, V

| Serial No. | Humus Percentage | Field Capacity | |
|------------|------------------|----------------|-------------|
| | | Experimental | By equation |
| 1 | 0.0 | 21.0 | 21.0 |
| 2 | 0.5 | 21.9 | 22.2 |
| 3 | 1.3 | 23.7 | 24.4 |
| 4 | 1.7 | 25.3 | 25.6 |
| 5 | 2.7 | 30.8 | 29.0 |
| 6 | 3.8 | 33.8 | 33.4 |

It will be seen that there was a gradual increase of the field capacity with the increase in humus. The results have a direct bearing on the phenomenon of conservation of moisture in soils. The results can be expressed by an empirical equation :—

$$MF = 21.0 + 2.3H + \frac{H^2}{4} \quad \dots \dots \dots (2 E. 1)$$

where MF = Field capacity.

H = Humus percentage.

The agreement between the experimental and the calculated value is excellent.

(3) HYDRAULIC GRADIENTS IN SOILS (MODEL EXPERIMENTS) (3)

ABSTRACT

As water moves through a saturated soil under the action of gravity (as distinct from its capillary movement) the flow is resisted by the soil particles (surface exposed in soil pores). Naturally finer the soil, greater the frictional resistance and greater the loss of head. The water gradient (drop in pressure head), therefore, should indicate the frictional resistance as is particularly noticeable adjacent to drains cutting a water table. Théoretically the hydraulic gradient is stated to be independent of the soil material so long as it is homogeneous. In earthen dams of uniform and homogeneous material, for instance, the gradient is said to depend on the geometrical shape and not on the material used. The present investigation has been taken up with a view to observing how for the soil factor affects the hydraulic gradients and if it can be ignored altogether.

(3) Poona Irrigation and Research Division, Public Works Department, Bombay, Poona, Annual Report, 1947, pages 38—46.

MOVEMENT OF MOISTURE

EXPERIMENT

Annual Report (Technical) of the work done during the year 1944 by the Indian Waterways Experiment Station (now Central Waterways Irrigation and Navigation Research Station) mentions on page 59 under "Dams and Reservoirs", certain experiments conducted at Khadakwasla in connection with the proposed Solani Khadir and Balta Jheel reservoirs in the United Provinces. The Solani Khadir soil material consists of fine silt containing 4.3 percent clay (diameter <40.0039 mm. $M=0.092$ mm.) and is pervious.

A masonry chamber (28 feet long, 6 feet wide and 8 feet deep) was used in these experiments. Figure 2E.2 shows the upstream water tank, the central soil chamber and the downstream percolation tank, the bed and side projections to prevent direct creep of water between the soil and the chamber walls. The same chamber was used in the present experiments after testing that it was water tight. Only two rows of observation tubes were kept instead of the three in the original Solani experiment. The automatic feed arrangement fully described in that report was also used in these experiments.

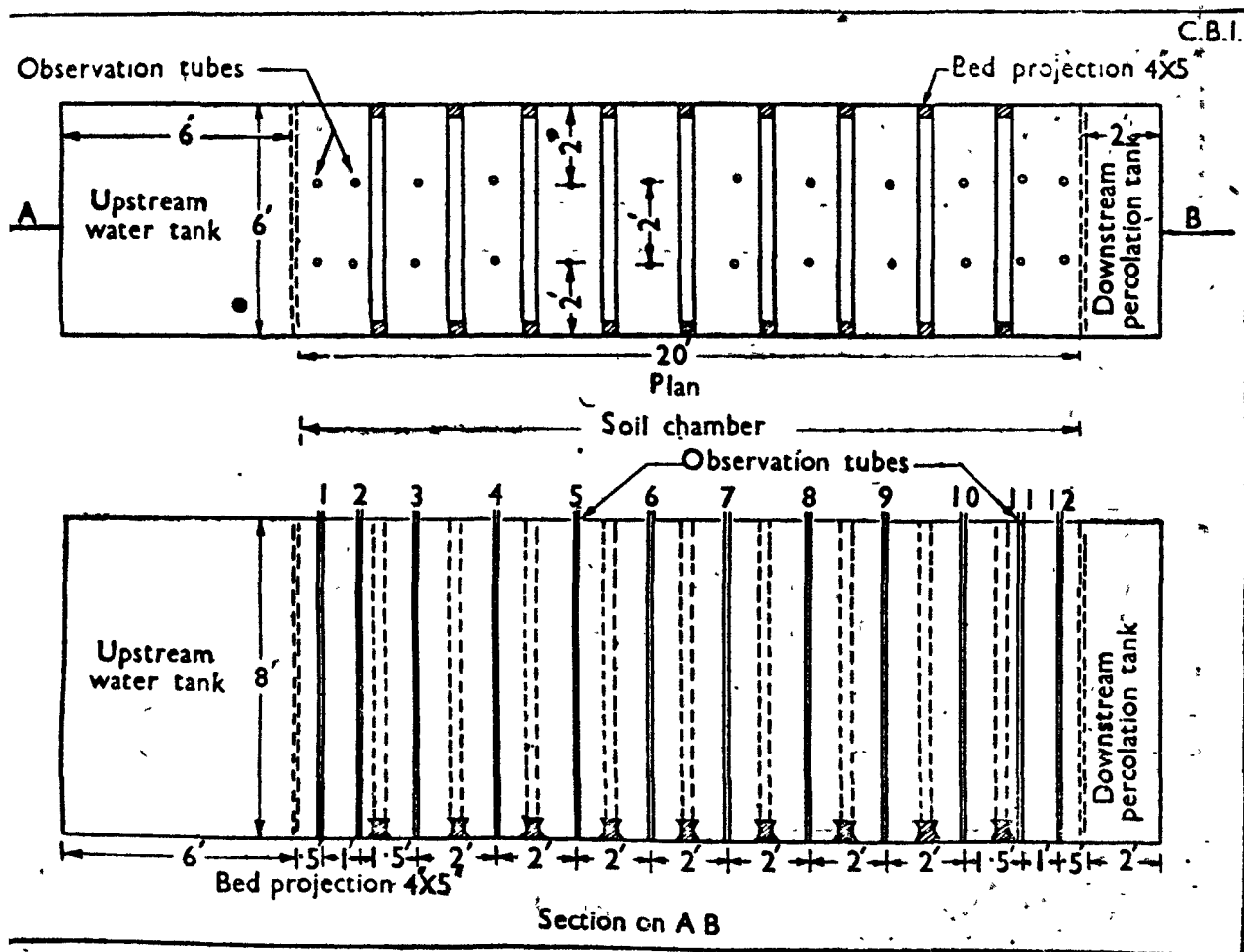


Figure 2E.2 : Showing masonry Chamber used for the hydraulic gradient (experiment at Khadakwasla).

Typical black soil of the Bombay Deccan, largely used for hearting in earthen dams was screened through $\frac{1}{4}$ inch mesh sieve and filled in the chamber in 4 inches layers after mixing it with 15 percent moisture. Each layer was rammed (with an iron rammer weighing 22 lbs. dropped from a height of one foot) until it did not consolidate further. Physical analysis and other data for this soil are given below.

Results of physical analysis and other physical properties of the Black Cotton Soil used in the hydraulic gradient Experiment at Khadakwasla.

(1) *Mechanical analysis* :—Without chemical treatment for dispersion.

TABLE 2E. VI

| Serial No. | Material | Diameter in mm. | % |
|------------|-------------------|-----------------|------|
| 1 | Clay | < .002 | 25 |
| 2 | Silt | .002-.02 | 30 |
| 3 | Fine sand | .02-2 | 37.7 |
| 4 | Coarse sand | > .1 | 7.3 |

Mean diameter = .074 mm.

Summation and distribution curves have been plotted in Figure 2E. 3.

(2) Absolute specific gravity = 2.392

(3) Liquid limit = 49.8

(4) Plastic limit = 31.5

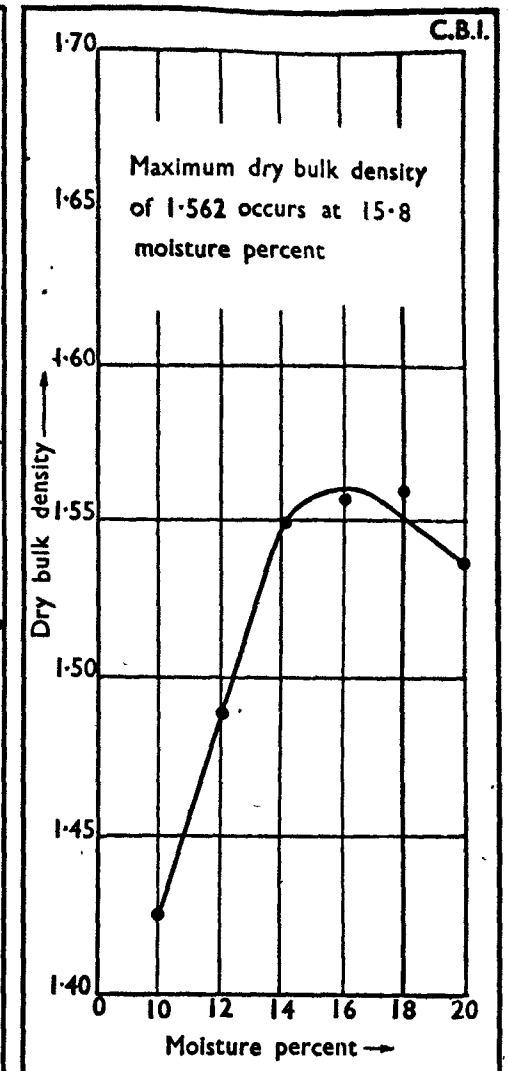
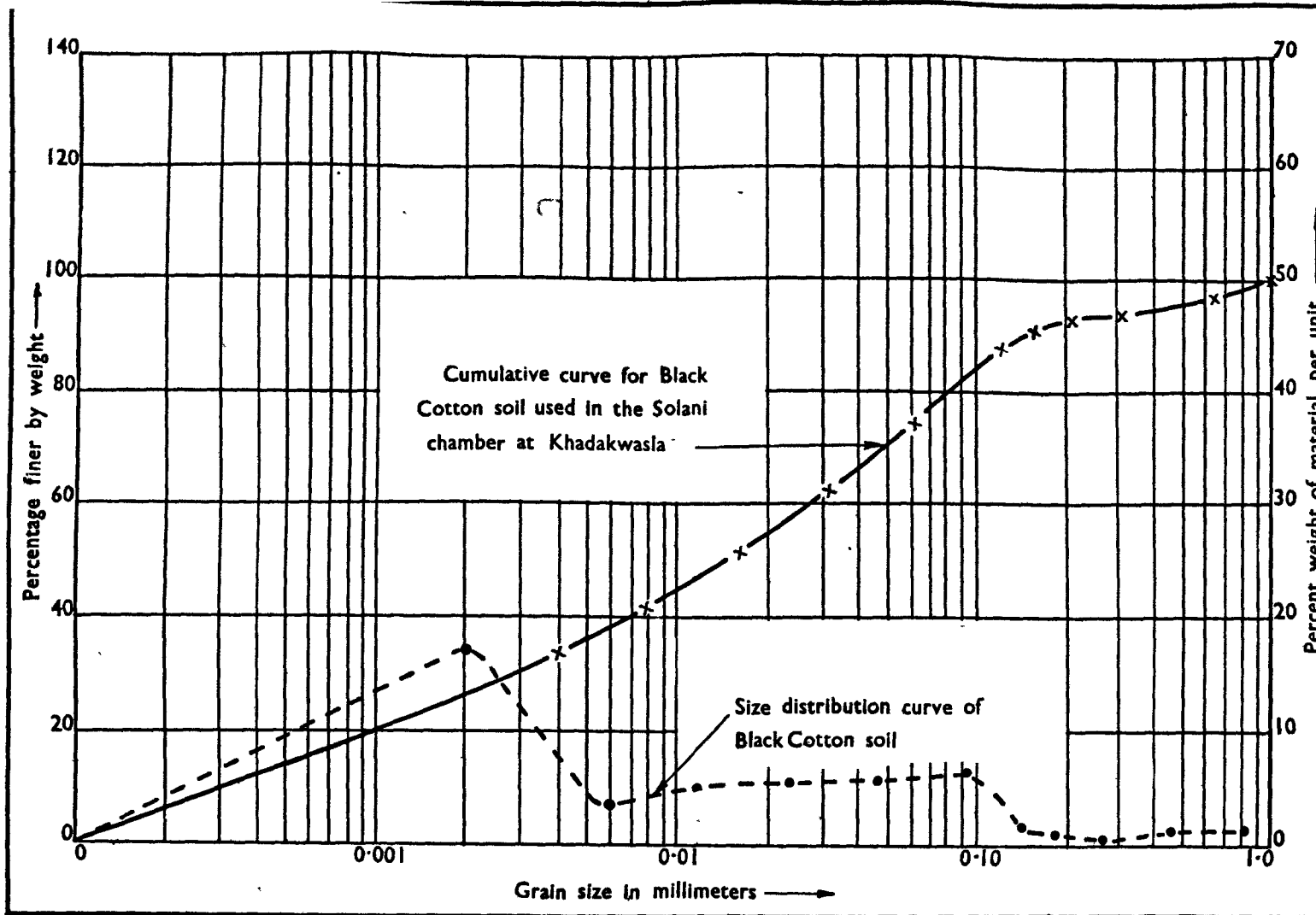
(5) Plasticity Index = 18.3

(6) *Volume weight of the soil* :—

The soil screened through $\frac{1}{4}$ inch size weighed 64 lbs. per cubic foot, while loose, but when rammed with a rammer of 22 lb. weight falling through a height of one foot it weighed 77 lb. per cubic foot. With moisture added at 15 percent, the dry bulk density of the compacted soil was found to be 83 lb. per cubic foot (or 1.33).

The dry bulk density as calculated from the total weight of the soil used in filling the R.C.C. Chamber and the actual volume occupied by the soil, was found to be 1.2992 or about 81 lbs. per cubic foot. Actual tests of compaction by driving a soil cylinder into the compacted soil in the chamber gave a dry bulk density of 1.191 (or 74.3 lb. per cubic foot) in the surface foot of the soil.

(7). Hygroscopic moisture in the soil = 10.4 percent.



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Figure 2E.3 (Left):- Cumulative & size distribution curves for Black Cotton soil used in Solani chamber at Khadakwasla

Figure 2E.4 (Right):- Relation between moisture content & dry bulk density under a constant compacting effort

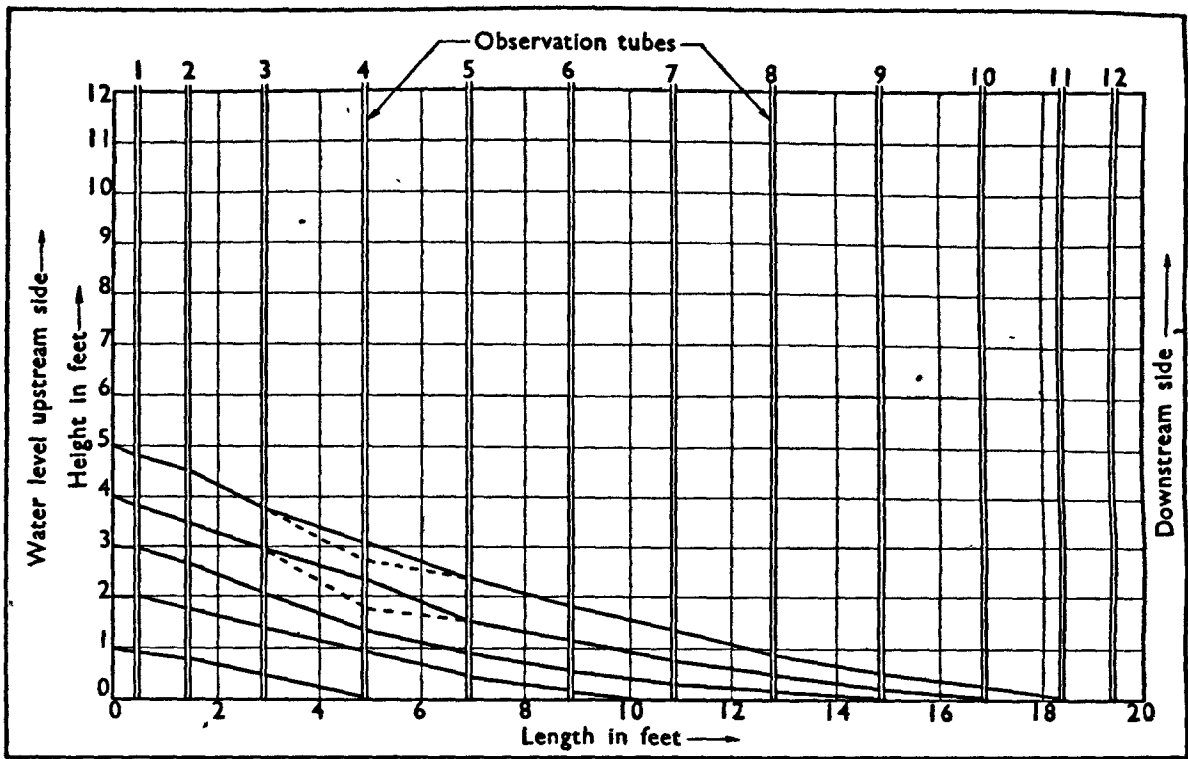


Figure 2E.5:- Showing hydraulic gradients in the initial dry stage of the soil

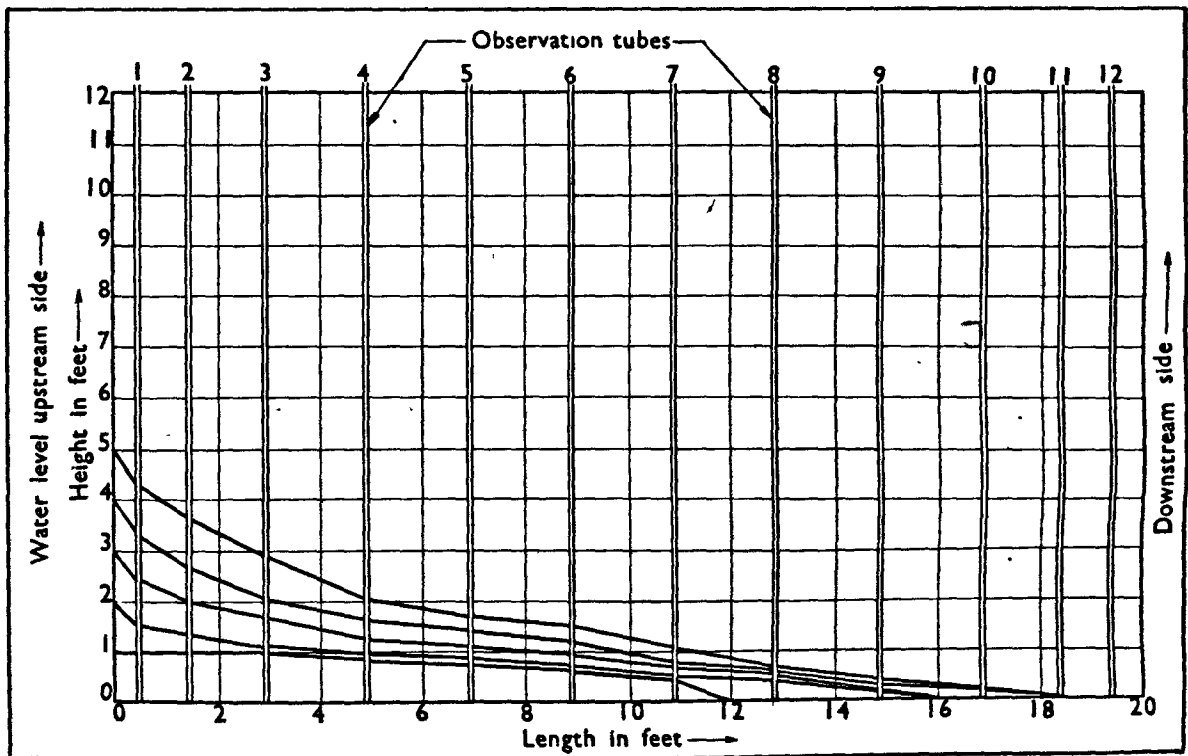
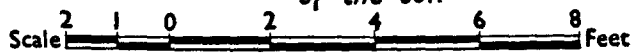


Figure 2E.6:- Showing hydraulic gradients in the final wet stage of the soil



(8) After the experiment was in progress for about five months, moisture content at different depths of the soil was estimated between eighth and ninth observation tubes. Table 2E. VII shows the travel of the moisture at different depths of the soil column.

TABLE 2E. VII

| Position of the sample | | | | | | | Moisture % |
|------------------------|----------|----|----|----|----|----|------------|
| Surface } foot. } | Upper 6" | .. | .. | .. | .. | .. | 18.6 |
| | Lower 2" | .. | .. | .. | .. | .. | 29.4 |
| 4th foot | .. | .. | .. | .. | .. | .. | 36.7 |
| 7th foot | .. | .. | .. | .. | .. | .. | 46.0 |

(9) The soil was compacted in steel cylinders diameter 3 inches \times 4 inches high in three layers with different moisture contents under a constant compacting effort viz., by a rammer weighing 11 lb. falling through a height of 18 inch of strokes being 25. Dry bulk density was calculated in each case with the results given in Table 2E. VIII.

TABLE 2E. VIII

| Moisture added. | | | | | | D.B.D. |
|-----------------|----|----|----|----|----|--------|
| 10% | .. | .. | .. | .. | .. | 1.424 |
| 12 | .. | .. | .. | .. | .. | 1.491 |
| 14 | .. | .. | .. | .. | .. | 1.549 |
| 16 | .. | .. | .. | .. | .. | 1.558 |
| 18 | .. | .. | .. | .. | .. | 1.5585 |
| 20 | .. | .. | .. | .. | .. | 1.537 |

These values have been plotted Figure 2 E. 4. From the graph it is seen that the maximum D. B. D. of 1.562 occurs at 15.8 percent. moisture.

Results :

There was no percolation and water absorbed by the soil could not be estimated quantitatively for reasons explained above. The gradients are, however, truly representative for gauges upto five feet when there was no disturbance of any sort. The initial readings when the gauges were raised and water flowed into a comparatively drier soil are shown in Figure 2E.5. The readings that were repeated in a comparatively moist soil later are shown in Figure 2E.6.

(i) Hydraulic gradients in Figure 2E. 5 are somewhat linear. The average gradient for each gauge was as given in Table 2 E. IX.

TABLE 2E. IX

| Depth of water (Feet) | Distance to which water reached (feet) | Gradient |
|-----------------------|--|----------|
| 5 | 18.5 | 1 in 3.7 |
| 4 | 17.0 | 1 in 4.3 |
| 3 | 15.0 | 1 in 5 |
| 2 | 10.0 | 1 in 5 |
| 1 | 5.0 | 1 in 5 |

(ii) Gradients in Figure 2E. 6 (for the moist state of the soil) show definite curvature. The curves are divisible into three portions.

- Steep slope at entry upto observation tube No. 1 showing greater loss of head. Figure 2E.7 shows the loss is proportional to head and is probably caused by the reduction in pore necks on swelling of the soil in contact with the upstream water face.
- There is a regular fall to a distance shown by a straight portion.
- This is followed by a flatter grade indicating negligible movement of water verging towards stagnation and consequent little drop in head.

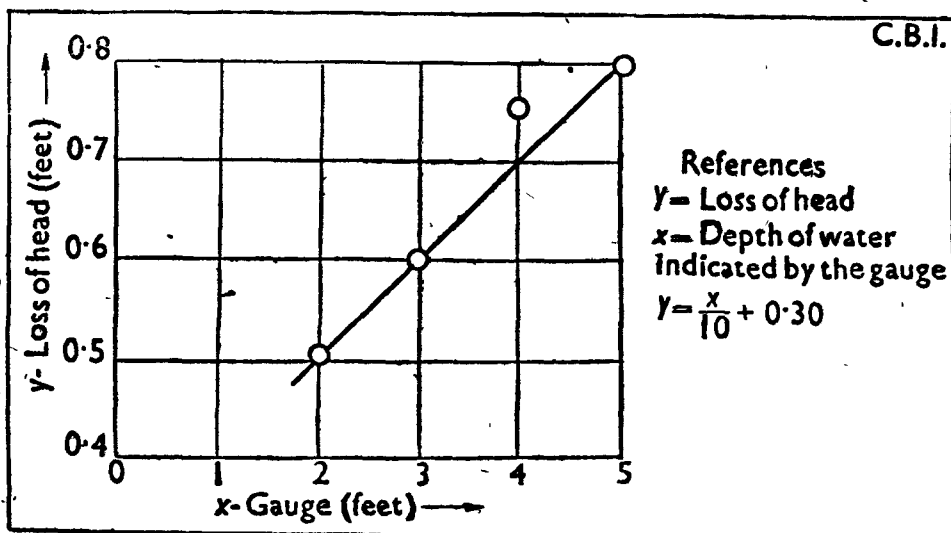


Figure 2E.7

TABLE 2E. X

| Gauge | Straight portion O.T. 1 to O.T. No. | Gradient | Flat portion gradient |
|-------|-------------------------------------|----------|-----------------------|
| 5 | 4 | 1.9 | 7.7 |
| 4 | 3 | 2.1 | 8.0 |
| 3 | 2 | 2.2 | 7.7 |
| 2 | 2 | 5.0 | 11.6 |
| 1 | .. | Reversed | 12.0 |

Neglecting gradients for one foot and two feet the rest are in close agreement. The gradient for the straight portion (1 in 2) not being influenced either by entry or draw down probably represents the true characteristic gradient for this soil. The remainder of the portion shows a tendency towards stagnation, the head having been consumed. As noticed from the asymptotic nature of the curves

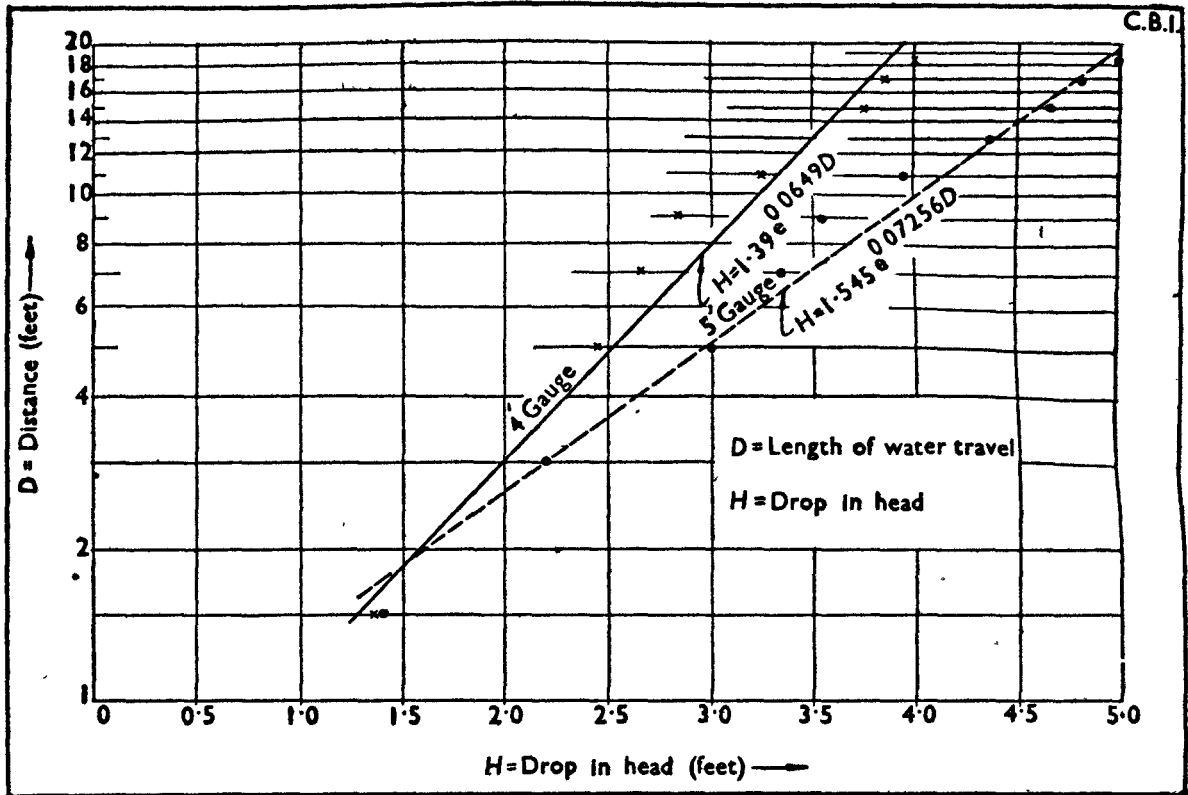
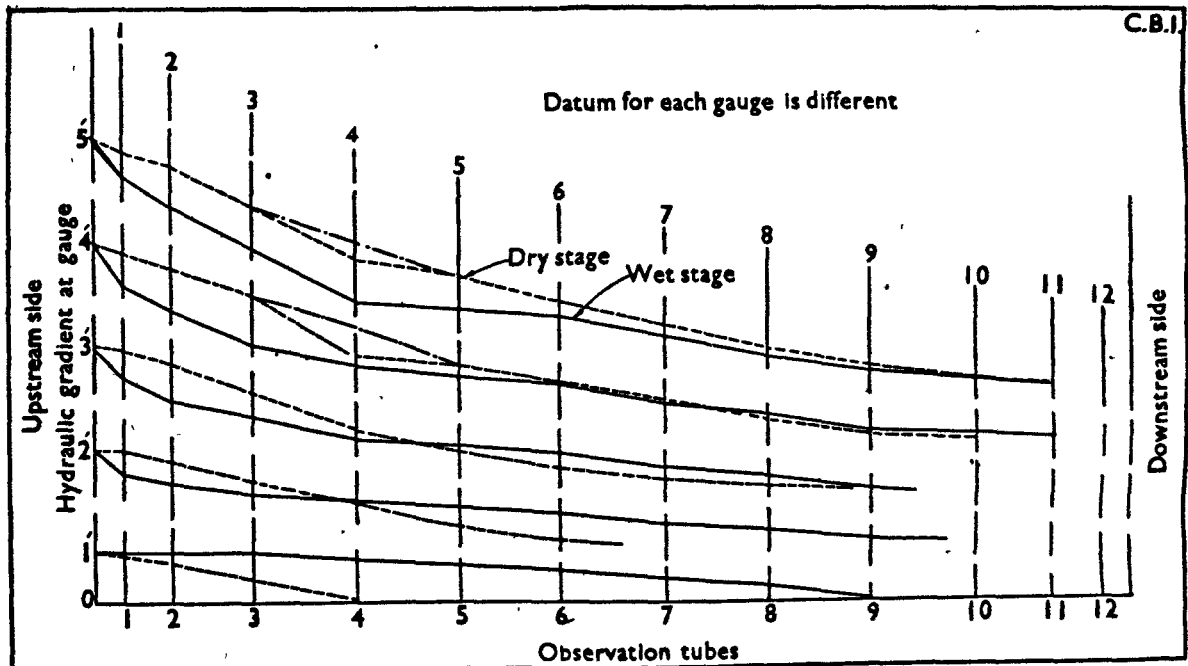


Figure 2E.8:- Hydraulic gradient experiment in Black Cotton soil showing relation between H and D



Reg. No 2717 XDD (C) 50-1.210 (P.2.0)

Figure 2E.9:- Hydraulic gradients Initial (Dry stage) & final (Wet stage) compared for each gauge



and absence of any percolation, the subsequent movement aided by absorption, evaporation and diffusion, merely resulted in stagnation or ponding.

(iii) The nature of these (drop in the line of saturation with distance) curves is exponential as shown in Table 2 E.XI.

The chamber was completely filled with the soil as the idea was not so much to investigate any particular section for a dam but to ascertain the nature of hydraulic gradient in black cotton soil in a uniformly deep soil area. The soil surface was covered with a tarpauline to prevent evaporation. A shed existed over the masonry chamber and was covered on all sides as a precaution against the effect of the sun and wind.

Water level in the upstream chamber was stepped up and maintained at each foot height (from first to fifth foot) for a sufficiently long period (one to two weeks) for the water levels in the observation tubes to attain equilibrium. The automatic feed device for maintaining a water level was used. Water levels in the two rows of observation tubes were read several times every day. The readings in all the tubes were recorded every day until when it was noticed that the water levels had attained equilibrium. Readings in the corresponding observation tubes in the two rows, with a few exceptions, were remarkably in agreement.

For water levels at six feet and above, the upstream tank was found to leak badly and a constant water level could not be maintained. It may be mentioned that there was no percolation in the downstream tank even when the water level was raised to 7.5, the soil being impervious. During the experiment, the soil, however, became more moist, whereafter readings for the first five feet though repeated several times were found to agree closely. These, however, differed from the initial readings taken by stepping up the water level foot by foot, when the soil was originally comparatively drier (15 percent. moisture content).

TABLE 2E. XI

Statement showing drop in head with distances

| Distance | Gauge 3 | Gauge 4 | Gauge 5 |
|----------|---------|---------|---------|
| 0 | 0 | 0 | 0 |
| 0.5 | 0.6 | 0.8 | 0.8 |
| 1.5 | 1.1 | 1.35 | 1.4 |
| 3.0 | 1.35 | 2.0 | 2.2 |
| 5.0 | 1.85 | 2.45 | 3.0 |
| 7.0 | 1.95 | 2.65 | 3.35 |
| 9.0 | 2.1 | 2.85 | 3.55 |
| 11.0 | 2.35 | 3.25 | 3.95 |
| 13.0 | 2.55 | 3.45 | 4.37 |
| 15.0 | 2.82 | 3.77 | 4.65 |
| 16.0 | 3.0 | | |
| 17.0 | | 3.85 | 4.8 |
| 18.5 | | 4.0 | 5.0 |

The readings for gauges 4 and 5 have been plotted on the semilog paper. It will be seen that the points lie on straight lines. The relation between H (drop in head) and D (distance of travel) is thus exponential and is shown in Figure 2E. 8 by the following equations :—

$$\text{5 feet gauge: } H = 1.545 e^{0.07256D} \quad \dots \quad (2E. 2)$$

$$\text{4 feet gauge: } H = 1.39 e^{0.0649D} \quad \dots \quad (2E. 3)$$

Figure 2 E. 9 shows the gradients for the comparatively dry condition (Figure 2 E. 5) and the moist condition (Figure 2 E. 6) of the black cotton soil on a separate datum for each of the gauges, Table 2 E. XII. It will be seen that the gradients in the latter case are lower in the upper section and higher in the lower one than those in the former (dry condition). The point of crossing advances as the gauge increases. For gauge 1 the point is the nearest and that for gauge 5 the farthest. Figure 2 E. 10 shows that the distance of the crossing is proportional to the pressure head (gauge).

$$Y \text{ (distance)} = 4 (x-1), \quad \dots \quad \dots \quad (2 \text{ E. } 4)$$

where $X =$ gauge.

Figure 2 E. 9 confirms the ponding theory. The inflow of water, however slight, and its movement further on is indicated by the gradient despite any marked drainage downstream. This could only be explained as the stagnation of water in the portion when the flow practically came to an end. This is borne out by the flattening of the gradient when the downstream slope and toe are extended by the addition of material (⁴). A slight movement is also probably caused by evaporation and diffusion through soil pores, although reduced to minimum by preventive measures.

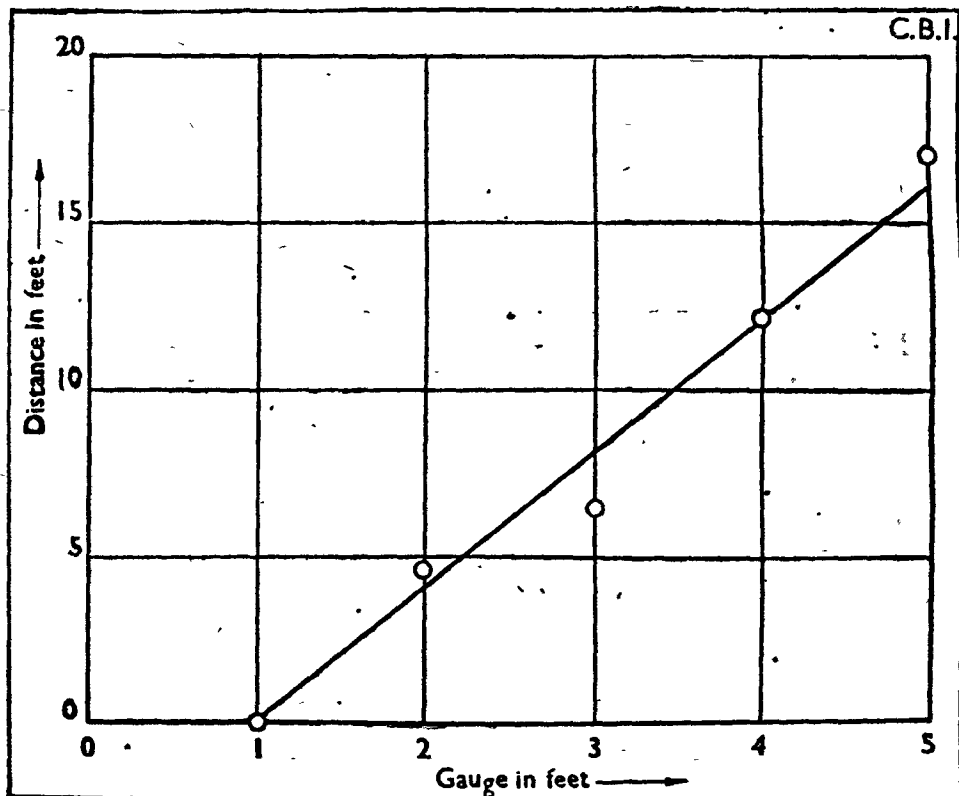


Figure 2E. 10

(⁴) Technical memorandum No. 17, United Provinces Public Works Department Irrigation Research Station Report on Research Progress during 1946. Drawing No. 1 (facing page 18).

TABLE 2 E. XII

Statement showing average gradients in different portions of the curvilinear water slopes and the overall gradients (Figure 2 E 6).

| Gauge | Steep fall at entry upto O.T. | | | Regular fall portion O.T. 1 to O. T. at kink. | | | | | Flatter or ponding portion | | | Overall gradient | | | Overall gradient in the initial stage when soil was drier. |
|-------|----------------------------------|------|---------------------------|---|------------------------|------|------------------------|------------|----------------------------|---------------------------|---------------|------------------|----------------|---------------|--|
| | W.L. in O.T. No. O. 5 : distance | Fall | Gradient for the distance | W.L. in O.T. (1) | W. L. in O.T. at kink. | Fall | Distance to kink tube. | Gradi-ent. | Fall in W.L. | Net distance for the fall | Gradient 1 in | Gauge | Total distance | Gradient 1 in | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| It. | Feet. | | 1 in | Ft. | Feet. | Ft. | Feet. | 1 in | Ft. | Feet | | Ft. | Ft. | | |
| 5 | 4.2 | 0.8 | 0.62 | 4.2 | 4)1.8 | 2.4 | 4.5 | 1.9 | 1.8 | 18.5-4.5=14.0 | 7.7 | 5.0 | 18.5 | 3.7 | 3.7 |
| 4 | 3.2 | 0.75 | 0.69 | 3.2 | 3)2.0 | 1.2 | 2.5 | 2.1 | 2.0 | 18.5-2.5=16.0 | 8.0 | 4.0 | 18.5 | 4.6 | 4.3 |
| 3 | 2.4 | 0.60 | 0.83 | 2.4 | 2)1.95 | 0.45 | 1.0 | 2.2 | 1.95 | 16.0-1.0=15.0 | 7.7 | 3.0 | 16.0 | 5.3 | 5.0 |
| 2 | 1.5 | 0.50 | 1.0 | 1.5 | 2)1.3 | 0.2 | 1.0 | 3.0 | 1.3 | 16.0-1.0=15.0 | 11.6 | 2.0 | 16.0 | 8.0 | 5.0 |
| 11 | .. | 0.4 | .. | .. | .. | .. | .. | .. | .. | 15.0-3.0=12.0 | 12.0 | 1.0 | 12.0 | 12.0 | 5.0 |

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The average gradients for the two sets of conditions are given in Table 2 E. XIII.

TABLE 2E. XIII

| Gauge | Hydraulic gradient | |
|-------|--------------------|-------------|
| | Initial dry stage | Moist stage |
| 5 | 3.7 | 3.7 |
| 4 | 4.3 | 4.6 |
| 3 | 5.0 | 5.3 |
| 2 | 5.0 | 8.0 |
| 1 | 5.0 | 12.0 |

The average gradient in either case is the same for each of the gauge, but as shown in Figure 2E. 9 the nature of the gradient is different.

Figure 2E. 11 shows the gradients observed in the very chamber under nearly similar conditions in respect of the Solani silt. It is seen that in this pervious silty material from Solani, although the hydraulic gradient H/L (total head *i.e.*, difference between upstream and downstream water levels divided by the distance) can still be said to be the same as that in the black cotton soil, the nature of the gradient is altogether different. The flatter gradient shows that water enters and flows with ease in the Solani material up to where it is disturbed by the draw down effect of the drain. This gradient is, therefore, quite the reverse of that in black cotton soil.

It would appear from the two types of gradients in Figure 2E. 11, that in earthen dams on impervious foundation under identical conditions, the gradient in a loose (homogeneous) material will be flatter (will not be affected by any appreciable loss at entry and soil resistance) but will be largely affected by the drawdown effect at the toe of the dam, and the slope of the gradient will be convex. The gradient in impervious (homogeneous) material on the other hand will be steeper at the upstream side and flatter at downstream side and its shape will be concave as shown in Figure 2E. 12.

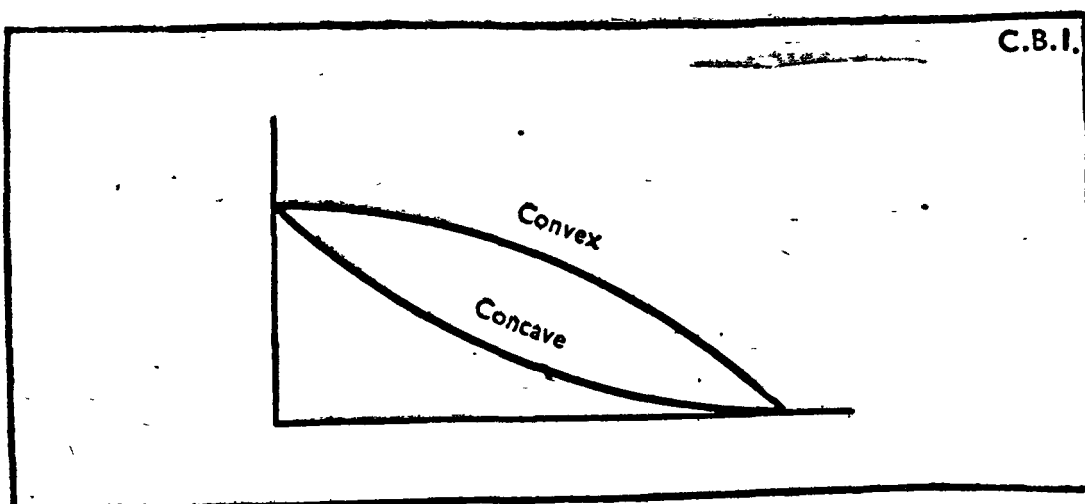


Figure 2E. 12

Water will pond and rise in the lower portion until it is able to force its way through the toe, and maintain a balance,

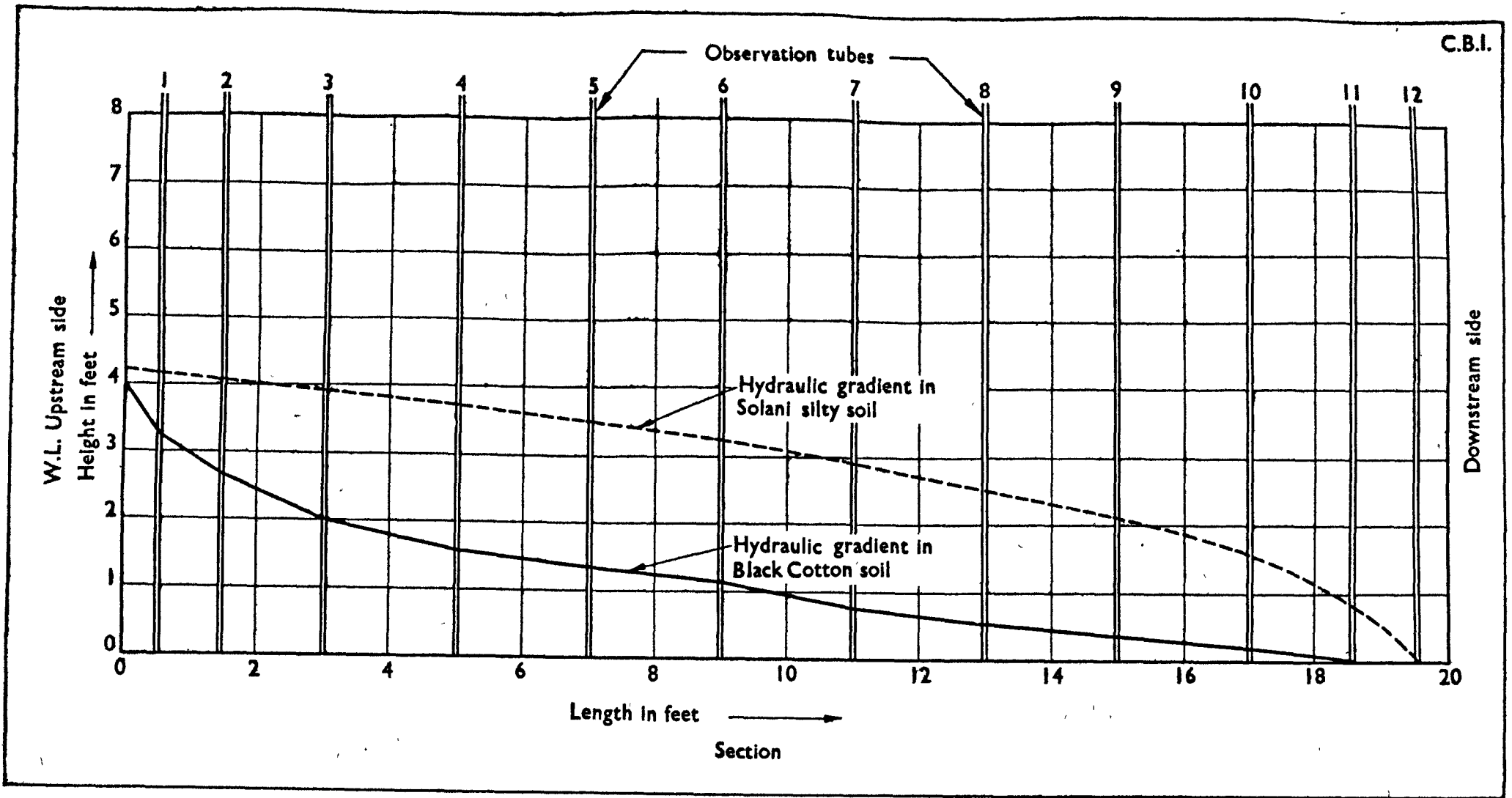
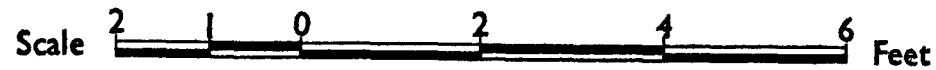
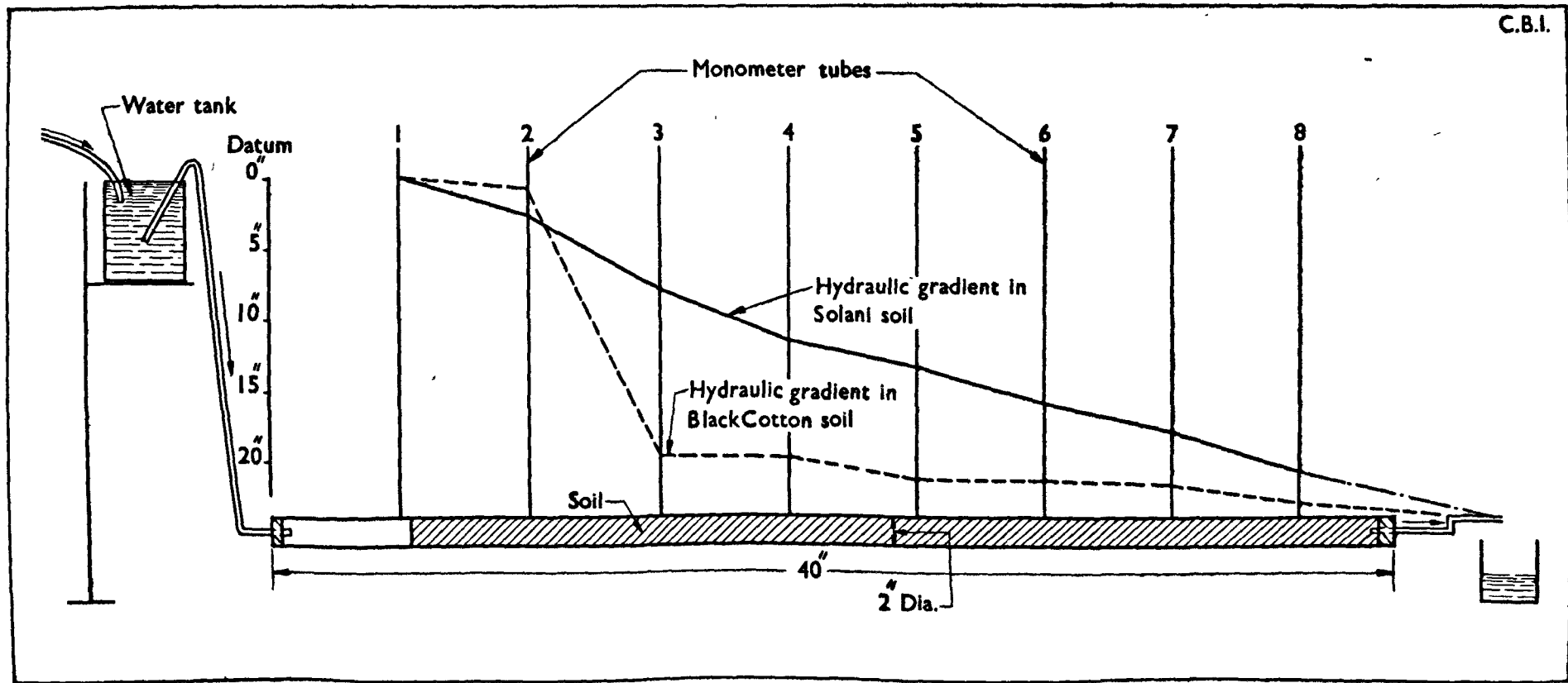


Figure 2 E.11:- Hydraulic gradients in silty soil from Solani khadir and Black Cotton soil in the Deccan





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Figure 2 E.13:- Showing the apparatus and the hydraulic gradients observed in Black Cotton soil and Solani silt

The line of saturation is thus affected by the soil material. The soil material therefore, forms one of the factors shaping the hydraulic gradient. By homogeneous material is meant a material consisting of particles of uniform diameter, irrespective of what the diameter is, or uniform texture and of uniform structure all over. Under these conditions percentage pore space and its nature is the same and independent of the material. Theoretically, a finer soil will transmit less water than a coarse one but the flow gradient will be the same in both. In actual practice soil material used in earthen dams is never homogeneous and is never packed to the same consistency throughout. The hydraulic gradient in earthen dams is besides largely affected by the entry and draw down effect at the toe and the nature of the gradient characteristic of the soil material is only to be found beyond the influence of the draw down effect as is shown in Figure 2E. 11 (or Figure 75 in the report of the Indian Waterways Experiment Station 1944 quoted above). Hydraulic gradients considered from the practical point of view, vary characteristically according to the type of material used and a knowledge of this is necessary in the design of dams.

(4) HYDRAULIC GRADIENTS IN SOILS (LABORATORY EXPERIMENTS) (5)

The results of the observations on hydraulic gradients in black cotton soil carried out in the masonry chamber at Khadakwasla are described in item (3) above. Experiments carried out with Solani silt and black cotton soil under controlled laboratory conditions are described in this note.

The apparatus used consisted of a glass tube two inches diameter, 40 inches long, with side tubes $\frac{1}{4}$ inch diameter, 4 inches long, spaced 4 inches apart. The complete arrangement of the experiment including the upstream water tank, the manometer tubes and the downstream exit end is shown in Figure 2E. 13. The manometer tubes extended to the centre of the glass tube so that they were in contact with the water flowing through the soil bulk.

The Solani silt and black cotton soil were packed in the glass tubes as uniformly as possible. The Dry Bulk Density obtained after packing was 1.233 in the case of black cotton soil and 1.381 in the case of Solani silt. The soils were allowed to saturate under constant hydrostatic head and the water levels were observed when they attained equilibrium. These water levels have been plotted in Figure 2E. 13.

From the figure it will be seen that the gradient in the case of Solani silt from tube No. 2 to tube No. 8 is 1 in 1.48, that in the case of black cotton soil is 1 in 0.237 from tube No. 2 to tube No. 3 and from tube No. 3 to tube No. 8 it is 1 in 6.5.

The percolation obtained in the case of Solani silt was 138 cc. per day and that in the case of black cotton soil 4 cc. per day. This gave a permeability coefficient of 0.000202 foot per minute and 0.0000608 feet per minute respectively in the case of Solani silt and black cotton soil.

From the figure it is seen that the gradient in the case of Solani silt is practically straight upto tube No. 4, tending to become convex further down, while that in the case of black cotton soil is concave.

This experiment confirms the conclusion of item No. (3) above that the soil material forms one of the factors shaping the hydraulic gradient.

(5) Poona Irrigation and Research Division, Public Works Department, Bombay, Poona, Annual Report, 1947, page 47.

(5) HYDRAULIC GRADIENTS IN CANAL BANKS (6)

ABSTRACT

The Nirā Left Bank Canal appeared to leak in several places and it was proposed to construct seepage drains along the toe of the embankments to keep the banks, dry, and obviate the danger of their slipping. Advantage of this was taken to observe hydraulic gradients in canal banks before and after drainage.

A cross section was taken near the Aqueduct No. 16, at mile 50, 2 furlongs, 100 feet, for this purpose (See Figure 2E. 14). Figure 2E. 14 also shows damage by seepage which is, however, slight. The bank is of black soil with a casing of coarse *murum*, Figure 2E.15. Sand is found in the last two pits (Nos. 6 and 7) near the toe. Bores were taken at the positions shown and water levels were observed daily during the running and closure periods of the canal, Table 2E. XIV). Water levels in the bores corresponding to the water flowing in the canal (at particular canal gauge) are shown in Figure 2E.16 and these represent the seepage flow gradients in the canal bank.

Curves (a) and (b) serial No. 3 and 5 of Table 2E. XIV show gradients when the canal was running for long periods of 19 and 22 days respectively at about nearly the same canal gauge and when water levels had become stable.

There is a sharp drop or rapid change in gradient, known as ground water cascade, from pit No. 5 to pit No. 6 due to the presence of a pervious material in pits, No. 6 and No. 7. Uniform material (black *chopan*) occurs upto pit No. 5 only. From pit No. 3 to pit No. 5, the water line is almost horizontal indicating little flow through the bank. The actual true gradient for the soil materials occurs from pit No. 1 to pit No. 3. The rapid fall from water edge to pit No. 1 being mainly due to resistance at entry. Water gradient from pit No. 1 to pit No. 3 works out to 1 in 5 which represents the true gradient characteristic for this soil. The nature of hydraulic gradient in the stiff black (*chopan*) soil is similar to the one explained in item (3) above for the black cotton soil. The little slope from pit No. 3 to pit No. 5 represents the ponding zone explained in that note and this field observation fully confirms the findings of laboratory experiment. Curve (c) shows the condition during a long closure (11 days). There was no water in the pits except in the sandy pits No. 6 and 7 at the toe. The gradients (a) and (b) showed little leakage during flow period and the leakage during the closure from the stagnant water in the canal must be very little, if any. The water level at the toe (pit No. 7) is only slightly lowered. The presence of water along the toe must be, therefore, due to seepage from the portion of the natural ridge higher up and not due to water seeping through the bank at this point. Curve (d) is a typical case for the flow period extending from October, 20, 1947 to December 23, 1947 viz., two months and curve (e) for a short closure of two days. These results substantially confirm what has been stated before viz., water gradient is 1 in 5 for black *chopan* soil. No drains have been constructed for this seepage section yet.

Another cross section was taken near aqueduct No. 15 at mile 47, furlong 1, feet 100 of Nira Left Bank Canal, (Figure 2E. 16). The soil section (Figure 2E.18) consist of black soil on a layer of black *chopan* which in a constructed

(6) Poona Irrigation and Research Division, Public Works Department, Bombay, Poona, Annual Report, 1947, pages 48-53.

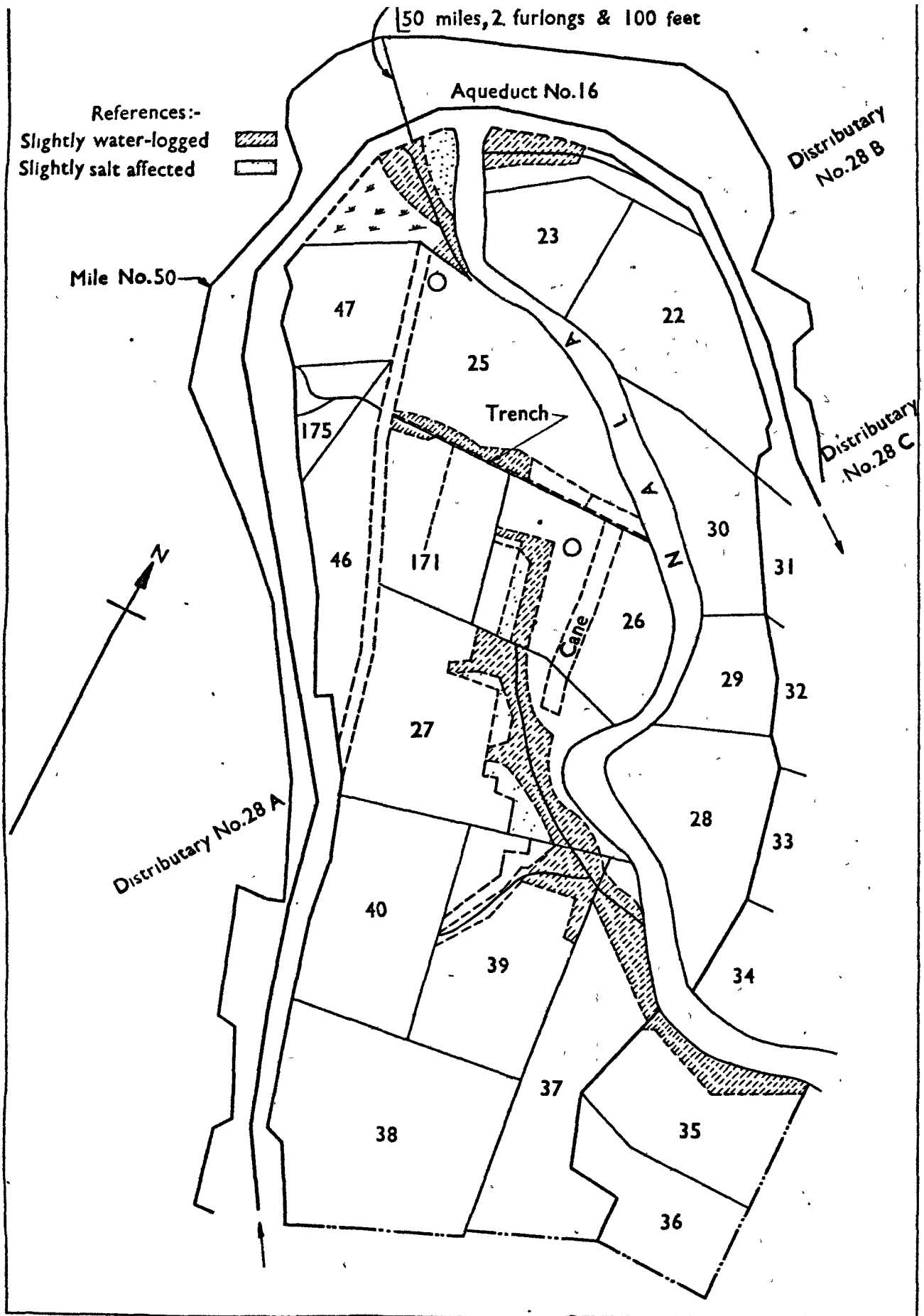


Figure 2E.14:- Showing position of cross section taken for hydraulic gradient observation in canal bank [Nira left bank canal]

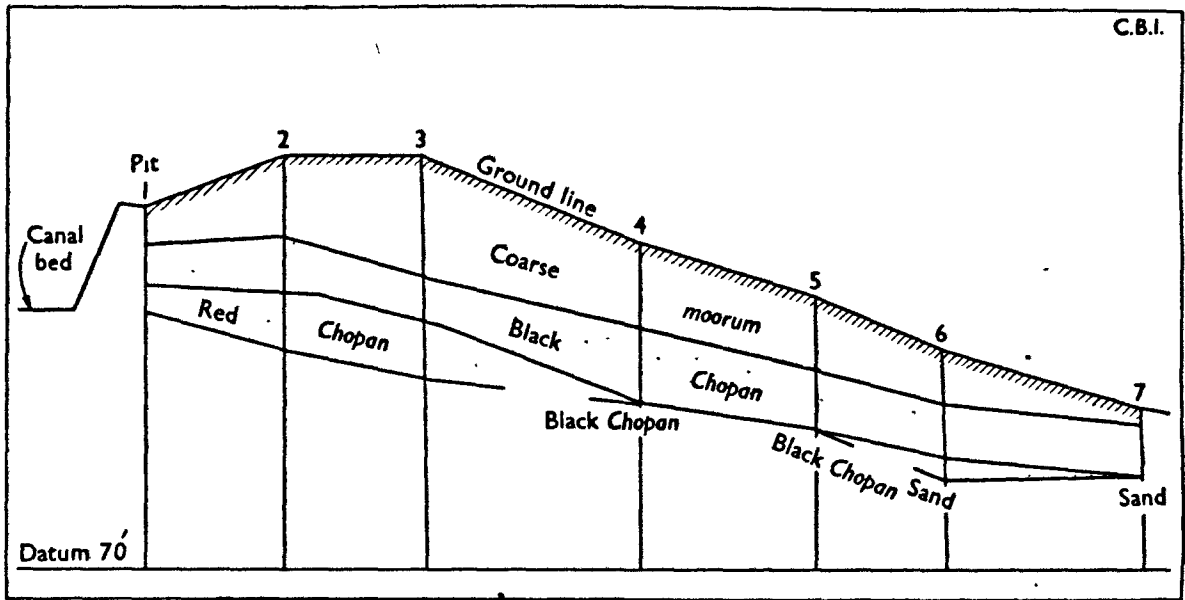


Figure 2E.15:- Cross section near Aqueduct No.16 showing soil section

Scale 10 5 0 10 20 Feet

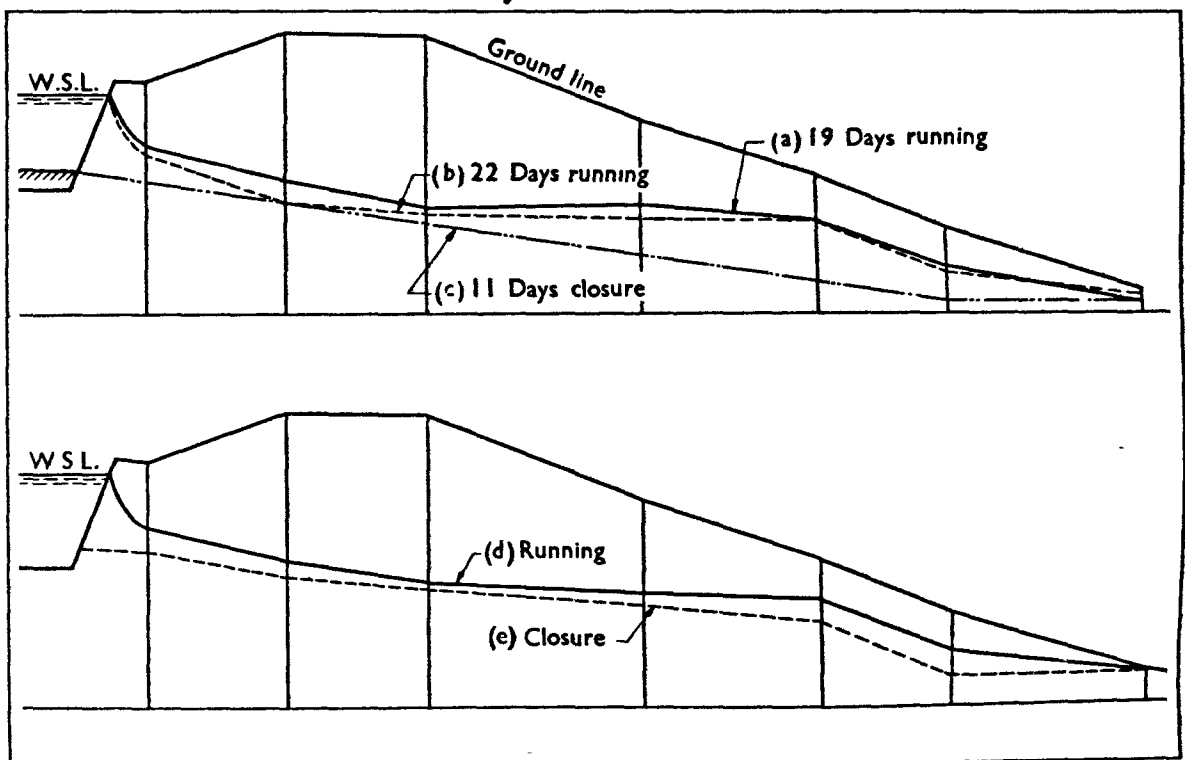


Figure 2E.16:- Hydraulic gradient in canal bank during running and closure of the canal

Scale 10 5 0 10 20 Feet

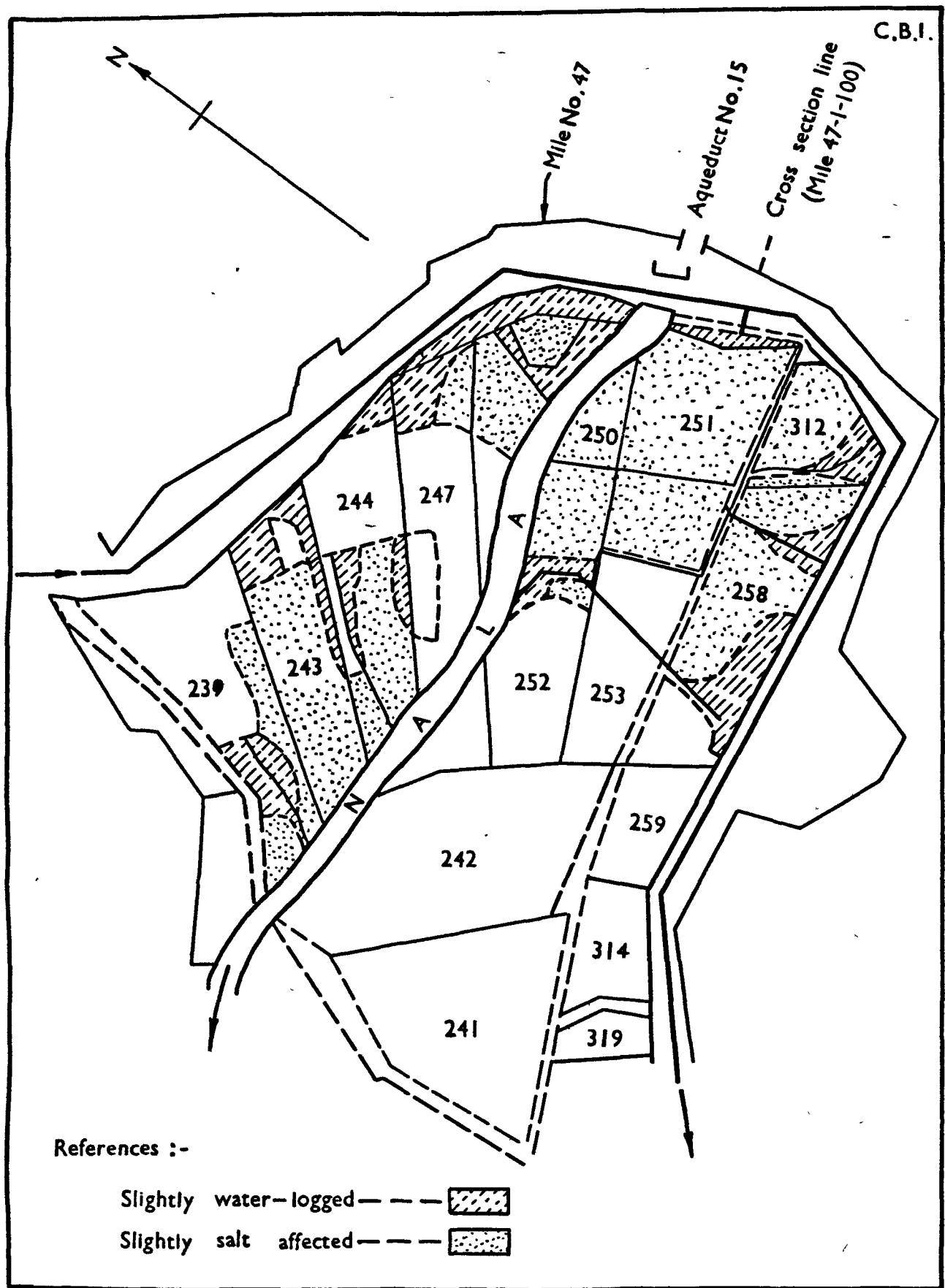


Figure 2E.17:- Showing position of cross section taken for hydraulic gradient observation in canal bank [Nira Left Bank Canal, Aqueduct No.15]

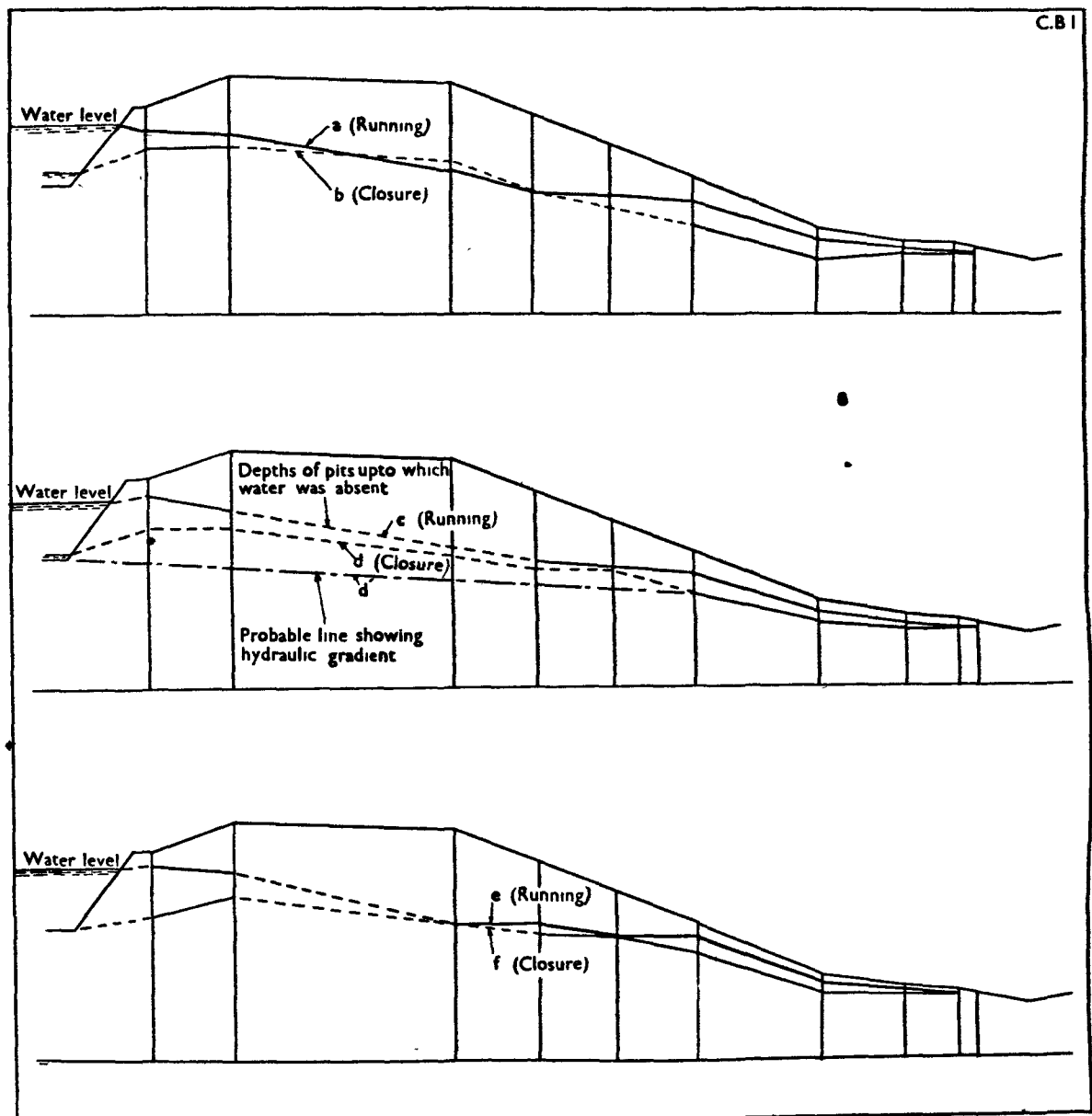
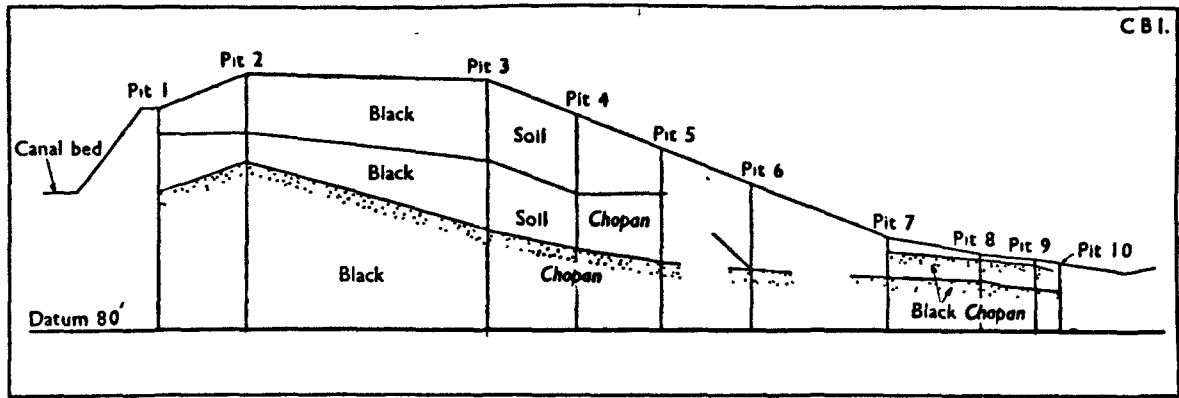


Figure 2E.18(Top):-Cross section near Aqueduct No.15 showing soil strata
(Nira left bank canal)

(Bottom).- Hydraulic gradient in canal bank during running and
closures of the canal

Scale 10 5 0 10 20 30 40 50 Feet

Water levels in pits for Hydraulic Experiment in mile No. 0/2 on Nira Left Bank Canal

| Serial No. | Rotation period 1947 | Gauge from canal girder | Pit No. 1 | Pit No. 2 | Pit No. 3 | Pit No. 4 | Pit No. 5 | Pit No. 6 | Pit No. 7 | Remarks |
|------------|------------------------------------|-------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|------------------|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1 | August 1 to August 6 | 3.77 | 5.31 | 11.22 | 13.27 | 7.16 | 3.75 | 3.50 | 1.95 | Running 7 days. |
| 2 | August 7, to August 8 | 8.06 | 6.75* | 13.0* | 14.0* | 8.95 | 5.81 | 4.35 | 1.17 | Closure 2 days. |
| 3 | August 9 to August 27 | 3.87 | 4.98 | 10.87 | 12.87 | 6.35 | 3.58 | 3.17 | .85 | Running 19 days. |
| 4 | August 28, to August 30 | 7.46 | 7.08* | 11.72* | 13.66* | 9.09 | 5.00 | 4.03 | 1.00 | Closure 3 days. |
| 5 | August 31 to September 21 | 3.96 | 5.23 | 12.48 | 13.35 | 7.52 | 4.18 | 3.49 | .95 | Running 22 days. |
| 6 | September 22 to September 25 | 5.06 | 7.02* | 13.09* | 14.17* | 8.42 | 5.19 | 3.51 | 1.00 | Running 4 days. |
| 7 | September 26 to September 27 | 4.27 | 5.95 | 13.33* | 14.17* | 9.58 | 6.34 | 4.21 | 1.00 | Running 2 days. |
| 8 | September 28, to October 8 | 8.95 | 7.17* | 13.33* | 14.17* | 9.92 | 7.12 | 5.14 | 1.19 | Closure 11 days. |
| 9 | October 9 to October 15 | 4.58 | 5.11 | 11.47 | 13.78* | 3.49 | 5.13 | 4.03 | .96 | Running 7 days. |
| 10 | October 16 to October 19 | 7.54 | 7.17* | 13.33* | 14.17* | 7.17 | 6.58 | 4.46 | 1.06 | Closure 3 days. |
| 11 | October 20 to October 31 | 4.36 | 4.81 | 11.07 | 12.39 | 7.17 | 4.61 | 3.60 | .93 | Running 12 days. |
| 12 | November 1 to November 15 | 4.16 | 4.38 | 10.43 | 12.60* | 6.72 | 3.81 | 3.29 | .81 | Running 16 days. |
| 13 | November 17 to November 30 | 4.02 | 4.79 | 10.50 | 12.07 | 5.56 | 3.14 | 2.88 | .60 | Running 14 days. |
| 14 | December 1 to December 23 | 3.98 | 5.69 | 11.29 | 12.72 | 4.97 | 3.63 | 3.32 | .70 | Running 23 days. |
| 15 | December 24 to December 25 | 8.60 | 6.83 | 12.0 | | | 4.75 | 4.90 | .81 | Closure 2 days. |
| 16 | December 26 to December 31 | 4.48 | 6.14 | 11.69 | 12.28 | | 4.55 | 3.71 | .81 | Running 6 days. |

*No water in the pits.

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bank only means more consolidated black soil. Water levels during different periods are shown in Table 2-E XV.

Curve (a) shows the gradient during a continuous running of the canal for 7 days. Due to overlying (loose) black soil, there does not appear any loss at entry. The gradient is almost straight upto pit No. 4 beyond which the stagnation or pending effect is seen by the horizontal water line. The hydraulic gradient from pit No. 2 to pit No. 4 is 1 in 5. From pit No. 6 to pit No. 10 at the toe the water level is kept low probably by evaporation. The falling gradient is mostly due to the sloping face of the embankment causing a reduction of flow section necessitating a steeper gradient to pass the discharge.

This has been observed in the case of Solani experiment at Khadakwasl (Annual Report I.W.E. Station Poona 1944, Page 61. Curve (b) shows the conditions during a closure of three days. A reversion of gradient from pit No. 2 towards the canal (due to fall in water level in the canal) is seen. The explanation is that the underlying layer of consolidated black soil does not relinquish its water very rapidly. Probable gradient towards the toe is also indicated by a dotted line.

Curve (c) shows the gradient during running of the canal for 22 days. The gradient is 1 in 5 from pit No. 1 to pit No. 3 and 1 in 6 upto pit No. 4. Curve (d) for a closure for 11 days and none of the pits showed any water level above the limit shown by the dotted line.

A probable line of water levels is shown by the curve (d). Curve (e) is again for long running of the canal (23 days). The gradient (pit No. 1 to pit No. 3) is 1 in 4.6.

Curve (f) is for a short closure of two days following the above mentioned running of the canal. No drains have been excavated yet for draining the toe.

One more observation was taken at the cross section in mile 35, 1 furlong 0 feet of the Nira Left Bank Canal, Figure 2E-19. The soil section (Figure 2E-20) shows *chopan* materials of various sorts. *Chopan* is an impervious material. *Murum* is noticed in pits No. 3 to No. 8 but not in pits No. 1 and No. 2 near the canal. This *murum* is probably a continuation of the *murum* ridge at mile 44 (Figure 2E-21). Longitudinal section of canal and this appears mainly responsible for the damage in S. No. 304, 317 and 177 (Figure 2E-19). Depressions on either side of the ridge (mile 44) are running towards the *nalla*. Drains have been constructed as shown in the Figures 2E-19 and 2E-20. The drains are actually choked and practically carry no discharge. Seepage water from the *murum* cutting flows along the natural depression and not through the drains. The construction of the rubble drains have, practically had no effect on the low lying portion near the aqueduct and the conditions have remained as they were.

Gradients (a) and (b) in Figure 2 E-20 show the conditions during two running periods of 10 and 23 days. The nature of the gradients show absence of any seepage from the canal. On the contrary a tendency of the flow towards the canal, is noticed. It is also seen that the rubble drains is not draining the toe but is feeding water to it. Gradient (c) shows conditions

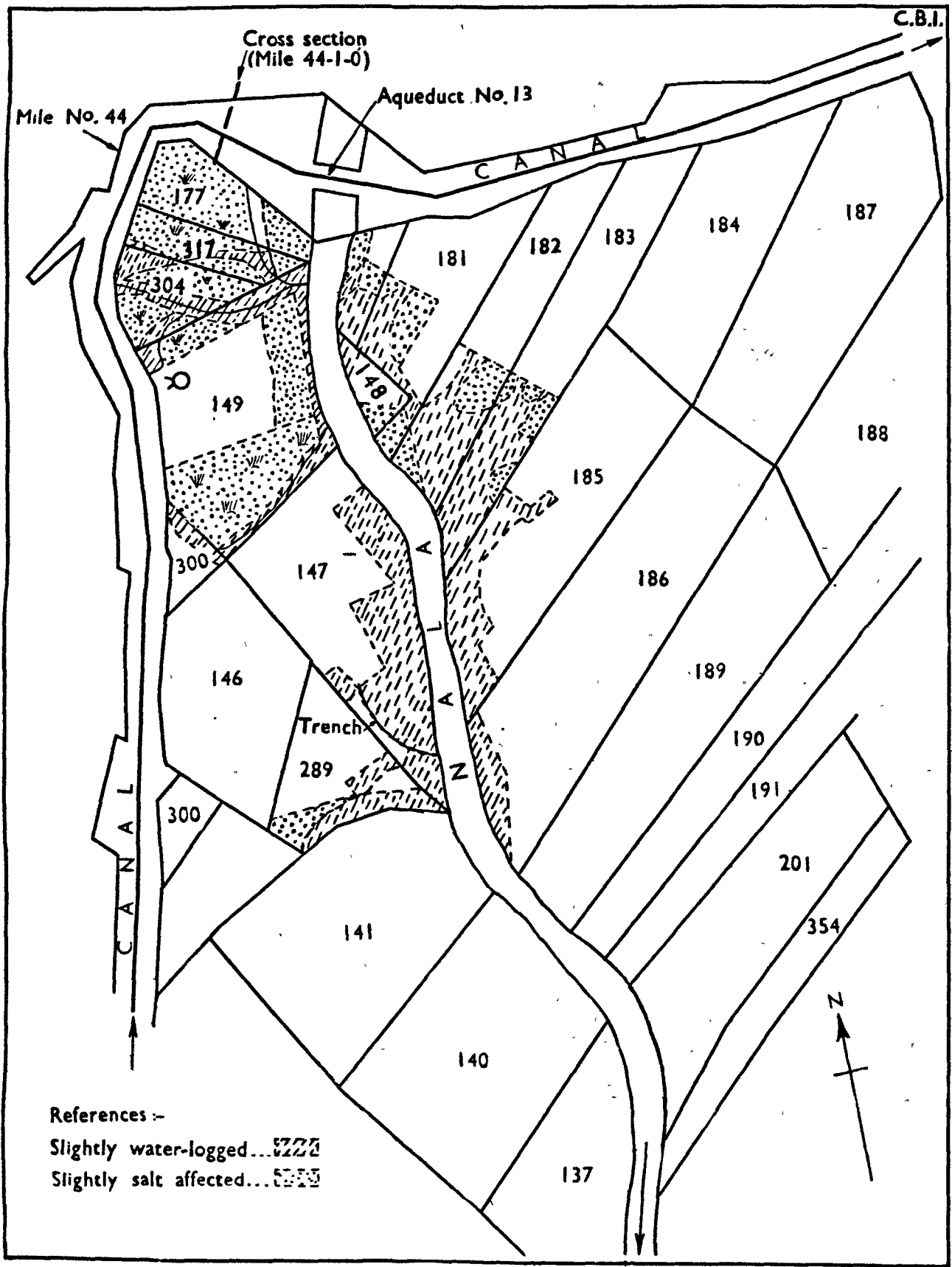


Figure 2E.19:- Showing position of cross section taken for hydraulic gradient observation in canal bank (Nira Left Bank Canal, Aqueduct No. 13)

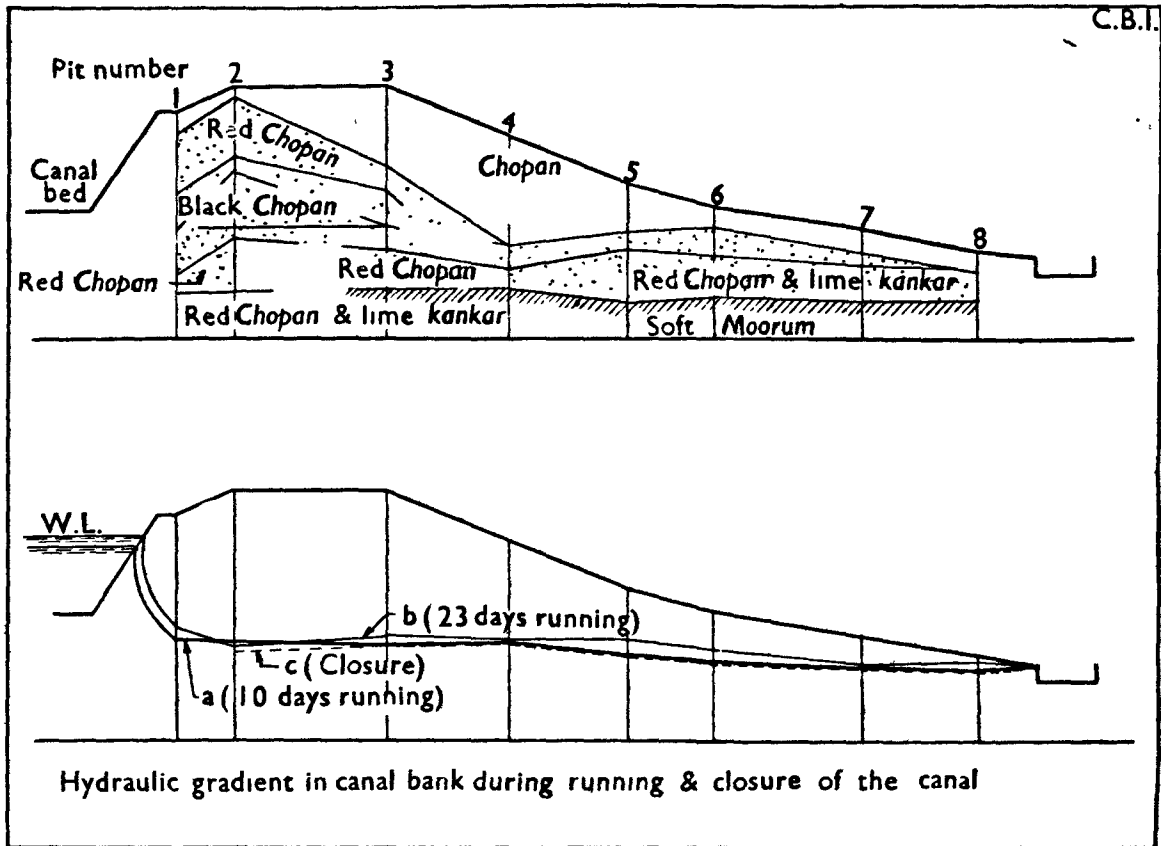


Figure 2E.20:- Cross section near Aqueduct No.13 showing soil strata

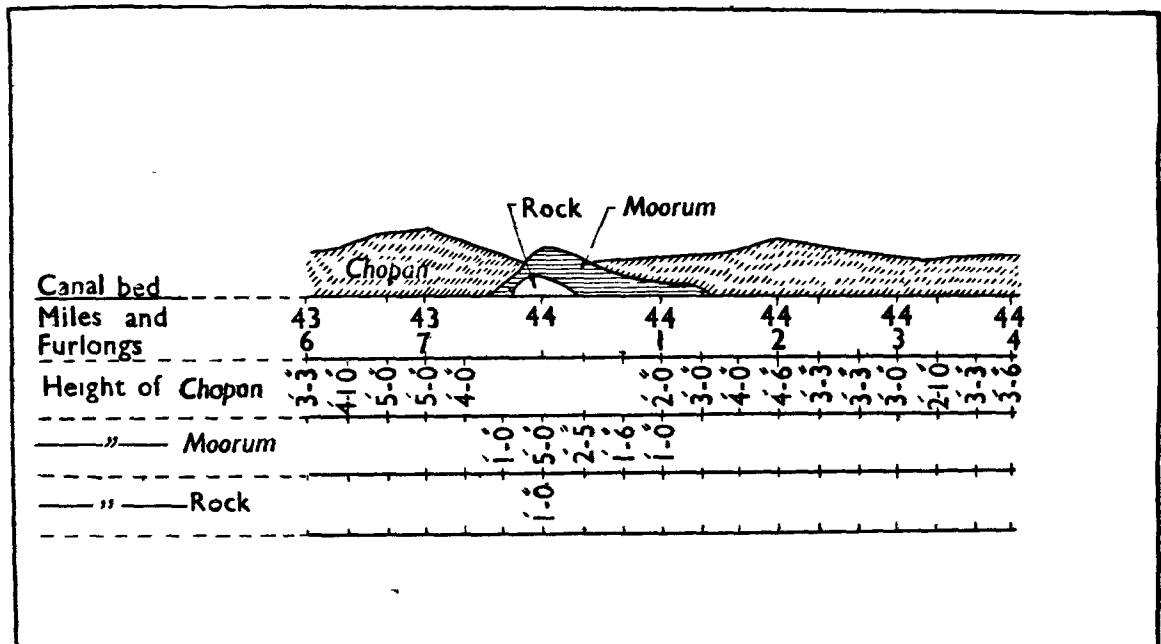
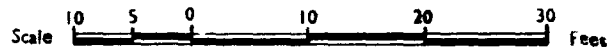
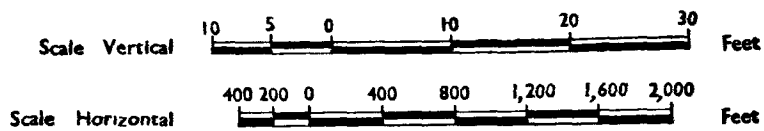


Figure 2E.21:- Longitudinal section of canal showing strata cut in mile No.44&45



| Serial No. | Rotation period. 1947 | Gauge from Canal Girder R.L.— 100·00 | Pit No. 1 | Pit No. 2 | Pit No. 3 | Pit No. 4 | Pit No. 5 | Pit No. 6 | Pit No. 7 | Pit No. 8 | Pit No. 9 | Pit No. 10 | Remarks |
|------------|------------------------------------|--------------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|------------|------------------|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 1 | August 1 to August 6 | 2·41 | 2·36 | 5·45 | 8·46 | 7·40 | 4·85 | 2·20 | ·85 | ·30 | ·58 | ·70 | Running 7 days. |
| 2 | August 7 to August 8 | 6·88 | 4·33 | 3·58 | 8·25 | 8·58 | 5·97 | 3·29 | 2·0 | 1·16 | 1·02 | ·96 | Closure 2 days. |
| 3 | August 9 to August 27 | 1·70 | 1·46 | 4·84 | 7·25* | 7·00* | 4·65 | 2·07 | ·65 | ·30 | ·64 | ·73 | Running 19 days. |
| 4 | August 28 to August 30 | 6·72 | 3·03 | 6·54 | 7·25* | 7·00* | 7·00 | 4·13 | 2·98 | ·96 | ·96 | ·89 | Closure 3 days. |
| 5 | August 31 to September 21 | 2·14 | 1·59 | 5·17 | 9·50* | 7·27 | 4·92 | 2·11 | 1·1 | ·63 | ·79 | ·79 | Running 22 days. |
| 6 | September 22 to September 25 | 2·92 | 4·61 | 7·05 | 9·50* | 7·00* | 3·61 | 2·83 | 1·89 | 1·0 | ·99 | ·91 | Closure 4 days. |
| 7 | September 26 to September 27 | 2·92 | 2·80 | 6·14 | .. | 7·58* | 4·38 | 2·46 | 1·44 | ·94 | ·96 | ·85 | Running 2 days. |
| 8 | September 28 to October 8 | 7·24 | 4·66* | 7·50* | .. | 8·00* | 4·61* | 3·74 | 1·92 | 1·18 | 1·02 | ·92 | Closure 11 days. |
| 9 | October 9 to October 15 | 2·51 | 1·93 | 5·14 | .. | 7·83 | 4·75* | 2·62 | 1·51 | 1·03 | ·94 | ·87 | Running 7 days. |
| 10 | October 16 to October 18 | 6·65 | 4·16 | 7·07 | .. | 7·92* | 5·38* | 3·23 | 1·90 | 1·27 | ·93 | ·90 | Closure 3 days. |
| 11 | October 19 to October 31 | 2·49 | 2·02 | 5·52 | .. | 7·30 | 4·98 | 2·32 | 1·42 | ·97 | ·97 | ·89 | Running 13 days. |
| 12 | November 1 to November 15 | 2·02 | 1·65 | 4·93 | .. | 6·57 | 4·21 | 1·70 | ·98 | ·68 | ·78 | ·72 | Running 15 days. |
| 13 | November 16 to November 30 | 1·80 | 1·52 | 4·93 | .. | 6·52 | 3·62 | 1·58 | ·63 | ·23 | ·55 | ·65 | Running 15 days. |
| 14 | December 1 to December 23 | 1·84 | 1·44 | 4·73 | .. | 6·24 | 4·18 | 1·49 | ·63 | ·23 | ·51 | ·62 | Running 23 days. |
| 15 | December 24 to December 25 | 6·83 | 4·53 | 6·75 | .. | 6·71 | 3·96 | 2·58 | 1·34 | ·79 | ·70 | ·70 | Closure 2 days. |
| 16 | December 26 to December 31 | 1·72 | 1·50 | 5·11 | .. | 6·34 | 4·00 | 1·78 | ·94 | ·81 | ·82 | ·71 | Running 6 days. |

*No water in the pits.

MOVEMENT OF MOISTURE

during a short closure preceding two running periods. The small variation noticed in these three gradients (a), (b) and (c) confirms that the bank is absolutely water tight and there is no seepage. If there is formation of liquid mud in this area, it is due to the water flowing in the depressions. This is evidently brought down from other sources *viz.*, percolating *murum* bridge or the junction of the cutting and embankment.

The banks are nearly 15 feet high and yet our observations show that there is no danger of this portion of the embankment slipping. The water-logged portion near the toe is due to the choking up of the nalla and want of sufficient grading to the nalla course.

CONCLUSIONS

Hydraulic gradients in stiff black soil in these cases are of the order of 1 in 5 to 1 in 6 (cross section near Aqueduct 16 and 15). *Chopan* is absolutely water tight and there is no gradient (cross section near Aqueduct 13). Gradients in black soil in the canal bank discussed above fully confirm the findings of the model experiment [item (3).]

6) MOVEMENT OF SUB-SOIL WATER TABLE AND FLOW GRADIENTS⁽¹⁾

ABSTRACT

Lay of the sub-soil water table, its relation, if any, with the configuration of the land and fluctuation in the water table consequent on the addition (irrigation) and the depletion (drainage) of water are points of great interest in hydrology. The cases investigated in this connection are from an area on (1) the Godavari Left Bank Canal Distributary No. 6 and (2) the Pravara Left Bank Canal, distributary No. 5.

Small areas with uniform sub-soil conditions and such as are least affected by local and extraneous factors were selected. The areas under investigation were divided into smaller suitable squares and auger pits (six inches in diameter) were taken on the corners of these squares. The pits were about 10 feet deep and penetrated a uniform sub-soil material. Water levels in the pits were observed until they were at equilibrium. Flow gradients were worked out along the lines of flow. Variations in water levels being narrow, the sub-soil water table is in a state of continuous, slow and uniform motion under a constant head of pressure. An attempt was made to observe if the flow gradient under the conditions mentioned is characteristic of the sub-soil material through which the water flowed.

Figure 2E-22 an index plan, shows the area selected for observation of Distributary No. 6 Godavari Left Bank—canal. It also shows the positions of the distributary, drainage trenches provided and other details.

Figure 2E-23 is an enlarged plan which shows the ground contours, water contours and sub-soil material in the pits at about 10 feet.

It will be seen that many of the pits near about the Distributary are dry but a uniform water table occurred in the *Man* (massive *kankar*) zone and the *Chopan* Zone shown in different outlines.

⁽¹⁾ Poona Irrigation and Research Division, Public Works Department, Bombay, Poona Annual Report 1947, pages 46—56.

Man or massive *Kankar* is a pervious material consisting of fine sand cemented with lime. The material is fissured throughout and is pervious on that account.

Chopan is a yellowish clay material more or less impervious.

Physical analysis of *man* (massive *Kankar*) and *Chopan* by the International method is given in Table 2 E-XVI.

TABLE 2 E-XVI

| Composition | Massive <i>Kankar</i> (percent.) | <i>Chopan</i> (percent.) |
|--|---|-----------------------------|
| Clay 0.002 and less mm. diameter | 36.25 | 50.75 |
| Silt. 0.002 to 0.02 mm... .. . | 25.00 | 14.0 |
| Fine sand 0.02 to 0.2 mm. | 16.73 | 7.64 |
| Sand. 0.2 to 2 mm. | 3.4 | 2.4 |
| CaCO ₃ | 11.5 | 14.72 |
| Moisture and loss on ignition | 7.0 | 10.00 |

It will be seen from Figure 2E-23 that ground fall is from west to east whereas the water contours fall from north to south. In fact water contours are at right angles or normal to the ground fall, which is rather peculiar for this area. It means the sub-soil water is mainly flowing in the valley along the drain fall.

A section (Figure 2E-24) is drawn along the direction of the flow of the water table. The Section runs into both the zones, *Man* (Massive *kankar*) and *Chopan*. The flow gradient in the pervious *Man* (massive *kankar*) Zone is of the order of 1 in 1350 (Pits 63 to 60) and that in the impervious *Chopan* of the order of 1 in 225 (Pits 60 to 57).

The observations were repeated in another area which consisted of *Chopan* only.

Figure 2E-25 an index plan shows the area selected on Distributary 5, Pravara Left Bank Canal and its surroundings, positions of the Distributary and drain etc.

Figure 2 E-26 an enlarged plan shows the ground and the water contours.

It will be seen that the water contours are falling in a definite direction (North West to South East)—regardless of the ground fall which is irregular. The water contours are approximately normal to the distributary and the drain. The gradients are sharply bent near the drain as is natural. The water contours have a definite direction of fall and two cross sections (Figure 2 E-27) are plotted along the line of flow. The average gradients in the two sections CD and EF are 1 in 246 and 1 in 250 respectively.

These results are in agreement with those for *chopan* given above.

SUMMARY AND CONCLUSIONS

Water levels in the equally spaced bores, give the lay of the water table. The water table bears little relation to the ground fall.

The movement of water is through the sub-soil valley and normal fall (or distributary and drain). Flow gradients are generally characteristic of the sub-soil material. In *Man* or Massive *Kankar* which is pervious, the gradient is about 1 in 1350. In *chopan*, which is impervious, it is about 1 in 225 to 150.

DISCUSSION BY THE RESEARCH COMMITTEE

DR. BOSE introduced item (1).

DR. DHAWAN introduced item (2) and said that the method for the determination of field capacity and the effect of clay, and initial moisture content had been dealt with in the last year's annual report. The effect of various salines and the humus was determined. The results showed that there was an appreciable decrease in the field capacity of soils by the addition of Sodium Chloride, while Sodium Sulphate did not affect it very much. Calcium Sulphate increased the field capacity to a very small degree. There was gradual increase in the field capacity with the increase in the humus.

Introducing item (3) MR. NAEGAMVALA said that experiments were conducted in Poona for the sake of the Gangpur Storage Reservoir.

DR. GOKHALE described the experiment in which a typical black cotton soil was rammed in a masonry chamber (20 feet \times 6 feet \times 8 feet). This chamber was connected to an upstream tank by a screen partition. Similarly there was a downstream tank for measuring percolation. The water level was maintained at depths varying from one to five feet and water levels were observed daily in observation tubes spaced at suitable intervals until the water levels were stable. These indicated the mean line of saturation (water gradient) in black cotton soil under the conditions mentioned.

This gradient was compared with that obtained for the Solani silt in the very chamber under almost similar conditions.

The nature of the curves was different in the two soils: (1) that for the black cotton soil being concave, and (2) that for the Solani silt convex. The experiment showed that the mean line of saturation (water gradient) was affected by the soil material also. This was contrary to the statement made on mathematical reasoning that the hydraulic gradient was independent of the soil material provided it was homogeneous. A further laboratory experiment as per item (4) in glass tube with these very soils confirmed this.

Referring to item (5) he said that the saturation lines in canal banks during continuous running of the canal at a definite gauge corroborated the statement made above.

Item (6) gave the flow gradients of sub-soil water. These were characteristic of the sub-soil strata through which water flowed. Water contours were normal to the ground slope on either side and the flow was mainly in the valley

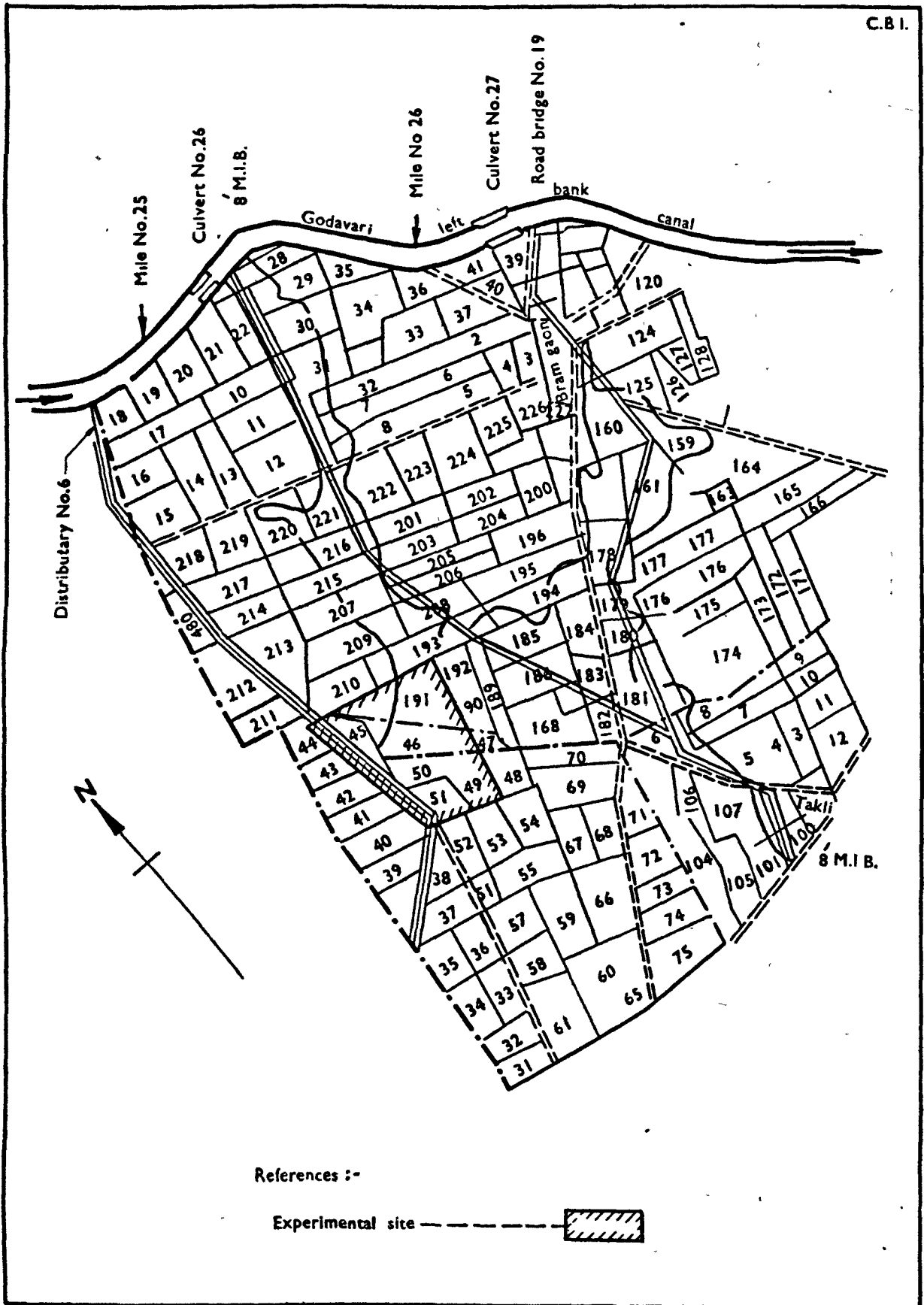


Figure 2E.22:- Showing hydraulic gradient observation area Distributary No.6
Godavari Left Bank Canal



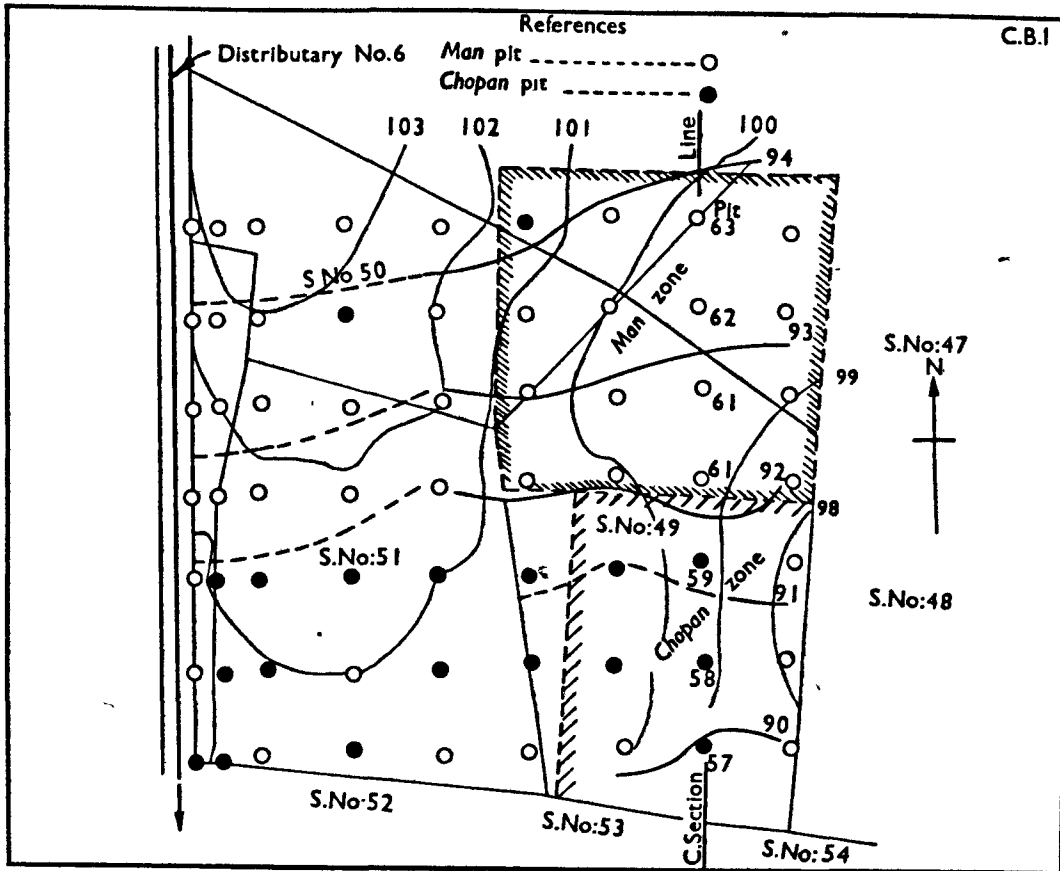


Figure 2E.23:- Showing hydraulic gradient observation area on Distributary No.6 Godavari Left Bank Canal

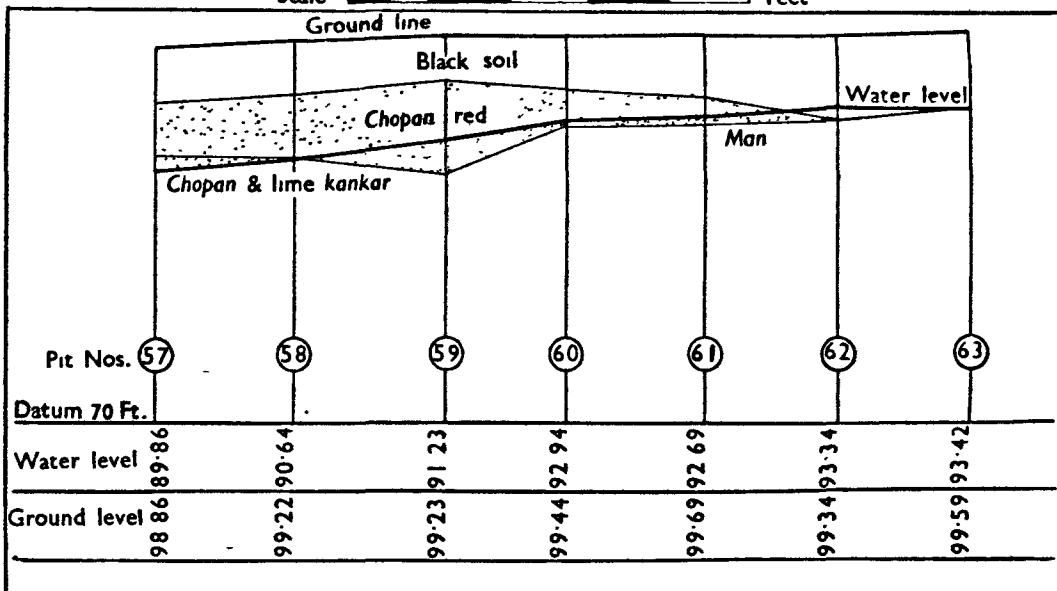
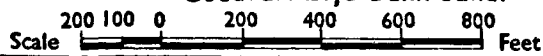
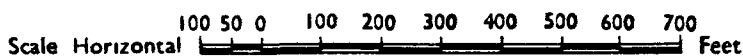
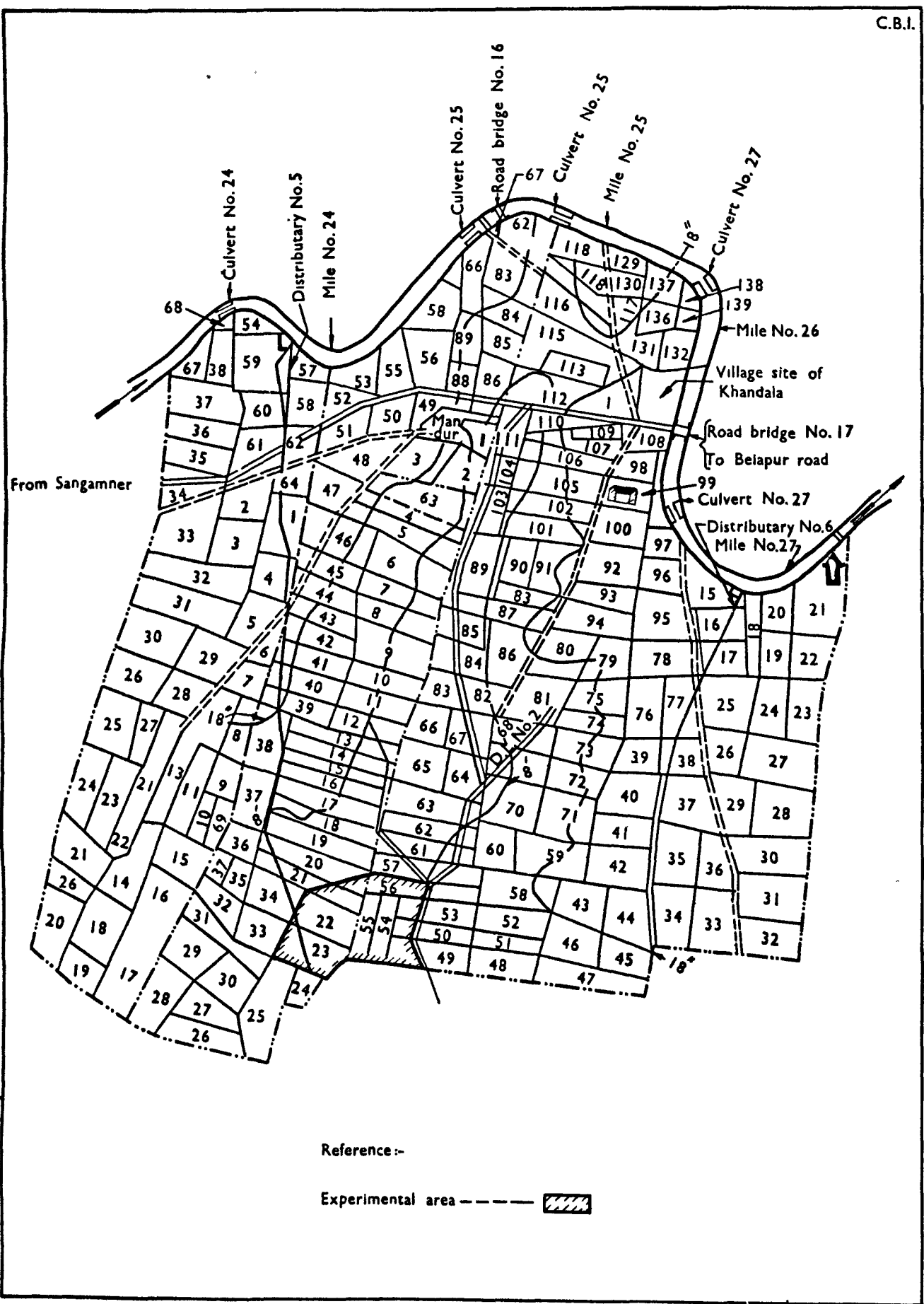


Figure 2E.24:- Showing cross section

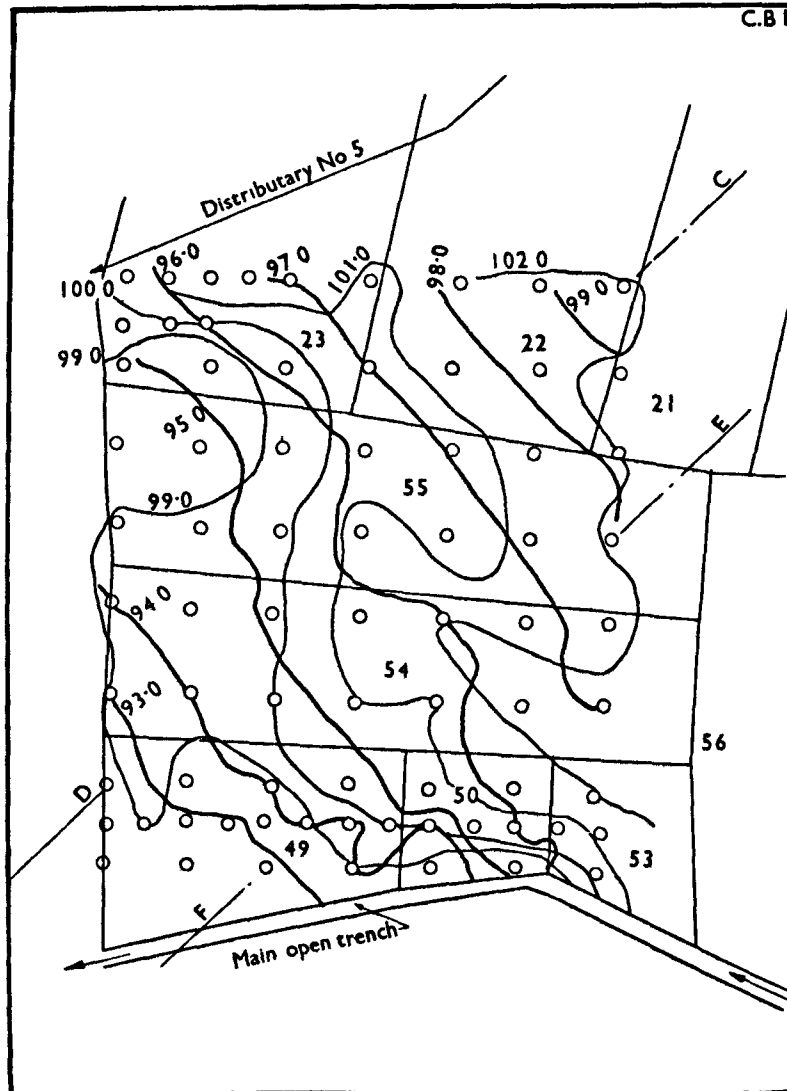




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Figure 2E.25 :- Showing hydraulic gradient observation area, Distributary No.5 Pravara Left Bank Canal





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Figure 2E.26:- Showing hydraulic gradient observation area on Distributary No.5, Parvara Left Bank Canal

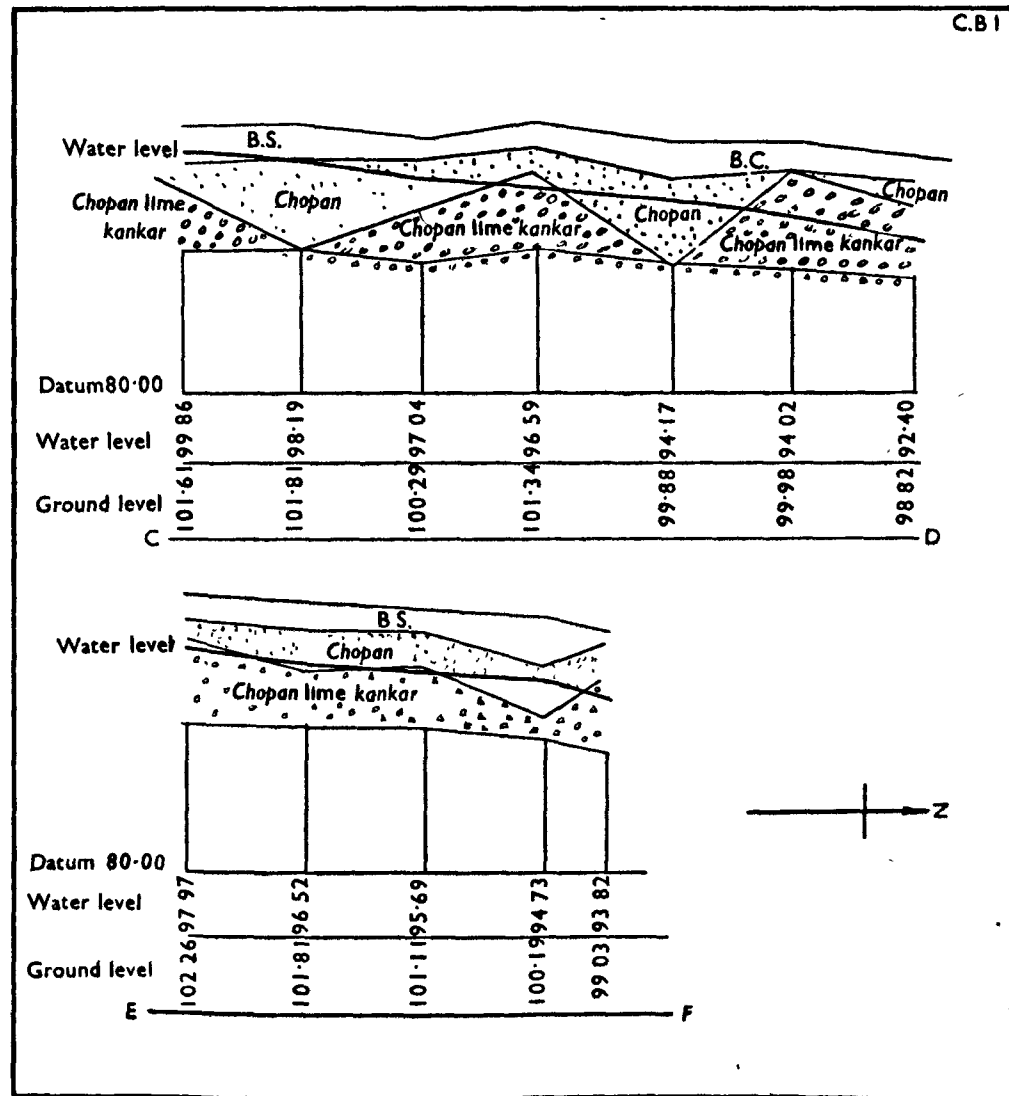


Figure 2E.27:- Showing hydraulic gradient along cross section CD & EF

DR. GOKHALE concluded that the shape of the hydraulic gradient depended on the soil type. Soil factor had to be taken into consideration and could not be ignored. The present mathematical reasoning based mostly on experiments carried out in sandy soils needed reconsideration in the light of experiments with clay soils like the black cotton soil.

DR. VAIDHIANATHAN said that the experiment with the black cotton soil was altogether wrong, being largely affected by evaporation. The difference in the shape of the hydraulic gradient line was not due to the difference in the material of the dam. It was a fundamental difference not dependent on material. In the experiment black cotton soil had been used which has a capillarity of about 10 feet and all the experiments mentioned had been done in the capillary range. By maintaining water at one face of the block, only a little portion of the block adjacent to the water had been saturated and the line actually got did not represent the hydraulic gradient.

DR. GOKHALE asserted that evaporation did not affect these experiments because (1) the capillary height in black cotton soil was four feet or even less; (2) the experimental chamber was covered with a tarpauline and a shed of bamboo matting protected it on all sides. After the cessation of the experiment the soil was found to be quite dry to a depth from two to three feet.

MR. GOVINDA RAO said that the hydraulic gradient had to be determined when the seepage flow lines in the dam reached a condition of dynamic equilibrium. The stable conditions seemed to have been reached after the opening of the canals for 22 days. Since the bank had not been of homogeneous soil the hydraulic gradient would run through two or three different soils. Hence the depth of the soil over the gradient line was also varying it was probably difficult to assert definitely the gradient in any type of soil in this bank. The same remarks applied to banks near an aqueduct.

DR. RAMDAS said that capillarity acted in all directions. He had reported about his experiments on this question last year. He was not sure whether his findings would be relevant to this problem.

DR. BOSE opined that what Dr. Vaidhianathan said was partially correct.

MR. NAEGAMVALA said that he liked to quote one example regarding earthen embankments and canals where it was observed that hydraulic gradients were found to get depressed with age. There were certain experiments carried out in America also by the United States Bureau of Reclamation which showed this phenomenon.

DR. BOSE said that it might be possible with Bombay soils. That was what Dr. Ramdas's experiments indicated.

DR. RAO said that it might be, because the hydraulic gradient was connected with the permeability of the soil. As the permeability became less and less, the gradient might get depressed.

MR. NAEGAMVALA said that Dr. Bose and Dr. Rao seemed to agree that the cause was decreased permeability. But the dam was still homogeneous and he thought that the permeability was an important factor in the determination of hydraulic gradient.

R.B. BIJAWAT said that the explanation given by Dr. Rao seemed to him to be correct. For example, in Okhla weir which was founded on loose soil the hydraulic gradient was somewhat horizontal. But as years passed on, the pores got filled, permeability decreased and the hydraulic gradient fell down to about 1 : 6.

It was decided that the subject should continue on the Agenda.

DISCUSSION BY THE BOARD

THE SECRETARY said that six items were discussed at the Research Committee meeting (page 357). There was no resolution. A sub-committee appointed by the Board to prepare a note on 'Fundamentals of experiments on soil research' was continuing its work.

3E. Land Reclamation

PRELIMINARY NOTE

This subject has been discussed at various meetings of the Board since its very inception, and appeared on the agenda of the Research Committee in 1939 under the heading "Water-Logging and Land Reclamation". The various resolutions passed by the Board are given in the Preliminary Note for 1946, on the subject.

In September, 1938, the Board issued publication No. 17, entitled "Note on Water-Logging and Land Reclamation in the form of a Questionnaire". Information received from Provinces was listed under 26 questions appertaining to water-logging and 23 questions concerning land reclamation.

In 1939 the Board decided that the reclamation of alkaline soils by lowering the water table was open to considerable doubt in view of the result of research work since carried out. As the subject was still being studied intensively, they considered it to be premature for them to express any further opinion at that stage. The Board considered that the Questionnaire on Land Reclamation be brought up to date.

On a recommendation of the Research Committee the Board decided in 1940, that "Land Reclamation" should be considered as a separate subject and "Water-Logging" be omitted.

In 1941, the Board resolved that the collection of further information by means of a questionnaire should not be continued, but that it was desirable that the progress up-to-date on reclamation in different provinces be written up where this had not already been done, and any further development be reported annually for the information of the Board. The subject was removed from the agenda of the Research Committee in 1942, but was retained on the agenda of the Board to keep the Board acquainted with developments. In the 1945 meeting of the Board, it was decided to bring this subject on the agenda of the Research Committee with two sub-heads as follows :—

- (i) Saline lands, and
- (ii) Water-logged lands.

(i) Saline lands

PRELIMINARY NOTE

The following items were discussed at the 1947 meeting of the Research Committee :—

- (1) Penetration depth of different intensities of irrigation
- (2) Vertical movement of salts under reclamation waterings.
- (3) Reclamation.

Recent Literature

1. Christiansen, J. E. :—Some permeability characteristics of saline and alkaline soils. *Agricultural Engineering*, Vol. 23, No. 4, April 1947.

2. Ramdas, L. A. and Mallik, A. K. :—Effect of sodium chloride in improving the permeability of alkali soils. *Current Science*, Vol. 16, No. 6, June 1947.

THE YEAR'S WORK

The following items were discussed at the 1948 Research Committee meeting :—

- (1) The occurrence and significance of Boron in Punjab soils.
- (2) How far a leguminous crop could restore the nutritive elements in a soil depleted of its nutritive elements by the process of reclamation.
- (3) Correlation of the yield of gram with soil factors.
- (4) Damaged areas in Deccan Canal Tract.
- (5) Improvement of soil tilth in drained lands.

(1) THE OCCURRENCE AND SIGNIFICANCE OF BORON IN PUNJAB SOILS ⁽¹⁾

Soil samples bearing different types of natural vegetation were analysed and the results of the typical properties are given in Table 3 F. I.

TABLE 3 F. I.

Showing the Calcium/Boron ratios of two typical Punjab Profiles

| Serial No. | Depths (CM) | pH | Boron in P.P.M. | Calcium Ratio | |
|--|-------------|-------|-----------------|---------------|-------|
| | | | | Calcium | Boron |
| (a) A typical deteriorated profile devoid of any vegetation. | | | | | |
| 1 | 0—1.3 | 9.28 | 8.0 | 48.0 | |
| 2 | 1.3—17.8 | .. | .. | .. | .. |
| 3 | 17.8—45.7 | 9.79 | 10.0 | 50.4 | |
| 4 | 45.7—81.3 | 10.90 | 10.0 | 18.0 | |
| 5 | 81.3—122.0 | 10.00 | 10.0 | 22.0 | |
| (b) A typical good profile of Jand. | | | | | |
| 6 | 0—5 | 8.58 | Nil. | X | |
| 7 | 5—26 | 8.02 | 2.5 | 556.8 | |
| 8 | 26—60 | 7.96 | 2.0 | 439.0 | |
| 9 | 60—70 | 8.12 | 4.0 | 142.5 | |
| 10 | 77—97 | 8.12 | 4.0 | 215.5 | |
| 11 | 97—122 | 8.22 | 3.0 | 156.6 | |

The main conclusions were :—

- (i) Boron was present in the Punjab soils as a trace element even to a depth of 4.0 feet.
- (ii) The *calcium* ratios of the deteriorated soils was considerably lower than that of the fertile soils.

⁽¹⁾ East Punjab Irrigation Research Institute, Amritsar, Annual Report, 1947, Page 67.

(2) HOW FAR A LEGUMINOUS CROP COULD RESTORE THE NUTRITIVE ELEMENTS IN A SOIL DEPLETED OF ITS NUTRITIVE ELEMENTS BY THE PROCESS OF RECLAMATION (2)

It was observed that during reclamation the soil lost considerably some of the most essential nutritive elements *i.e.*, Nitrogen, Phosphate and Manganese. The results of this investigation were given in the Annual Report for 1946. Soil samples were taken from different reclaimed fields before and after the harvesting of gram and analysed for the above elements.

It was concluded that the gram crop proved a great ameliorative and the nitrates and the available phosphates were sufficiently restored. For any successful reclamation the inclusion of leguminous crop in the usual rotation is thus very essential.

(3) CORRELATION OF THE YIELD OF GRAM WITH SOIL FACTORS (3).

Soil samples were taken from a number of sites giving varying yields of gram and were analysed for percentage of salt content, *pH*, Calcium Carbonate, exchangeable bases, Manganese, available Phosphate, Nitrogen and Nitrate content.

There was no relation between the yield of gram and the percentage of soluble salt content of soils, *pH* and Calcium Carbonate.

(4) DAMAGED AREAS IN THE DECCAN CANAL TRACT (4)

ABSTRACT

The Nira Left Bank Canal was opened for irrigation in 1885. Canal irrigation was then still in its infancy and water had to be supplied wherever demanded, for popularising and developing canal irrigation. Supply there was in excess of the demand and water was available in copious quantity. Sugarcane which is a robust crop, resistant to heavy irrigation and highly remunerative, was grown wherever possible regardless of the amount of water or type of soil over which the water was used. Cane was mostly grown by tenant-cultivators who migrated from outside (*Saswad malis*) and had little interest in the land. The local cultivator was generally poor and had not enough capital to grow the costly cane crop nor was he acquainted with cane cultivation as the *Saswad malis*. The result was ill-managed heavy irrigation and extensive damage by water logging and salt ensued all over in the cane irrigated area. Damage increased rapidly with cane irrigation as was obvious from survey carried out at different times.

The Godavari Canals were opened for irrigation in 1911-12 and the *Saswad malis* from the Nira Left Bank Canal migrated there in numbers. The same tale as on the Nira Left Bank Canal was repeated on the Godavari Canals in a still worse form. Government realizing the seriousness of the evil opened in 1916 a new Research Division (then called Special Irrigation on District) for investigating the causes of damage and determining measures for preventing further increase in damage and reducing that which had already occurred.

(2) East Punjab Irrigation Research Institute, Amritsar, Annual Report, 1947, Pages 67-68.

(3) East Punjab Irrigation Research Institute, Amritsar, Annual Report, 1947 page 68.

(4) Poona Irrigation and Research Division, Public Works Department Bombay, Poona, Annual Report, 1947, pages 57-61.

WORK DONE BY THE RESEARCH DIVISION

From 1918 to 1928 this Division has carried out—

- (1) A systematic soil and sub-soil survey of all the major canal areas in the Deccan,
- (2) Annual survey of areas damaged by water logging and salt,
- (3) Hydrological surveys of ground water (rise of sub-soil water levels),
- (4) It has also solved the problem of land drainage and reclamation by conducting a series of experiments at Baramati and constructing drainage for demonstration on each canal.

As a result of experiments and experience gained, this Division with a view to achieving maximum efficiency in—irrigation and drainage has recommended—

- (i) Installation of modules and other measuring devices for controlling irrigation water with a view to serving minimum requirements of crops for water and preventing over-irrigation.
- (ii) Selection of area depending on soil and sub-soil conditions to suit crops requiring irrigation of different intensity. As damage is closely associated with cane irrigation, limit to which cane should be restricted in cane fit areas is also laid down in such cases to prevent damage to other lands also. Cane is also concentrated in well drained (naturally or artificially) area in upper reaches of the canal as far as possible to reduce losses by evaporation and absorption.
- (iii) Construction of artificial drainage where economically feasible.

The principles enumerated above applied as far as possible to all the major canals in the Deccan because it was not so simple a matter to enforce these rigorously for various reasons such as vested interest of irrigators, loss of revenue although temporary, political aspect *etc.* The only attempt made was to shift cane irrigation to suitable lands as far as practicable. This was possible only when demanded for cane irrigation exceeded the supply, since the establishment of sugar factories in 1935 and due to the world war thereafter.

As regards moduling and drainage these improvements can only be introduced when funds are made available. This has not been possible up to now.

During the period of investigation, another major canal—the Pravara Canal—was opened for irrigation in 1924.

RESULTS

As shown in note No. 2·21, Poona Irrigation and Research Division Annual Report for 1946 page 30, damaged areas are closely related to cane irrigation and if damaged areas on each canal are compared with cane areas, it can roughly indicate efficiency of irrigation due to selection of areas and limiting, cane area, to suit them.

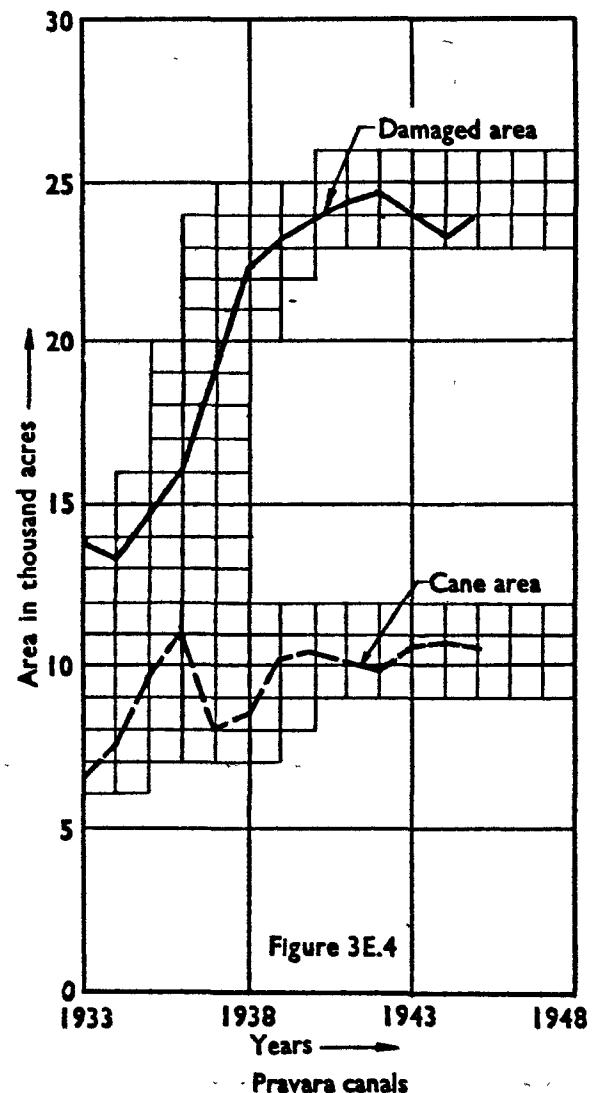
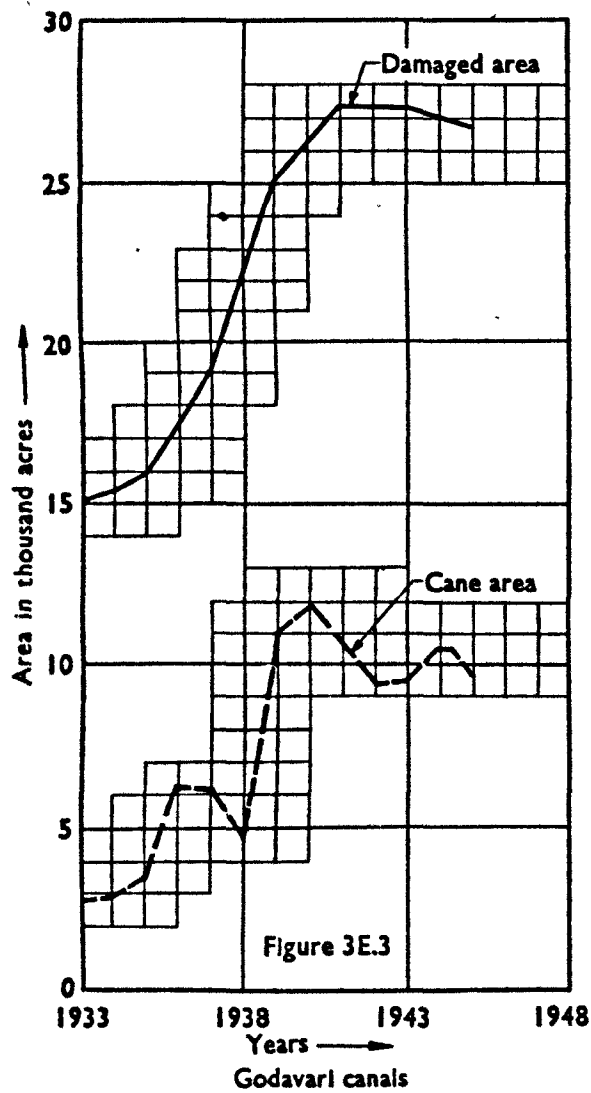
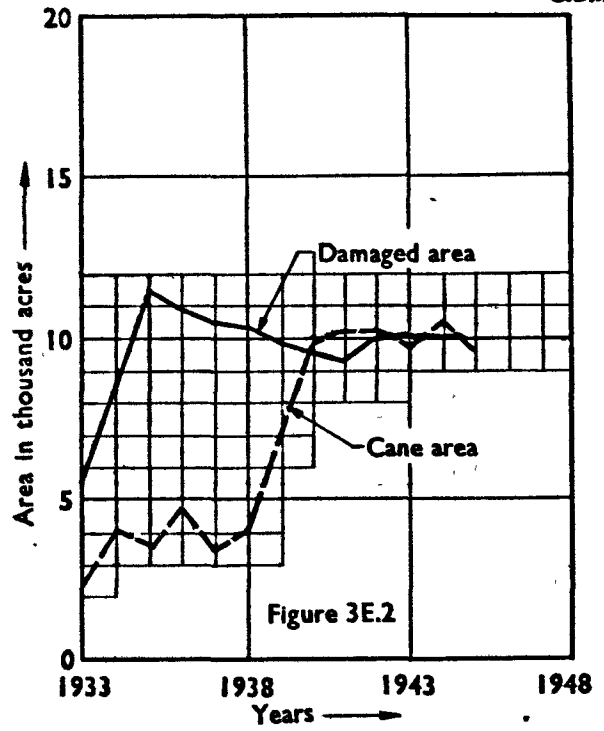
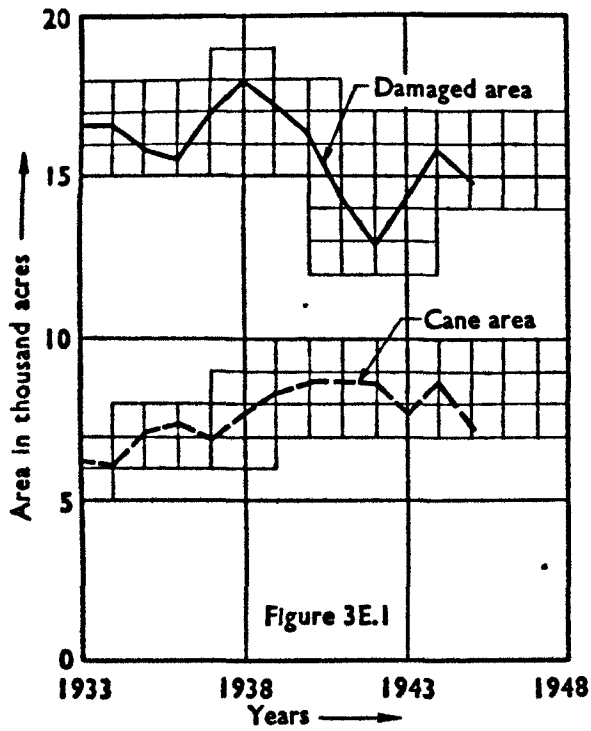
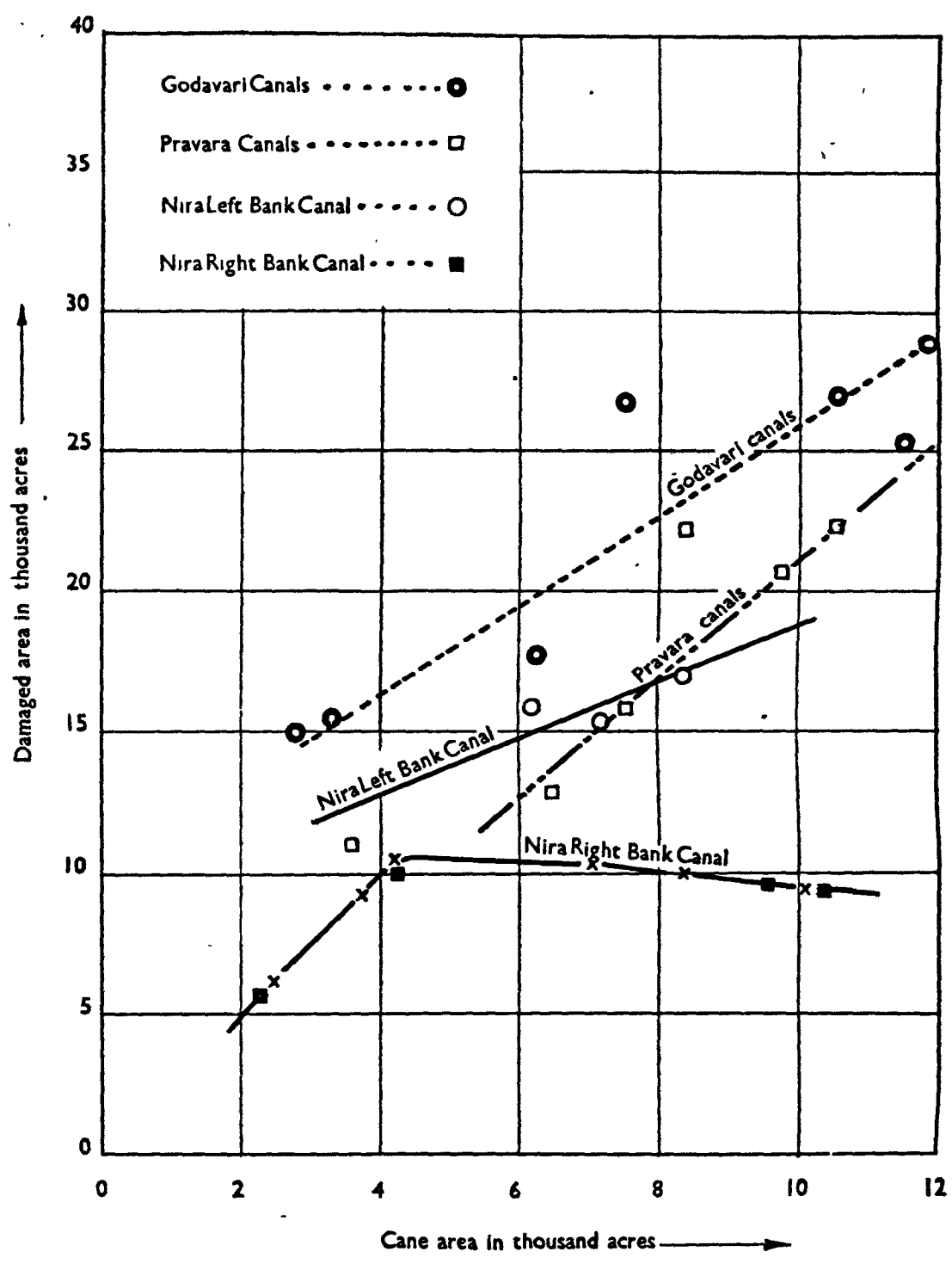


Figure 3E.1, 3E.2 } Showing cane and damaged areas
 3E.3&3E.4 } on major canals in the Deccan



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Figure 3 E.5:- Showing relation of damage to cane from 1933 to 1945

Nira Left Bank and Godavari which are old canals exhibited the seriousness of the damage and led to the formation of the Irrigation Research Division. Pravara Canal as mentioned before was opened in 1924 during the period when investigations by the Irrigation Research Division were still in progress. The principles evolved by this Division were really introduced on the Nira Right Bank Canal from the very start *i.e.*, when it was opened for cane irrigation in 1933, and it is this canal that would show the benefits arising out of our selections for once.

Figures 3 E-1 to 3 E-4 show cane and damaged areas on the Nira Left Bank Canal, Godavari and Pravara Canals for a corresponding period from 1933 to 1940. These figures also show the relation between cane and damage. Even taking into account that some of the damage is due to seepage from canal and not wholly due to cane, the association between the two is fairly close.

Figure 3E. 5 shows the correlation between cane and damage (by grouping the data for suitable periods).

Godavari shows maximum rate of damage (per unit of cane). Pravara stands next.

As Nira Left Bank Canal is an old canal, cane area is stable and does not fluctuate much and hence the readings are few for drawing a complete line of correlation.

On the Nira Right Bank Canal cane area has increased rapidly and attained its maximum limit.

For an area of 10,000 acres of cane according to this graph the damaged area on the Godavari is 26,000 acres, Pravara is 22,500 Nira Left Bank Canal 19,000 and Nira Right Bank Canal 10,000. The figures show that the Nira Right Bank Canal has the least damage per acre of sugarcane.

CONCLUSION

The Nira Right Bank Canal, where the principles of area selection and imposition of sugarcane limits were introduced from the start, show the least damage.

(5) IMPROVEMENT OF SOIL TILTH IN DRAINED LANDS (5)

Ambadi and Tamarind leaves stand first and second respectively in raising the crop outturn. *Hundi Jawar* which was tried after the application of four different types of green manures showed the efficiency of the above green manures over the rest. In a succession crop of *Khapla* tried in the *rabi* season, tamarind leaves stood first in point of view of out turn followed by Dhaincha.

In the acid compost series farm yard manures plus—molasses and molasses plus acid leaves gave superior results to the rest of the treatments in case of both the *Hundi Jawar and Khapla* crop.

In case of acid irrigation waters molasses and sulphuric acid treatment gave superior outturns over the rest of the treatments. Gypsum stood third

DISCUSSION BY THE RESEARCH COMMITTEE

DR. C. L. DHAWAN introducing item (1) said that investigations had been carried out with respect to the significance of Boron in soils. The soils were classified according to Calcium Boron ratio in soils. Regarding problems (2) and (3) conclusive results of the investigations could not be presented due to handicaps encountered in 1947. They hoped to be able to give the results in the next year's report.

MR. J. P. NAEGAMVALA next introduced item (4) and said that damage was generally restricted by proper soil selection.

DR. V. K. GOKHALE introduced item (5) and said that soil tilth did not recover easily after drainage in the case of stiff soils unless treated.

The experiments were conducted in an extremely stiff soil in the Manjri Drainage Area ($P_H=10$). The stiff soil was treated with green organic manures *viz.*, (1) *Ambadi* (*Hebiscus Canabinus*), (2) *Vinchuka* (*Martinia Diandra*), (3) Tamarind leaves (*Tamarindus indica*) with a view to neutralising alkali. F.Y. M. was kept as control. None of the green manures excelled F.Y.M. (10 to 20 tons). Molasses and rude sulphuric acid and alum *etc.*, were applied with irrigation waters. Molasses gave better results.

RAI BAHADUR R. L. SETHI said that these experiments by the Irrigation Departments were of an agricultural nature and were of great interest to the agricultural department. He did not know why Boron was particularly selected in these investigations by the Punjab Research Institute, perhaps because of its high micronutrient value. It could have been seen easily from the studies of the yield rather than of the soil. Studies of this nature were being carried out by the Indian Council of Agricultural Research at New Delhi. In addition there were certain plants that indicated the presence of Boron in soils easily. The sun flower for example, if it grew in a particular area it was enough proof to show that there was Boron in that area. By this method one could find out the presence of the various ingredients of the soil. Soil analysis was not so very essential.

(5) Poona Irrigation and Research Division, Public Works Department, Bombay, Poona, Annual Report, 1947, pages 62-69.

Referring to item (2), RAI BAHADUR R. L. SETHI said that this was of a fundamental nature. Trials were being carried out in the Agriculture Department regarding the increase in yield by the use of leguminous crops. But it was heartening to know that the Irrigation Department too was carrying out the analysis of the soil and then carrying out the detailed investigations. They would watch with interest the results of these investigations. They were not so very simple, as would appear at first.

THE PRESIDENT explained the main purposes of these experiments. They were made in connection with reclamation of land.

DR. R. C. HOON briefly referred to the experiments done in the Punjab a few years back. As would appear from the table, Boron had been determined in soils of very high p_H . It would greatly increase the value of the work if experiments were carried out with variety of soils manifesting varying crop yields instead of going by the p_H value as the sole index of soil quality.

DR. DHAWAN in reply to R. B. Sethi said that the present investigation was in continuation of the work already carried out by them on trace-elements *i.e.*, Manganese. Regarding R. B. Sethi's remarks about item (2), Dr. Dhawan drew attention to his paper on the "Effect of Reclamation on Soil-Nutrients," in which he had concluded that the soil was depleted of its essential nutritive elements after reclamation. It was, therefore, necessary to see how far gram crop could restore the equilibrium. Replying to DR. HOON, DR. DHAWAN said that the field was considered good as the yield of wheat on the plot was 20 maunds per acre.

Regarding R. B. Sethi's remarks about the preliminary character of these experiments, Mr. S. L. Malhotra said that when they were in West Punjab they were faced with the problem of reclamation and hence the necessity of these studies. Now in East Punjab the problem did not exist to the same extent.

DISCUSSION BY THE BOARD

THE SECRETARY said that five items were discussed at the Research Committee meeting (page 386). There was no resolution.

(ii) Water-Logged Lands

PRELIMINARY NOTE

The following items were discussed at the 1947 meeting of the Research Committee :—

- (1) Effect of heavy canal irrigation on sub-soil water table in deep soil area near Jinti—Nira Right Bank Canal.
- (2) { Effect of perennial canal irrigation on sub-soil water table and consequent damage to lands.

Recent Literature

(1) Markwick, A. H. D. and Dobson, A. F. :—Application of electrosmosis to soil drainage. *Engineering* Vol. 163, No. 4230, February 1947.

(2) Haile, W. H. :—Flood prevention schemes in Holland and the Zuider Zee Reclamation Scheme. *Journal of the Institution of Municipal and County Engineers*, Vol. 72, No. 12, July 21, 1946.

(3) Gain, E. W. :—Wartime drainage in England. *Agricultural Engineering*, Vol. 28, No. 2, February 1947.

THE YEAR'S WORK**DISCUSSION BY THE RESEARCH COMMITTEE**

There were no contributions on this subject. The item was, however, retained on the agenda.

DISCUSSION BY THE BOARD

THE SECRETARY said that there was no contribution and no discussion at the Research Committee meeting.

4E. Water Requirements of Crops

PRELIMINARY NOTE

At the 1946 Research Committee and Board Meeting " Factors affecting area irrigated and growth of crops " was one of the subjects introduced under the head " Miscellaneous ". The subject " Water Requirements of Crops " was also discussed by the Board in 1936 under the heading " The fair incidence of cost of irrigation water in different classes of crops " and the following resolution was passed :—

" The Board is of the opinion that there appears to be a necessity for introducing a more satisfactory method of assessing water rate for crops, which will afford encouragement to the *Zamindar* to cultivate in a more scientific manner, and the rates should bear more relation to the value of the crops and their water requirements. In regard to the latter, further investigations are desirable by the irrigation and agricultural departments to ascertain more precisely the water requirements for particular crops.

" It is resolved that, while appreciating the benefits likely to be derived by introducing scientific crop rotations, this Board is of the opinion that the question raised of attempting to enforce them must be entirely a provincial one as it does not lend itself to general application ".

In 1938, the Research Committee passed the following resolution :—

" In the opinion of this Committee the study of basic problems, common to all provinces in India, of the application of water to crops should be undertaken at the Imperial Agricultural Research Institute at New Delhi. For this purpose irrigation officers should be deputed to a special section directed by an irrigation officer, which would ensure the co-operation of the Agricultural and Irrigation officers in the investigation of joint problems. The committee considers this most essential ".

A similar resolution was passed by the Board at their 1946 meeting—

" In order that the results of experiments carried out by the Agricultural Departments on the water requirements of crops be more representative and comprehensive than at present, the Research Committee recommends to the Board to address the Government of India, the Imperial Council of Agricultural Research and the Provincial and State Governments with a request that all research in respect of water requirements of crops be conducted by the Agricultural, Meteorological and Irrigation Departments jointly or in co-operation with each other. Further the Board may request the Imperial Council of Agricultural Research to issue a directive in this respect to all experimental farms operating with funds supplied by the Indian Council of Agricultural Research".

The Crops and Soils Wing of the Board of Agriculture and Animal Husbandry in India in its 1945 meeting made certain recommendations on the subject*.

At the 1947 meeting of the Board the following resolution was passed :—

“ Resolved that with a view to ensuring effective co-operation and co-ordination between Irrigation, Agriculture and Meteorological Departments in the research towards the determination of water requirements of crops in different parts of the country and other allied problems like quality of waters, land reclamation, soil survey and rotation of crops, the Government of India be requested to form, for the purpose, a permanent advisory committee comprising five representatives of the Central Board of Irrigation, five representatives of Indian Council of Agricultural Research and two representatives of the Meteorological Department.

“ That this Committee should meet once a year just before the Research Committee meeting to review research on the subject that has been carried out during the previous year, examine the technique, suggest improvements and make suitable recommendations on the subject to the Central Board of Irrigation, the Indian Council of Agricultural Research and the Meteorological Department.

“ The Central Board of Irrigation and the Indian Council of Agriculture Research may request all Research Organisations connected with them to afford the fullest co-operation to the proposed committee.

“ Resolved further that in every province and major state similar local committees be set up, if one does not exist already, comprising two representatives each of the local Irrigation and Agriculture Departments and one representative of the Meteorological Department. The function of these local Committees should be to carry out and supervise the research being carried out in their administrations on the subjects mentioned above and to assist in carrying out the policy to be laid down by the Committee to be formed at the centre ”.

In response to the resolution of the Board, both the Indian Council of Agricultural Research and the India Meteorological Department expressed whole-hearted co-operation and have nominated their representatives on the Permanent Standing Advisory Committee. The Committee now consists of :—

Indian Council of Agricultural Research

- (1) The Agricultural Commissioner with the Government of India.
- (2) The Director, Indian Agricultural Research Institute.
- (3) Dr. J. K. Basu, Soil Physicist to Government of Bombay, Sholapur.
- (4) The Head of the Division of Agronomy, Indian Agricultural Research Institute or any other eminent Agronomist from provinces.
- (5) Rai Bahadur Dr. R. D. Rage, Deputy Director, Agriculture, Bombay, Poona.

* The Central Board of Irrigation Journal, April 1946, page 111.

Central Board of Irrigation:

- (1) Rai Bahadur A. N. Khosla, I.S.E., Chairman, Central Waterpower, Irrigation and Navigation Commission, New Delhi.
- (2) Rao Bahadur A. R. Venkatacharya, I.S.E., Chief Engineer for Irrigation, Madras, Chepauk.
- (3) Shri N. D. Gulhati, I.S.E., Secretary, Central Board of Irrigation.
- (4) Shri R. S. Chaturvedi, Research Officer, P. W. D., United Provinces Irrigation Branch, Haridwar.
- (5) Shri J. P. Naegamavala, B. S. E. (I), Executive Engineer, Poona Irrigation Research Division, Poona.

Indian Meteorological Department

- (1) Dr. S. K. Banerji, Director General of Observatories, India Meteorological Department, New Delhi.
- (2) Dr. L. A. Ramdas, Director Agricultural Meteorology, Poona.

It has also been agreed by the Indian Council of Agricultural Research that Rai Bahadur A. N. Khosla will be the Chairman and the Secretary, Central Board of Irrigation as member Secretary of the Committee.

The following items were discussed at the 1947 Research Committee Meeting:—

- (1) Water requirements of crops (Experiments to determine water requirements for sugar-cane and wheat crops for the maximum yield with the most economical use of water).
- (2) Amount of water utilized per acre of sugar-cane by sugar factories in the Bombay Deccan Canal areas.

Recent Literature

- (1) Hunter, A. S. and Kelley, O. J. :—A new technique for studying the absorption of moisture and nutrients from soil by plant roots. *Soil Science*, Vol. 62, No. 6, December 1946.
- (2) Absorption of moisture by the plant materials. (Reprinted from *Science and Cultures*, Vol. 12, 1946-47).
- (3) Chakladar, M. N. :—Influence of soil moisture on the yield of paddy. *Indian Journal Agricultural Science*, Vol. 16, Part II, April 1946.

THE YEAR'S WORK

There was only one item on this subject which was discussed at the 1948 Research Committee meeting viz.,

- (1) Water requirements for sugarcane, wheat and paddy crops.

(1) WATER REQUIREMENT FOR SUGARCANE WHEAT AND PADDY CROPS⁽¹⁾**ABSTRACT**

Agricultural experiments were continued at Bara Banki, Bulandshahr, Atarra (Banda), Tisui (Mirzapur) and Nagina farms to determine the water requirements for the sugarcane, wheat and paddy crops for the maximum yield with the most economical use of water. Only sugarcane and wheat experiments were conducted at the first two of the above mentioned farms, for which the year under review is the fifth for the experiments. At the remaining farms, paddy experiments alone were taken up for the second year in succession. The latter (paddy experiments) were also initiated at Bahadradab this year.

(a) PADDY

Details of experiments conducted for the second time at Nagina (Bijnor) Atarra (Banda) and Tisui (Mirzapur) farms and for the first time at Bahadradab Research Station during this year are given below :—

Object.—To study the effect on yield of varying frequencies and depths of watering, using 0, 3, 6 and 9 inches depths at intervals of 14, 24 and 28 days for Nagina and Tisui Farms, and 0, 3, 4½, 6, 7½ and 9 inches depths at intervals of 14, 17½, 21 and 28 days for Atarra and Bahadradab farms.

Table 4 E-I gives details of date of sowing, harvesting, rainfall, type of paddy used, etc., at the different farms.

This year's results of paddy experiments are again inconclusive (with the exception of Atarra Farm), and it is recommended that these should be continued for a number of years with a view to determining the most economical depth of irrigation for maximum and optimum yields.

(b) WHEAT

Detailed description of experiments on wheat carried out at Bara Banki and Bulandshahr farms is given below :—

Objects :—(1) To study the effect of a single watering of varying depths, 0, 2, 3, 4, 5 and 6 inches applied in the middle of the 'Kor' period.

(2) To find the optimum time of irrigating wheat with two irrigations of two, three and four inches depths with respect to the date of sowing.

Type of wheat used :—P-52 and Pb-59I were used at Bara Banki and Bulandshahr Farms respectively.

⁽¹⁾ United Provinces Irrigation Research Station, Report on Research Progress during 1947. Pages 112-115.

TABLE 4 E. I

Showing details of experiments at Nagina, Mirzapur, Banda and Bahadrabad for 1947

| Details of experiments | Nagina | Mirzapur (Tisuihi) | Banda (Atarra) | Bahadrabad |
|--|--------------------------|-----------------------|-------------------|--------------------------|
| 1. Area of each plot in acre ... | $\frac{1}{158.4}$ | $\frac{1}{158.4}$ | $\frac{1}{158.4}$ | $\frac{1}{229.3}$ |
| 2. Variety of paddy used ... | 1=12 (medium) (early) | T-36 | T-36 | T-21 (medium) (early) |
| 3. Type of soil ... | Clayey | Black cotton | Parwa | Clayey |
| 4. Date of sowing .. | 6-6-47 | .. | 22-6-47 | 11-6-47 |
| 5. Date of transplanting .. | 10-7-47 | 23-7-47 | 17-8-47 | 13-7-47 |
| 6. Date of harvesting .. | 20-10-47 | 23-11-47 | 3-12-47 | 18-10-47 |
| 7. Total rainfall in inches during the crop season '47. | .. | 28.05 | 42.4 | 44.6 |
| 8. Normal rainfall in inches .. | .. | 48.0 | 35.64 | .. |

TABLE 4 E-I—contd.

| Details of experiment | Nagina | Mirzapur (Tisuhi) | Banda (Atarra) | Bahadrad |
|--|---|---|--|--|
| 9. Treatment combinations .. | 0", 3", 6" and 9" with 2, 3 and 4 weeks intervals. | 0", 3", 6", 9" with 2, 3 and 4 weeks intervals. | 0", 3", 4½", 6", 7½" and 9" with 2, 2½, 3 and 4 weeks intervals. | 0", 3", 4½", 6", 7½" and 9" with 2, 2½, 3 and 4 weeks intervals. |
| 10. Maximum yield per acre .. | 21.16 mds. with 6 in. depth of irrigation at 2 weeks interval. | 15.3 mds. with 9" depth of irrigation at 2 weeks intervals. | 15 mds. with 9 in. depth of irrigation at 2 weeks intervals. | 21.50 mds. with 6 in. depth of irrigation at 2 weeks intervals. |
| 11. Optimum yield per acre .. | 20.51 mds. with 3 in. depth of irrigation at 4 weeks intervals. | 12.3 mds. with 3" depth of irrigation at 2 weeks intervals. | 12 mds. with 3 in. depth of irrigation at 2½ weeks intervals. | 20.87 mds. with 7 in. depth of irrigation at 4 weeks intervals. |
| 12. Percentage ratio of optimum yield/Maximum yield. | 96.8 | 80 | 80 | 96.7 |
| 13. Total depth of irrigation in inches (including monsoon rainfall) for Maximum yield. | .... | 73.5 | 96.4 | 80.66 |
| 14. Total depth of irrigation in inches (including monsoon rainfall) for optimum yield. | .... | 43.05 | 57.4 | 67.1 |
| 15. Percentage of total water required for optimum yield against that for the maximum yield. | .... | 58.9 | 59.5 | 83.2 |

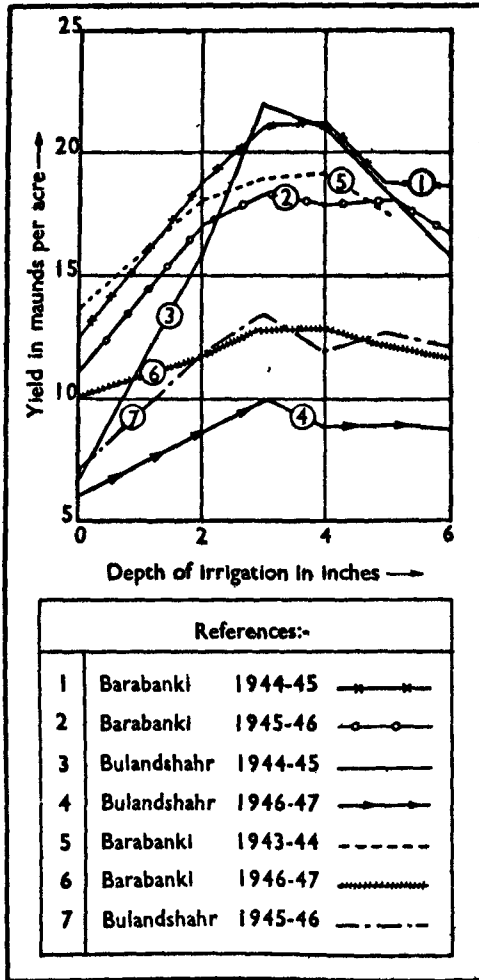


Figure 4E.1:- Showing comparative yield of wheat at Barabanki and Bulandshahr for one irrigation treatment from 1943-44 to 1946-47

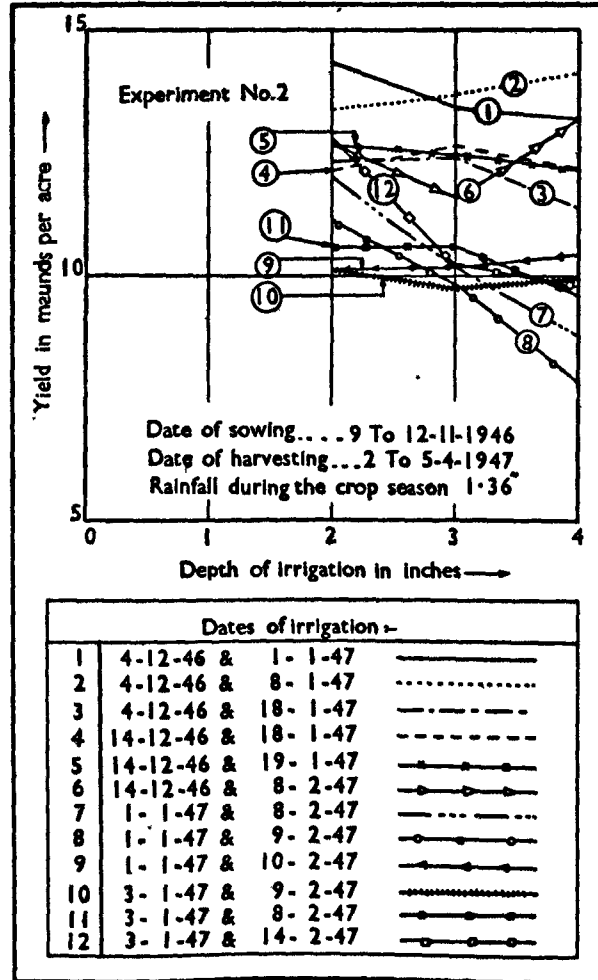


Figure 4E.2:- Showing yield of wheat at Barabanki farm for the year 1946-47

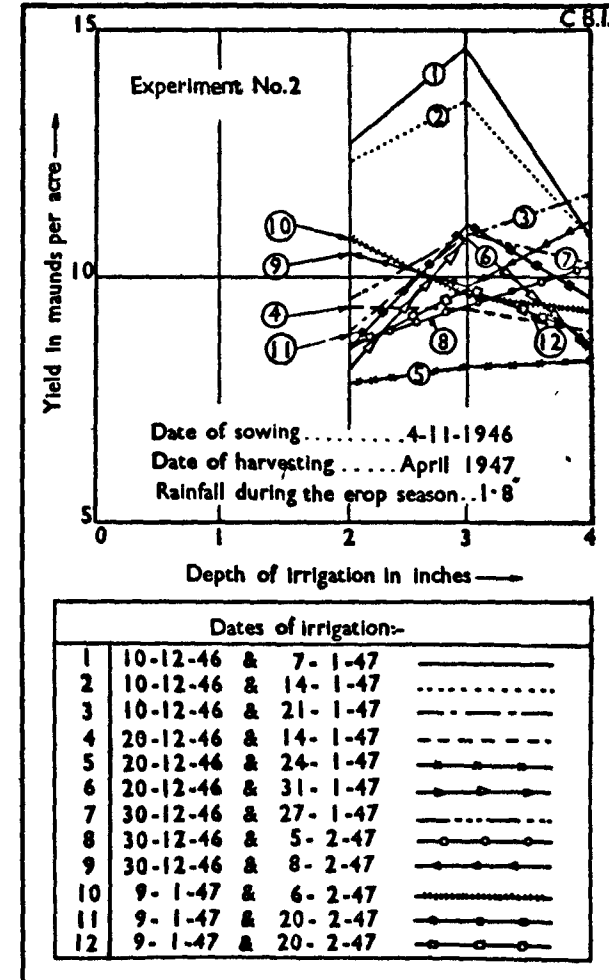


Figure 4E.3:- Showing yield of wheat Pb-591 at Agriculture School Farm Bulandshahr for the year 1946-47

Records.—Records of germination, tillering, growth, water logging and other essential data were maintained. Rainfall figures for Bara Banki and Bulandshahr were 1.36 and 1.8 inches respectively during the crop season. The yield data for different treatments was collected. Figure 4 E-1 has been plotted from a comparative statement giving the yield in *maunds* per acre for Bara Banki and Bulandshahr for one irrigation treatment.

CONCLUSIONS

Experiment No. 1 :—For Bara Banki, it is found statistically that there are no significant differences in the mean yield due to three, four and five inches depths of irrigation, although the maximum yield is obtained at four inches depth, being only slightly higher than that for three inches depth. It may be seen that graphical results are also the same, *vide* Figure 4 E-1 which shows that the maximum yield is obtained with both three and four inches depths. Last year, the maximum yield was obtained for three inches depth only. The most economical depth of watering is two inches which gives about 90 per cent. of the maximum yield obtained with three inches depth. This is in conformity with last year's results.

For Bulandshahr, it is brought out both statistically and graphically that three inches depth of irrigation produces the maximum yield. The most economical depth of watering, in this case also, is two inches, for which the mean yield is almost the same as that for four inches and six inches depth and is about 83 per cent. of the maximum yield obtained with three inches depth.

From Figure 4 E-1, which gives figures for last four years, it is brought out that the trend towards three inches depth giving the maximum yield is clearly exhibited (except for one or two cases where 4 inches gives slightly higher yield but the difference is insignificant). From the same graph it is also brought out that two inches is the most economical depth of irrigation. Experiment No. 1 may, therefore, be said to be finalised with the above conclusions, needing no more repetitions. The conclusions are also confirmed by statistical analysis.

Experiment No. 2 :—For Bara Banki, it is found graphically (*vide* Figure 4 E-2) that two inches irrigation at four weeks interval gives the maximum yield which is in agreement with last year's findings. It is 111.88 per cent. of the maximum yield with one 3 inches irrigation. The results, however, are statistically insignificant, only the effect of dates is significant which means that an early irrigation produces a good effect on the yield of wheat.

For Bulandshahr, it may be seen from Figure 4 E-3 that 3 inches depth of irrigation at 4 weeks interval gives the maximum yield, which, too, is in conformity with last year's conclusions. The yield is 146.27 per cent. of the maximum yields obtained with one three inches irrigation, thus justifying the necessity of two irrigations in the drier districts of the western part of the Province. The data, however, does not give any statistically significant results.

DISCUSSION BY THE RESEARCH COMMITTEE

MR. S. N. GUPTA introducing item(i) said that agricultural experiments were being conducted in different parts of the United Provinces with a view to determining the minimum amount of water needed for the maximum yield of a particular crop. The crops under experiment were wheat, paddy and sugarcane.

Some of the interesting conclusions were :

(i) One 3-inch depth of watering given in the middle of the *Kor* period gave the maximum yield in the case of wheat crop both in the Eastern and the Western parts of the United Provinces.

(ii) The maximum wheat crop yield increased by 50 per cent. with two irrigation treatments in the Western districts whereas the increase was only 10 per cent. in the Eastern districts indicating the necessity of two irrigations in the drier parts of the United Provinces.

No conclusive results had yet been arrived at in the case of paddy and sugarcane.

RAI BAHADUR R. L. SETHI liked to make a few observations on the paddy growth experiment. He thought it would have been better to select any station other than Bahadurabad. Between Najibabad and Bahadurabad it would not show much difference. The interval of $17\frac{1}{2}$ days looked rather difficult for calculation. In Agricultural Department no half days were calculated in the matter of irrigation. It was better to have complete days. Then again he suggested that a split plot design would have been better than the randomised design actually adopted, as a number of factors were involved. The experiments showed that there was variation between the varieties of dates of sowing and transplanting. The plot size $\frac{1}{50}$ acre was too small for carrying out irrigation trials. Regarding wheat also he had similar remarks to offer.

DR. L. A. RAMDAS said that he had not carried out any extensive field trial in connection with intensity of irrigation on crops. He would like to make a few general observations on some laboratory experiments done by him. His experiments did not deal with superficial irrigation but might throw some light on sub-soil irrigation. It consisted of a vessel full of soil with seedlings sown on top and with water tables maintained at different levels. The results of these had been sent to the Central Board of Irrigation Journal and might be published soon.

MR. M. P. MATHRANI enquired of Mr. Gupta as to how they accounted for rainfall separately in the experiments conducted in the United Provinces.

MR. S. N. GUPTA replied that they gave waterings independent of the rainfall.

MR. KAHAI liked to know whether the porosity factor of the soil was taken into consideration. The porosity was of great importance in these experiments. The texture of the soil affected the results a great deal. He would like to know as to what was the water table, because water table again affected the requirements of water for crops.

THE CHAIRMAN (SARDAR BAHADUR SARDAR SARUP SINGH) said that he happened to read a book about 'The Man, Moon and Seed'. The time of the sowing of the seed was important stated the book. The relation was with the Moon. That factor might also be taken into consideration in future experiments.

MR. S. N. GUPTA in reply to R. B. Sethi's questions said that they adopted randomised block design in consultation with Agriculture Department, Lucknow. It might not be advisable to adopt split block design midway when the experiments had been going on for the last few years. Bahadurabad was different from Najibabad in a way as the former was more of a *tarai* and latter in plains. The interval of seventeen and a half days was adopted in view of the suggestion from the Executive Engineer, Mirzapur Canal. Perhaps this interval suited his area better.

MR. B. P. SAXENA said that with regard to the rainfall it varied differently in all these localities. They had been doing these experiments considering that their canals were running continuously. Their aim was to determine the interval which was required for giving water to the various areas irrespective of rainfall, which in any case was practically nil in the month of September when the water was given.

MR. M. P. MATHRANI opined that for the Gangetic region, unless the position of the water table was ascertained for different rainfall conditions the results of these experiments might not be useful.

It was decided that the subject should continue on the Agenda.

DISCUSSION BY THE BOARD

THE SECRETARY said that only one item was discussed at the Research Committee meeting (page 395). The resolution passed by the Board last year to form a permanent Advisory Committee for research on the subject was still under the examination of the Government of India.

DR. BANERJI said that he liked to invite special attention to the importance of the subject. The preliminary enquiry which was carried out had brought out very important aspects of this problem. It had been pointed out in the survey which was carried out that the transpiration losses and evaporation losses, on a tentative estimate, would amount to 40 per cent. of the total rainfall which showed that it was a very large figure to account for and, therefore, if any savings could be made by these investigations, then the sooner they carried a thorough investigation, the better. That would give them a better idea as to how their water resources had been utilized. The subject, to his mind, involved laboratory experiment as well as open air experiments. They had yet to know the transpiration losses and the evaporation losses separately. This was a subject in which so many parties were interested. All those who were using water resources were interested, *viz.*, the Irrigation Department, Agricultural Department and the Meteorological Department. So he thought that they would have to put up a combined effort. He suggested asking all the interested departments to come together for investigation so that they

could get measurements on which they could rely. So he strongly urged that apart from the formation of the committee they ought to find out ways and means of doing this work and if this was done satisfactorily they would have to approach the departments concerned so that all collectively contributed to this work.

MR. BHATTACHARYA said that since the last meeting at Simla, results had been finalized and conclusions drawn regarding water requirements for sugar-cane crop at Bulandshahr, which is representative of Western U.P.

DR. N. K. BOSE said that perhaps Dr. Banerji might be knowing the action the Damodar Valley Corporation had taken on this matter.

RAI BAHADUR KANWAR SAIN said that it would be appreciated that the subject was of a very great economic value to the Irrigation Engineers particularly when a large number of storage projects were under active consideration. If the engineers could find a way of saving some water they certainly could make an improvement in the irrigation performance. It was a subject of research on which the storage projects should be able to spend much more money. It would ultimately make the projects financially more promising. He referred to some literature which showed that at least 30 percent economy of water could be made if the water was given properly at the proper time. So he would submit that the subject was of very great importance not only on account of its academic interest but it was really in the interest of immediate economic development of the country and perhaps the Agriculture Department might be able to contribute something towards the cost of these experiments.

MR. J. C. HARDIKAR said that the procedure adopted by the U.P. Research Station for experiments to determine the water requirements of crops was that, fixed quantity of water was applied at fixed intervals. He felt that this was not a correct procedure. Rather than giving a fixed quantity of water every week or every alternative week *etc.*, a better method would be to study the water requirements of different crops under three categories.

- (a) Quantity required for plant growth, (b) Quantity required for evaporation from surface of the field, (c) Quantity lost due to percolation from the field.

In Hyderabad some preliminary experiments on these lines were conducted under Nizamsagar. These experiments were conducted with paddy crop. Some soil plots were cultivated in the normal way; while a concrete bed with draining arrangements was provided for other soil plots. Evaporation losses were recorded on an evaporation pan adjoining the plots. Losses due to percolation were recorded from the plots with concrete bed by collecting the water percolated. The total quantity of water supplied was measured. Deducting the evaporation and percolation losses from the total quantity of water supply, the actual quantity utilized for plant growth was derived. The results were very interesting. It was found that out of the total quantity of approximately fifty five inches of water required for the crop the plant utilization was about ten inches only. Other investigators in India have also found that the water requirements for plant growth of paddy was about 800 pounds of water per pound of paddy.

Thus these preliminary experiments indicated that the actual requirements for plant growth was little compared to the total quantity required by the crop. It may not be possible for us to control the evaporation losses, but means can be devised for controlling and reducing the percolation losses. The percolation losses observed were in order of twenty two inches out of the total of fifty five inches. He thought that experiments conducted on these lines will yield very useful information.

These experiments also indicated that the water requirements for a particular crop also varied during the crop period. There were certain periods for the paddy crop when the requirement of the crop was actually 2 to 2½ times the average rate for the whole crop period. This feature will have an important bearing on the design of the carrying capacity of canals. Normally the canal for paddy crop is designed to discharge 1.3 times the average requirements during the crop period. But if the peak rate of requirement is of the order of 2 to 2½ times the average, as indicated by experiments, the canal will fail to serve the needs of the crop. A canal designed with a carrying capacity of 2½ times the average requirement will naturally be uneconomical. Thus more experimental work on these lines is necessary to study not only the total water requirements for the whole crop period, but also its variation during the crop period.

MR. A. C. MITRA said that he thought that they were not taking into account variation of the crop output with the total quantity of water used. This was very important when supplies were short. The problem arises whether the optimum water was to be distributed to a few fields or over a larger area for the maximum total yield. This aspect of the problem should be investigated.

THE SECRETARY said that two aspects were being dealt with. One was regarding the investigation (as requested by Dr. Banerji) about the water requirements of crops. He did not think that Damodar Valley Corporation would not fall in line with the suggestion of the Board and carry out these investigations.

Regarding the point, raised by Dr. Banerji and Rai Bahadur Kanwar Sain, the idea of this Committee was to co-ordinate research and to determine the objectives. Actually different experiments were being carried out by different administrations. These experiments had to be sponsored by their respective provincial Governments. Experiments carried out in the Punjab might not benefit Madras. For each project, this work had to be carried out and the entire cost should be borne by the respective provinces or units. Therefore, the suggestion of the Board was that in addition to the committee at the centre, every province and major state should set up similar local committees comprising 2 representatives each from the local Irrigation and Agricultural Departments and one representative of the Meteorological Department. The function of these local Committees should be to carry out and supervise the research being carried out in their administrations on the subjects mentioned above and to assist in carrying out the policy to be laid down by the Committee to be formed at the centre.

DR. N. K. BOSE said that he did not mean that Damodar Valley Corporation would not cooperate. But they said that they would not be able to bear the cost. Their contention was that the results of these experiments would be useful for other parts of the country also.

MR. S. N. GUPTA wished to raise a word of caution *viz.*, that before one entered into the fineries of agricultural experiments, he should be able to decide about the preliminaries. In the last July meeting at Simla Dr. Sethi pointed out that the experiments should be planned on the split block system, whereas now in U.P. they were using randomised block system. He sent his statistical officer to Lucknow to get details from the Statistician of the Agricultural Department about the split block system and they just pointed out to him that this type of system was only used for very specialised type of experiments. "Thus randomised block system was better suited for carrying out experiments which were primarily meant to be conducted under conditions which a cultivatar is likely to face in the field. This will readily afford a means to save every cusec of water which is being wasted these days on our canals."

THE PRESIDENT observed that this was a matter of detail which the committee might look after. He said the Committee should be able to form a questionnaire on the subject.

THE SECRETARY requested the Provinces and States to form committees on this basis, if that had not already been formed.

5E. Soil Surveys

PRELIMINARY NOTE

This subject was introduced for the first time in 1947 and the following resolution was passed by the Board :—

“ Resolved that scientific soil surveys, both reconnaissance and intensive, should be carried out for all irrigation projects from the points of view of suitability of lands for cultivation, alignment of irrigation channels, and drainage prevention of water logging, alkalinity and other cognate matters.

“ That a fairly representative number of soil bores to adequate depths should be examined for purposes of intensive soil surveys and field notes, as comprehensive as possible, collected during such survey work. The classification of soils should be based on specific soil standards and use may also be made, wherever possible, of the results and experience of the agricultural and health departments of the soils of the areas under survey.

“ Resolved further that a sub-committee comprising Rai Bahadur Sethi, Dr. Gokhale of Bombay, Dr. Krishnan of Hyderabad, Mr. S. B. Kahai of Sind, Mr. M. L. Mehta of East Punjab and Dr. Hoon as convener be formed to define soil standards for soil survey to be carried out by various research stations and to review those standards from time to time on the basis of the experience gained by such work ”.

In response to the above resolution information has been received from the Central Waterpower, Irrigation and Navigation Commission detailing the steps taken to implement the Board's decision.

The practice adopted by the Irrigation Department Ceylon as regards soil surveys has been explained by that department as follows :

“ Before an irrigation project is taken up for construction, preliminary investigations are done regarding suitability of site of a dam and the general layout of the area to be developed. The area to be developed is surveyed by the Agricultural Chemist.

“ In studying the foundation materials for the construction of the dam, bore holes are driven and samples of soil are obtained. These samples are tested in the soil Mechanics Laboratory and the soils are classified. The soil classification adopted is similar to the one adopted by the American Bureau of Soils.”

Bombay has replied saying that the resolution has been given effect to and the Superintending Engineers of the different circles have been asked to bear the points mentioned in the resolution in mind while preparing project reports.

Bihar has said that the resolution will be kept in mind while proceeding with the projects in the Province.

The United Provinces informs that no steps have so far been taken to implement the resolution but it is proposed to carry out soil surveys when major irrigation projects are undertaken in future.

Assam informs that proposal for starting a Research Irrigation and Soil Laboratory in the Province is under contemplation and soil surveys *etc.* referred to in the resolution can be taken up when the Laboratory is completed.

The Central Provinces, Orissa and Bikaner regret that no action on the resolution is possible at present.

Replies from others are awaited.

The sub-committee set up as per resolution has not met so far. It is proposed that its first meeting will be held prior to the Research Committee Meeting—1948.

The following item was discussed at the 1947 meeting of the Research Committee :—

- (1) Soil survey of the area commanded by the Mor Project.

Recent Literature

(1) Soil survey procedure and its application in road construction. Department of Scientific and Industrial Research, Road Research Bulletin No. 4, 1946.

(2) Soil mechanics fact finding survey progress report triaxial shear research and pressure distribution studies on soils. War Department, Corps of Engineers, Mississippi River Commission, Waterways Experiment Station, Vicksburg, April 1947.

(3) Soil sampling and testing instruments. Roads and Road construction, Vol. 23, No. 276, December 1945 and Vol. 24, Nos. 278-280, February, March and April 1946.

(4) Hubble, G. D. :—Soil survey of part of Water House Estate, Country of Dorset, North East Coast Tasmania. Journal of Council of Scientific and Industrial Research, August 1946.

(5) Pendleton, R. L. :—Soils of India—four soil surveys in Gwalior State. Soil Science, Vol. 63, No. 6, June 1947.

(6) Ray Chaudhuri, S. P., and Mukherjee, S. K. :—Present position of soil survey in India. Journal of Scientific and Industrial Research, Vol. 6, No. 10, October 1947.

(7) Sen, A., Vakil, A. C., Mukherjee, S. K., Biswanath, B. :—Comparative studies on Indian Soils IV—mechanical analysis of soil profiles. Indian Journal of Agriculture Science, Vol. 16, Part III, June 1946.

(8) Das, S., Mukherjee, S. K., Sen, A., and Biswanath, B. :—Comparative studies on Indian Soils III. Base exchange properties. Indian Journal of Agriculture Science, Vol. 16, Part III, June 46.

(9) Mukherjee, B. K., and Mukherjee, P. :—Studies in Gangetic alluvium of United Provinces—cultivated soils of Unao District. Indian Journal of Agricultural Science, Vol. 16, Part III, June 1946.

(10) Smith, H. W. and Moodie, C. P. :—Collection and preservation of soil profiles. Soil Science, Vol. 64, No. 1, July 1947.

(11) Winterkorn, Hans F.—Engineering uses and limitations of pedology for regional exploration of soils. International Conference on Soil Mechanics and Foundation Engineering, Rotterdam, Vol. 1.

(12) Belcher, Donald J., Associate Professor of Civil Engineering, Cornell University, Ithaca, New York.—The determination of soil conditions by aerial photographic analysis. International Conference on Soil Mechanics and Foundation Engineering, Rotterdam, 1948, Vol. I.

(13) Frost, R. E. and Woods, K. B., Purdue University.—Aerial photographs used for an engineering evaluation of soil materials. International Conference on Soil Mechanics and Foundation Engineering, Rotterdam, 1948, Vol. I.

(14) Oosterbeck Jr., H. J. Assistant of the Soil Mechanics Laboratory, Research Department, Delft., Holland.—Soil Vibrations. International Conference on Soil Mechanics and Foundation Engineering, Rotterdam, 1948, Vol. III.

THE YEAR'S WORK

The following two items were discussed at the 1948 Research Committee meeting :—

- (1) Survey and analysis of the Suri (Tilpara Ghat) soil for the purpose of land acquisition.
- (2) Soil investigation for Lower Bhavani dam area.

(1) SURVEY AND ANALYSIS OF THE SURI (TILPARA GHAT) SOIL FOR THE PURPOSE OF LAND ACQUISITION⁽¹⁾

In connection with the acquisition of land for the Mor Project it was necessary to test the fertility of paddy fields on either side of the proposed afflux *bund* near Tilpara Ghat. This area was to be acquired for the Mor Project and the quality of the soil was to be determined for the purpose of paying compensation. Accordingly a survey was arranged for getting samples from these fields. The area comprised of about 500 acres and consisted of a high land paddy field and a low land paddy field differing in level by nearly 15-16 ft. Both the fields had a rolling topography ; the drainage water generally accumulated in the low land from where it was directed to the Mor river through a drainage channel. The afflux *bund* has been put up

⁽¹⁾ River Research Institute, West Bengal, Annual Report, 1947, pages 163-165.

recently separating the two fields. A rapid survey of the high land area showed that the surface soil was apparently of a uniform character and had the following features. The surface soil was grey loam of granular structure but towards the lower depths the compactness gradually increased. The roots of plants, however, were seen even at 4 feet depth. There was an abundance of *kankar* nodules which were firmly embedded in the compact soil mass. The surface soil of the low land was also almost uniform throughout and had a loamy nature but the profile characters were somewhat different from the high paddy field. The greyish surface soil changed its colour to brown at lower depths. The surface soil had a crumb structure and became pulverized under press of fingers. At lower depths between 4-5 feet accumulation of large-sized stony materials was observed. The soil was moist throughout as a result of its low level. The roots of plant penetrated to about 3 feet. The compactness of the high land soil at lower depths appeared to be a limiting factor for consideration of its suitability for agricultural purposes so far as drainage was concerned, but the high level of the land might be taken advantage of by increasing artificial drainage. The construction of drainage channel seemed to be necessary in view of the proposed afflux *bund* since the latter might prevent natural drainage. The low field did not seem to be affected by any such topographical defects.

In order to examine the soil chemically in the laboratory samples were collected from different depths of the profile. As no sharp horizons were discernible, the depths were arbitrarily chosen. The clay and silt contents gave an idea of the physical condition of the soil. It was seen that both these constituents increased towards lower depths in the case of high land paddy field corresponding to the compactness of the soil as observed in the fields. This increase of compactness at lower depths is generally due to the process known as alluviation which is of general occurrence in continuously ploughed lands and gives rise to plough pans. The surface soil was rich in nitrogen and moderately so also in phosphorous and potash. The contents of P_2O_5 and K_2O at lower depths were also reasonably good. A satisfactory feature in spite of the high clay content and compactness of soil was the presence of lime carbonate which contributed although indirectly to a high value of exchangeable calcium. The presence of calcium in the soil in larger amounts made the soil permeable and also suitable for growth of such useful bacteria as *azotobacter* and *nitrosomonas*. The alkaline *pH* was not due to the presence of undesirable alkalies but was a result of high calcium saturation of the soil and the presence of calcium carbonate. The low land soil seemed to be equally good in nutrient status particularly when the figures for surface soil were considered. The low content of potash at lower depths (3-5 ft.) was not harmful for such crops as paddy which are not deep rooting. The lighter texture of soil at lower depths as revealed from the clay and silt figures is also not very harmful because level of the land was sufficiently low to enable the soil to supply with necessary amount of moisture. The high clay and silt contents of upper layers of the low land were most likely the result of their enrichment with materials washed from the high paddy fields. The values of exchangeable calcium and *pH* were quite satisfactory.

(2) SOIL INVESTIGATION FOR LOWER BHAVANI DAM AREA (2)

A preliminary investigation of the types of soils available in the region round about the proposed Lower Bhavani Dam was undertaken.

By progressive classification of the test results in respect of the 64 samples received, eight groups of soils were recognized in the Lower Bhavani Dam site area. A representative sample for each group was thereafter picked up and tested for its permeability. Tentative standards of the grain size distribution, plasticity and permeability values were arrived at ; and in relation to these standards the suitability of the different groups of soils was assessed. The conclusions arrived at were that (a) Group II to VI could be used for the impermeable section, (b) Groups I to VI could be used in semi-permeable sections of the earth dam and (c) Groups VII and VIII could be used in the puddle core of the dam.

Trial pits were recommended to be dug at intervals of about 250 feet on a grid system and samples of soils from different layers from each pit taken out and completely tested. Each of the trial pits would have to be taken down to the bedrock, which was likely to be in general within 6 feet depth from the ground level, in the area under consideration except in the Bagadudorai region. This was suggested to enable quantity survey to be made of the different soils available.

DISCUSSION BY THE RESEARCH COMMITTEE

DR. BOSE introduced item (1).

MR. SESHADRI introduced item (2) and said that the experiments referred to the preliminary investigation of soils that were available for the proposed Lower Bhavani Dam. During the survey, 45 borrow pits were dug and soil samples from each were taken and sent to the laboratory at Madras for testing. As a result of these tests, eight distinct types of soil were recognised and the results were given in tabular form. Classification for these was done according to Casagrande's method. Soils used in American dams were studied with reference to these soils and it was found that these soils corresponded nearly to the soils that were used in the various American dams. The permeability factor was also determined. From the experience of the American dams tentative standards of permeability value for soils to be used in the impermeable, semi-permeable and permeable zones of the dams were fixed. The entire survey procedure had been described in the report.

DR. HOON wished to know how the permeability of the soil with a great percentage of the coarser material was determined especially of the portion that passed through No. 4 mesh, and how the results of permeability in terms of the full sample were interpreted.

DR. D. G. KULKARNI explained his experience of the work he did in Gujrat with respect to soil survey for agricultural purposes.

(2) Irrigation Research Station, Madras, Annual Report, 1947, pages 150-156,
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DR. VAIDHIANATHAN said that the 'Coefficient of permeability' given by Madras should really be read as "Transmission Constant" as it had not been divided by viscosity.

RAI BAHADUR KHOSLA asked Dr. Hoon to introduce briefly the report of the Sub-Committee on "Standards for Soil Surveys" and the recommendations made by it.

DR. HOON said that the results obtained by some provinces must be of some use to others at least in the interpretation put on the exact characteristic of that soil. It was the view of the Committee that reconnaissance soil survey was essential before intensified soil survey was taken up in any area. After the reconnaissance soil survey one would be able to come to some decision regarding the quality of soil samples, and it had been laid down that usually one sample per 400 acres of land might be taken for the purpose of this soil survey. Similarly a limit of four square miles had been fixed for the trial pits. The wording had been left elastic so as to take into consideration all the aspects of the country. It had also been stated that the number of soil sample sites could be increased, if found necessary, at any particular locality.

It had been also decided that it was much better to take the samples from the pits rather than by auger because by taking them from the pit one could actually see the height and the horizons of different layers.

DR. BOSE enquired as to what size of pit had been recommended.

DR. HOON replied that the sampling depth was mainly determined by the depth of the soil crust. It had been recommended that the soil samples might be obtained for the entire depth where the soil crust was shallow. With deeper soil crust it might be necessary to go up 10 to 12 feet depth but at a few sites the sample should be carried right up to the water table. If the water table was higher, then sampling might be restricted up to the water table only.

Regarding the field notes, it was intended to draw out printed or cyclostyled forms that would quicken the soil surveyor regarding the information required to be collected by him.

Stress had been laid on how sub-soil water level should be noted. The reading had to be taken from the open wells at an early time in the day so that if the well were to be used then there might not be some depletion in the water level. For intensive soil sampling it had been decided to dig one bore hole for nearly 10 acres of land.

The laboratory examination of the soils in the case of soil samples of intensive soil survey was necessary, that is, one had to study phosphates, potassium in these soils also.

Finally it had been recommended that the Central Board of Irrigation might move the Government of India and Agriculture Department so as to bring about greater collaboration between the two so that the results of one Department could be utilised and studied by the other Departments, and it was also thought necessary that one or two more members from each Department who were actually engaged on the soil survey work might compare notes occasionally.

R. B. SETHI said that there was some difference in the proceedings in respect of collaboration especially between Agriculture and Irrigation Departments. The Committee at the outset had decided that soil conservation was required to be carried out by many departments such as Forest, Irrigation and Agriculture, and a recommendation had been made by the Indian Council of Agricultural Research that a Central Survey Committee should be established consisting of members from all the departments. In fact it was thought that no work should be carried out actually before taking decision on that Committee. But the actual work could not wait. Then it was decided that the Committee should proceed. That Committee was very essential in order to avoid duplication of work being carried out by different departments. That was the main introductory part which had not been included in these proceedings. In order not to delay the present work of the Irrigation Department, it was thought that the work should proceed as it existed and that when the All-India Committee was constituted the work of this Committee should be taken over by that Committee.

MR. S. L. MALHOTRA observed that Mr. Mehta who was formerly in the Committee had now left and he wanted Dr. Dhawan to be included as a representative from the Punjab. This was agreed to.

MR. GOVINDA RAO suggested to Dr. Hoon that the sodium and potassium contents in a few flora might also be investigated during soil surveys as an indication of soil fertility and suitability for various agricultural crops.

DR. VAIDHIANATHAN opined that this was not only duplication but quadruplication of work. They had already instruction for preparing the particulars for underground watertable and when it would be printed, it would contain much of the particulars required by this Committee.

MR. BIJAWAT said that so far as the movements of sub-soil watertable was concerned, their department had undertaken the work, and secondly, they were going to print in their year book monthly tables giving detailed movements of watertable. That year book would contain two maps, one giving movements of the watertable on May 15, and the other on October 15. What he meant was that year book would contain complete information so far as movement of watertable was concerned and that further work by any other department would be more or less duplication of work. They did not know anything about this Committee being formed, otherwise they would have pointed this out earlier.

MR. GULHATI referring to the remarks made by R. B. Sethi said that the proposal had been referred to the Board by the Ministry of Agriculture and it would be considered by the Executive Committee.

With regards to remarks on the sub-soil watertable he thought that this was mixed thinking. What they were discussing here was soil survey and during the survey one would be recording the watertable as a secondary item. So there was no duplication. He had, no doubt, that the recommendation now made by Ground Water Organisation regarding the manner in which this work would be conducted would be taken up by the Committee as soon as information was available. The intention was that it should be reviewed from time to time

MR. MATHRANI wanted to know how far this was being done on a systematic basis. What he liked to know was what was the object of the All-India Committee? Was it only an Advisory Committee or was it a Committee which would organise the work, *i. e.*, organising and carrying out of the soil survey work? In Sind, for example, where there was no cultivation, they did not generally do any extensive soil survey. The purpose of these intensified soil surveys should be to get a record of soil profile for the whole country.

MR. KHOSLA said that they must adopt the recommendation of the Sub-Committee with one or two suggestions made and keep the thing on the agenda.

DR. HOON replying said that with regard to Mr. Sethi's remarks that certain things had not been reported, he wanted to mention that it had been decided that only the main points on which they had decided regarding standardisation were to be recommended. Regarding the Survey Committee, there existed already a Soil Survey Department in the Agricultural Institute; but how far its present activities covered the work that was required by the various projects was doubtful. It was on that basis that it was decided that this Committee should proceed on with the present work of standardization, because it was felt that since the work of the projects had a very great priority, they could not await the decision of that central body.

Replying to Mr. Govinda Rao he said that the analysis of the sodium and potassium contents of the flora could only be done in such cases where that sort of information could be advantageous but the inclusion of that work as a part of the routine soil analysis for survey work could be very difficult.

The following recommendations of the Sub-Committee were then adopted by the Research Committee:—

STANDARDS FOR SOIL SURVEY*

1. For purpose of soil survey use should be made of the India Survey Department's survey and contour maps and the village revenue maps for fixing sampling sites.

2. The reconnaissance soil survey must necessarily be carried before undertaking intensive soil surveys.

(A) RECONNAISSANCE SOIL SURVEY

(1) *Intensity of soil sampling sites :*

(a) for the purpose of reconnaissance soil survey, one soil sampling pit should represent every about 400 acres or at the maximum 4 sq. miles, *i. e.*, 1/10 of the normal grid, in areas where the land terrain is fairly even.

(b) for areas where the land is uneven, it is difficult to lay down specific limits, but the sites should be so selected as to afford a fair representation of almost all the major aspects at any place.

(c) the number of sampling sites may be suitably increased if the variation in soil texture, *pH*, zones of soluble salts, calcareous strata, *etc.*, so justify.

*—Framed by a Sub-Committee comprising (1) Rai Bahadur R. L. Sethi; (2) Mr. H.S. Kahai of Orissa; (3) Mr. Mehrotra of the I. S. I.; (4) Dr. V. K. Gokhale of Bombay; (5) Dr. J. N. Mukerjee of I. A. R. I.; and (6) Dr. R. C. Hoon (Convener).

(2) *Soil sampling should preferably be done from pits excavated at each sampling site for that purpose than by soil augers.*

(3). *Sampling Depth.*—The depth to which the soil sampling may be done :

(a) is mainly determined by the surface geology ; *i.e.*, the depth of soil crust and nature of sub-strata information regarding which can be obtained by sampling, say, upto 30 feet or so from deeper test pits made at representative places, say, one in each four square miles, *i.e.*, 1/100 of the normal main survey grid.

(b) at places where the depth of the soil crust only extends to about six feet, the sampling should be done upto its full depth, with a soil auger or a boring machine.

(c) at places with comparatively deeper soil crust sampling should be done to a depth of 10 to 12 feet or even upto the watertable.

(4). *Collection of soil samples.*—The soil sampling should preferably be done according to the various horizons along the profile exposed. However, in such cases, where a marked differentiation of horizons in the profile is not met with, the sampling can alternatively be done by scale.

(5). *Field notes.*—The surveyor must be given complete instructions regarding the systematic collection of field notes and relevant information about cropping scheme, drainage, natural flora, *etc.*, in the area in general and in the proximity of the sampling site in particular. Printed forms bound in books of suitable size must be supplied to field parties, to enter all field data in a systematic manner. With regard to natural flora, more popular local names may be recorded and, if possible, their botanical names ascertained later from suitable source.

(6). *Sub-soil Watertable.*—It is very necessary that as complete information as possible should be recorded about the watertable, its seasonal fluctuations and the quality of the sub-soil water in the area surveyed. Where the depth of the water level in the wells is recorded, an attempt should be made to take observations as early in the day as possible to cut out variation due to the subsequent working of that well. For more systematic observations 1½ in dia. G.I. pipes 30 feet deep, one in each four square miles, will have to be fixed.

As far as possible, information regarding the internal drainage may also be collected.

(B) INTENSIVE SOIL SURVEY

(1). The location of test pits for the purposes of intensive soil sampling will very largely depend on the local variation and the information made available as the result of the reconnaissance soil survey. One bore in every 25 acres may be a fairly good unit for the intensive soil survey. One bore in 16 to 32 acres will probably fit in the location of the bores on the grid system better and can be adopted wherever possible.

(2). With regard to the depth of the test pits and methods of soil sampling, same conditions as suggested for the reconnaissance soil survey may be adopted.

(3). The laboratory examination of the samples collected during the intensive soil surveys, will have to be more comprehensive and include, besides other analysis, the determination of organic carbon, *N.P.K.* especially in the top soil the contents of *Na*, *K*, *Ca* and *Mg* in the exchange complex, total base exchange capacity, *etc.* For more detailed information regarding the genetic classification the chemical analysis of clay fraction has to be done.

(C) MISCELLANEOUS RECOMMENDATIONS

(1). In view of the magnitude of the future soil survey work over the whole country, the Sub-Committee considered that a close collaboration between the Ministry of Agriculture and the Central Board of Irrigation in this matter is very essential. It will be advantageous if the future work is put on a more unified basis. It will undoubtedly entail a big organisation and the training of a very large number of surveyors for the future work apart from the extensive laboratory facilities for the examination of soils.

(2). The Sub-Committee must continue to function to review the standards in future on the basis of experience gained by the surveyors engaged on this work. Moreover, a few more members, actually engaged on that type of work, be added to the Sub-Committee, so that while reviewing the standards, they may have the benefit of their field and laboratory experiences.

(3). When a Central Soil Survey Organisation is established, it may become possible to circulate relevant information for the benefit of other agencies in various parts of the country engaged on similar work.

DISCUSSION BY THE BOARD

THE SECRETARY said that two items were discussed at the Research Committee meeting. The Board last year appointed a sub-committee to define standards for soil survey to be carried out by various research stations and to review these standards from time to time on the basis of the experience to be gained by such work. The sub-committee submitted its recommendations at the Research Committee meeting. These had been adopted by the Research Committee and were on page 412 to 414. The Board might confirm the recommendations.

DR. R. G. HOON explained the resolution which was adopted by the Board.

6E. MISCELLANEOUS

THE YEAR'S WORK

The following one paper was discussed at the 1948 Research Committee Meeting :—

(1) Routine Analysis.

(1) ROUTINE ANALYSIS ⁽¹⁾

During 1947 altogether 62 water samples, one soil sample and one sand sample were received for routine chemical analysis. The water samples sent from different river systems were analysed for their clay and silt content, *pH* and salt content. The soil sample was submitted to mechanical analysis and also to chemical analysis for its salt content, organic matter content and *pH*. The sand samples collected from Mor River bed was analysed for its moisture content, specific gravity, absorption, material passing No. 200 screen, distribution of particles of different sizes, and Fineness Modulus in order to find its suitability for making concrete structures.

DISCUSSION BY THE RESEARCH COMMITTEE

DR. BOSE introduced item (1)

There was no discussion.

DISCUSSION BY THE BOARD

THE SECRETARY said that one item was contributed at the Research Committee meeting. There was no discussion.

⁽¹⁾ River Research Institute, West Bengal, Annual Report, 1947, Page 166

Section F
Water Utilization Projects

1 F. Study of Individual Projects

PRELIMINARY NOTE

The following projects were discussed at the 1947 Board meeting :—

- (1) “ Two crore scheme for dealing with minor irrigation works in the Mysore State ” by Shri M. Narasimhaiya, Chief Engineer, Mysore.
- (2) “ The project for constructing a dam at Gangapur near Nasik, Bombay—feasibility of constructing the dam in earth ” by Shri N. P. Gurjar, I.S.E., Chief Engineer, Bombay.
- (3) “ The Meshwa Canal Project, Bombay—Design of the weir and head regulator on pervious foundations ”, by Shri N. P. Gurjar, I.S.E., Chief Engineer, Bombay.
- (4) “ Nangal Hydel Project ” by Shri S. A. Gadkary, I.S.E., Chief Engineer, Electricity Branch, East Punjab.

Shri Gurjar was requested by the Board to forward in good time, for next meeting of the Board, a note on subjects (2) and (3) with plans *etc.*, and after making such modifications as he might consider necessary as a result of the informal discussion held on the subject.

THE YEAR'S WORK

The following items were presented to the 1948 Research Committee Meeting :—

- (1) The Sakri River Project (Bihar).
- (2) Indus water to Kutch State : A note on the possibilities of bringing—
- (3) The Don river irrigation project in the Bijapur District.

The following items were presented for discussion at the 1948 Annual Meeting of the Board.

- (4) “ Hydro-electric development—the Mahanadi Hirakud site ” by S.A. Gadkary.
- (5) “ Piprai Dam ” by B. P. Saxena.
- (6) “ Yamuna Hydro-electric Scheme ” by A. C. MITRA.

(1) THE SAKRI RIVER PROJECT (BIHAR) (1)

INTRODUCTION

The project provides for an inundation canal taking off from the Sakri River in Bihar. The principal function of this canal is to fill tanks *etc.* so as to enable the irrigators to lift water at their convenience.

The project is suggested to be developed in three *stages* as under :—

1st Stage :—

The Canal is to draw up to a maximum of 1,000 cusecs and must depend for sand exclusion mainly on the proper positioning and alignment of the head regulator.

2nd Stage :—

Should the sand exclusion by natural curvature be found inadequate after three to four years, a sand ejector is to be constructed.

3rd Stage :—

The Canal Section and Head Regulator are to be remodelled for increased demand of water up to maximum of 2,000 cusecs.

The case was referred to the Station for general advice regarding the design of a sand-excluding Head Regulator, of the canal and allied works in the project.

As the project is to be developed in three stages, the design has been dealt with, accordingly, in three parts.

PART I

Project design for conditions in Stage 1.

REQUIREMENTS

The gross requirements including losses worked out to 9,650 cusecs days.

HEAD REGULATOR

(i) Positioning of Head Regulator :

The *first* requirement governing the choice of site for the Head Regulator is sufficiently developed favourable natural curvature in the parent channel. Experience and experiments made at the Poona Station have shown that, in alluvial rivers, reliable and effective silt—or, more correctly, sand-exclusion can be obtained by correctly positioning the off-take of a canal towards the

(1) Central Waterways Irrigation and Navigation Research Station Poona, Annual Report Technical 1947, pages 199—202.

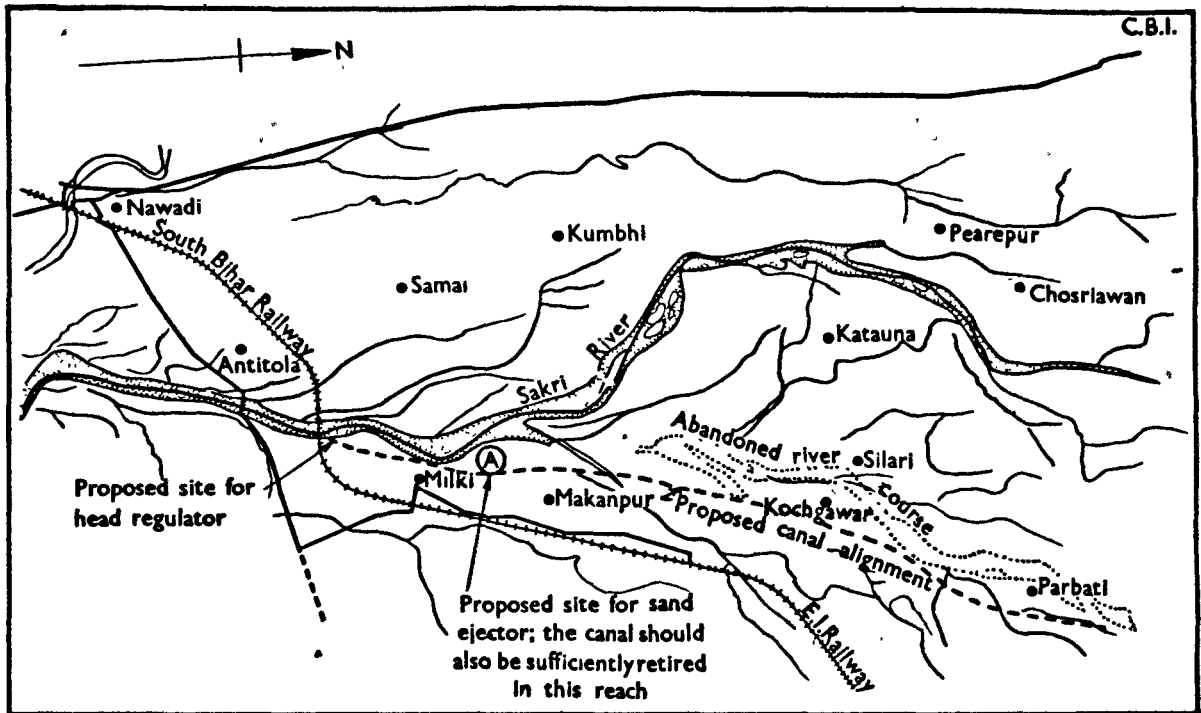


Figure 1F.1:- Index plan showing proposed canal head regulator and site for sand ejector in the Sakri River project

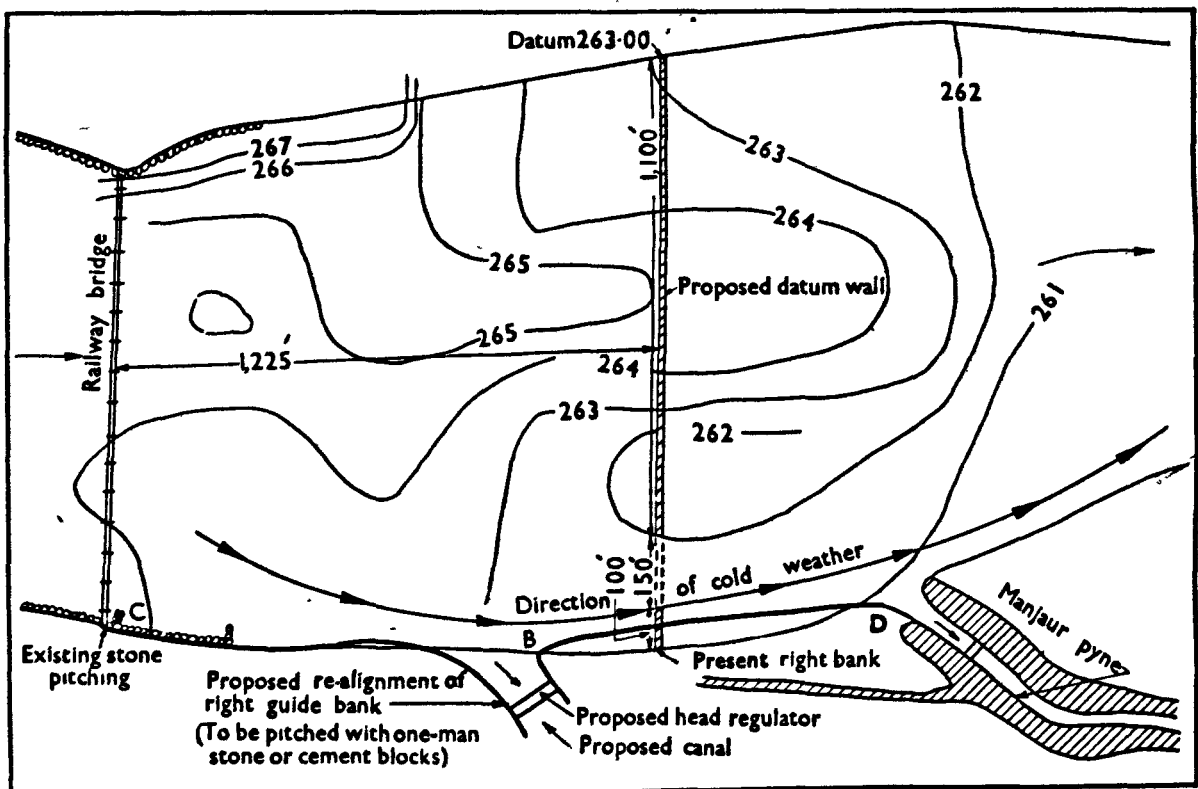
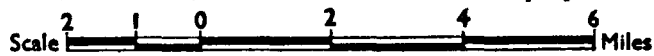


Figure 1F.2:- Showing datum wall and proposed head regulator for Sakri project canal



lower end of a suitably concave bank so as only to draw off the relatively sand free, surface water, the bottom bed water being deflected into the river. This is Nature's way of exclusion and experiments with the Sarda Barrage⁽²⁾ and the Son Anicut⁽³⁾ have shown this open-type excluder to be efficient even with relatively coarse material. A site was suggested which appeared suitable for natural exclusion in this manner, see Figure 1F.1.

The selection of the site was also guided by other considerations such as stability of the river reach in the vicinity, availability of hard and reliable strata at the proper level for foundations, adequate command of the area proposed to be flow irrigated, etc.

(ii) *Alignment of the Head Regulator :*

It was suggested that the Regulator should be located on the curved right bank facing fairly square to the current and the canal made to take off tangentially to the river curve—as shown in Figure 1 F.2.

This would result in the optimum sand exclusion possible under the existing conditions ; and incidentally help in obtaining a high velocity of approach—practically equal to the river velocity—which will enable some hortening of the regulator width.

(iii) *Clear waterway of the Head Regulator*

The only hydrograph available was for the year 1946. After detailed study and analysis of this hydrograph, the sill of the Head Regulator was proposed to be at R. L. 263.00, i.e. six inches above the river bed. The clear lineal waterway required to pass the necessary discharges, at all stages, will be proportionate to the river discharge, as desired.

(iv) *Details of the Head Regulator :*

It was suggested that the Head Regulator should consist of 10 spans, with piers 2.5 feet wide provided with semicircular cut-and ease-waters. The width between abutments will then be 122.5 feet, i.e. equal to the width of the canal, designed for a *high* bed width/depth ratio.

(²) Indian Waterways Experiment Station, Poona, Annual Report, Technical, 1941-42, page 19.

(³) Indian Waterways Experiment Station, Poona, Annual Report, Technical, 1941-42, page 20.

In order to enable the canal to tap only the surface, sand-free water at low and medium river stages, a set of sliding gates was suggested by the Station. The design of the regulator gates proposed is shown in Figure 1 F.3.

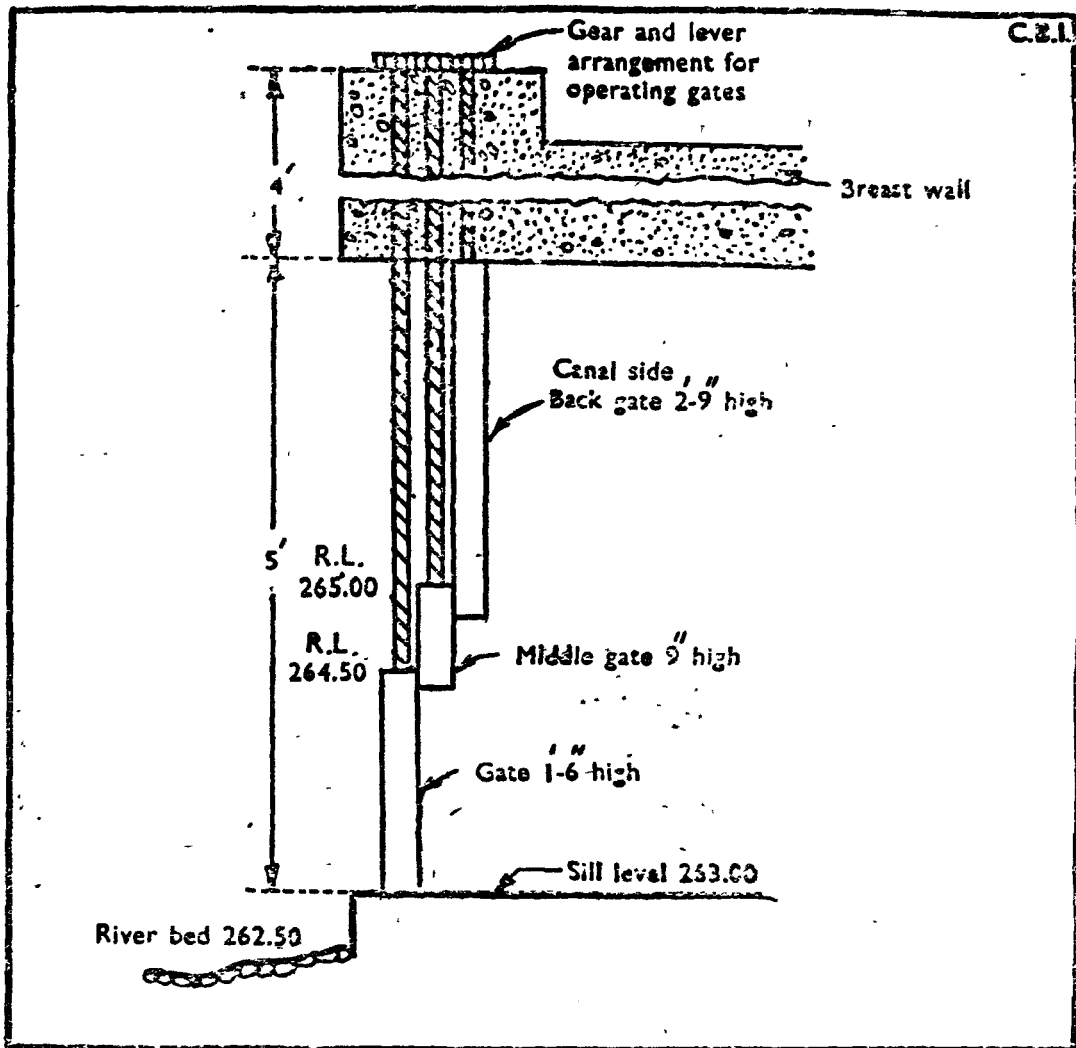


Figure 1F.3

CANAL DESIGN

(i) *Capacity :*

The design was made for 1,000 cusecs capacity with scope for increase, and for transporting lower discharges without undue risk of silting.

(ii) *Conditions guiding the canal design :*

The Full Supply Level of the canal, in this case, will mainly depend on the river water level available for passing 1,000 cusecs through the Head Regulator; and has to be as low as possible with non-silting slope so that it will run in low cutting avoiding heavy losses.

The $\frac{B}{D}$ ratio of the river = 180, indicating a heavy bed charge in the river. A wider, shallower and steeper canal than according to the Lacey's dimensions was, therefore, suggested. A wide initial section was also desirable to allow the deepening of the canal for passing increased discharges, in future, rather than widening it as the latter would be more expensive entailing alterations to cross-drainage works, crossings, etc. The steeper slope provided would avoid the necessity of subsequent raising of the banks following sanding due to deficient slope.

The canal was designed for $\frac{1}{2} : 1$ side slopes but was recommended to be constructed to flatter side slopes so as to allow sufficient capacity even after berming of $\frac{1}{2} : 1$ slope.

(iii) *Canal section and slope adopted :*

Various alternative designs, with different slopes and with a width equal to or wider than the width between abutment of the Head Regulator, were prepared according to Lacey and Kennedy formulae.

Conditions guiding the design—mentioned above suggested the choice of the following design :—

| | |
|------------------------------------|---|
| Bed width | = 120 feet. |
| Slope | = 0.0004, i.e. 1 in 2,500. |
| Surface Slope | = $1/2 : 1$ (to be constructed at $1 : 1$) |
| Depth for 1,000 cusecs | = 3.22 feet |
| Velocity for 1,000 cusecs | = 2.61 feet per. sec. |
| Full Supply Level for 1,000 cusecs | = R. L. 262.03. |

(iv) *Canal alignment :*

The canal alignment proposed by the local Project Engineer approached dangerously close to the river at the point, marked (A) in Figure 1 F. 1. The river in this reach is flowing along a sharp bend, and the possibility of an inroad into the canal must not be overlooked. It was, therefore, suggested that the canal should, from the start, be sufficiently retired in this reach to avoid the necessity of a subsequent diversion.

PUCCA DATUM

A "pucca datum" across the river designed to maintain its bed at the same level as the Regulator sill was proposed by the Project Engineer.

In order to protect the Datum wall from scour and subsequent undercutting, loose stone pitching—as in Figure 1F. 4—was suggested. This will also prevent any retrogression of levels downstream of the datum affecting the bed levels upstream.

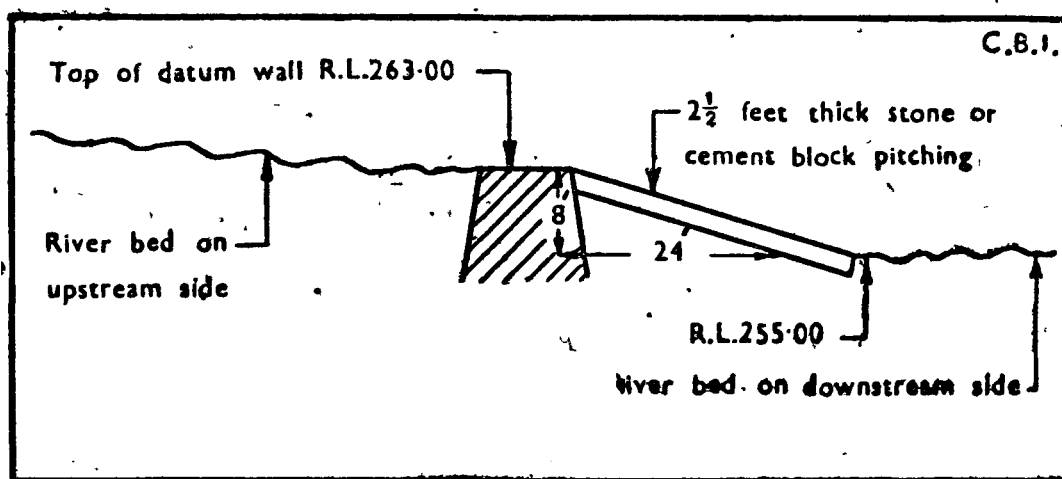


Figure 1 F. 4

TRAINING WORKS

To hold the river between its present high banks, to provide a smooth approach and to stabilise the existing favourable concave curvature along the right bank for a suitable offtake, it was recommended that the right bank should be pitched and sufficient apron be provided against the probable scour.

PART II

Project design for conditions in Stage 2

There is scope in the proposed design for the subsequent addition, in the future, of an ejector near point A in Figure 1 F. 1 if at all found necessary.

PART III

Project design for conditions in Stage 3

In future, the requirements are expected to increase to double the present requirements.

The modifications then required will be as follows :—

- (1) The Head Regulator will have to be sufficiently widened, or flumed and widened, to double the discharging capacity.
- (2) The canal will have to be remodelled and/or lined, the choice being governed by the considerations of economy and efficiency.

The design suggested, while meeting the present requirements, allows full scope for such alterations and modifications as are likely to be necessary.

(2) INDUS WATER TO CUTCH STATE—A NOTE ON THE POSSIBILITY OF BRINGING⁽⁴⁾

ABSTRACT

A note by Brigadier Hawes on "the possibilities of bringing Indus water to Cutch State" is discussed.

Brigadier Hawes' Proposals.—Brigadier Hawes first considered the feasibility of bringing the Indus water to Cutch *via* the Nara canal ex the Sukkur Barrage and the Puran Dhoro but condemned it on the grounds of prohibitive cost.

The suggestions sponsored by him was to take off a *separate Feeder* from the proposed Lower Sind Barrage, (then contemplated to be constructed near Hajipur) about 75 miles from the nearest point in Cutch Territory, alternatively for taking water to (a) Village Luna to irrigate lands near Banni or (b) the border of the Rann at mile 75 to commence irrigation for the lands thereabout, Figure I F. 5. He, however, himself considered the proposal (a) to be a rather hopeless task as the Feeder from Cutch boundary to village Luna would have to run in very heavy banking and thus be expensive and constantly liable to serious breaches. He favoured the latter proposal (b) as it would enable dropping the Full Supply Level from R. L. 29.80 to R. L. 16.0 through falls at two places resulting in the reduction of the cost of the scheme.

The costs of these two alternative schemes as worked out by him were Rs. 1,64,20,000 and Rs. 70,70,000 respectively.

Brigadier Hawes' note was written in July 1943, when the Lower Sind Barrage was proposed to be sited at Hajipur, about 75 miles from the nearest point in Cutch Territory. It has since been finally decided to locate the Barrage near Kotri, some 23 miles further upstream on the river. This will make the nearest point in Cutch about 100 miles away from the Barrage in a proposal similar to that of Brigadier Hawes.

The costs worked out by Brigadier Hawes were based on very rough figures, without surveys, quantities or proper estimates. Actually the figures used by Brigadier Hawes are about only one-third the present estimates.

The estimates would also be out as due allowance would have to be made for 33 per cent. additional length of the Feeder from Kotri.

Brigadier Hawes' proposals are, moreover, impracticable with a barrage at Kotri; because it would not be possible to give the required Full Supply Level at Luna in Cutch with a separate Feeder.

(4) Central Waterways, Irrigation and Navigation Research Station, Poona; Annual Report Technical, 1947, pages 219—220.

Such an idle Feeder running in very heavy bank (as already anticipated by Brigadier Hawes himself) would be very expensive, liable to breach, difficult and costly to maintain. The transit losses would be heavier than expected by Brigadier Hawes, leading to waste of very valuable water and the risk of possible water-logging. Lining of this Feeder running in heavy bank (20 to 30 feet above ground) has been considered impracticable by Brigadier Hawes, it would certainly be a costly and hazardous undertaking. Without lining, however, there would be considerable risk of water-logging of the Sind areas through which the Feeder would pass, resulting in complications, disputes and claims for compensation by Sind, which must all be taken into account in any reasonable financial forecast. Sind would, moreover, strongly oppose any such scheme at any price.

The meagre balance river supplies available (except in July and August) particularly the *essential* supplies in early and late *Kharif* months required for sowing and maturing, have been already fully appropriated for the new Sind and Punjab Canals. The burden of shortages would, therefore, fall on the new-comers, particularly as Cutch would find it hard to establish herself as a "*repaarian*" state with a valid claim on the waters of the river. These shortages would be very heavy in five years out of ten, especially in May and June, and, on a conservative estimate Sind should count on 20 percent remissions on an average, on account of shortages of supply, excessive losses, breaches *etc.*, This makes the poor financial aspects of Brigadier Hawes' scheme a most gloomy.

It is also doubtful whether Sind and Punjab would agree to participation by Cutch except legal agreement that their canals would have complete priority in all circumstances, *i.e.* the Cutch Feeder would only get supplies when and if river supplies would be in excess of the full requirements of Sind and Punjab and that Sind and Punjab would not be called upon to share supplies with Cutch at such times. Under such conditions participation would be of little value to Cutch.

Alternative proposals.—The only scheme worthy of consideration would be a *separate branch* for Cutch upto Luna from the tail of the Fuleli Canal System, preferably with the main lined Fuleli lined up to its tail.

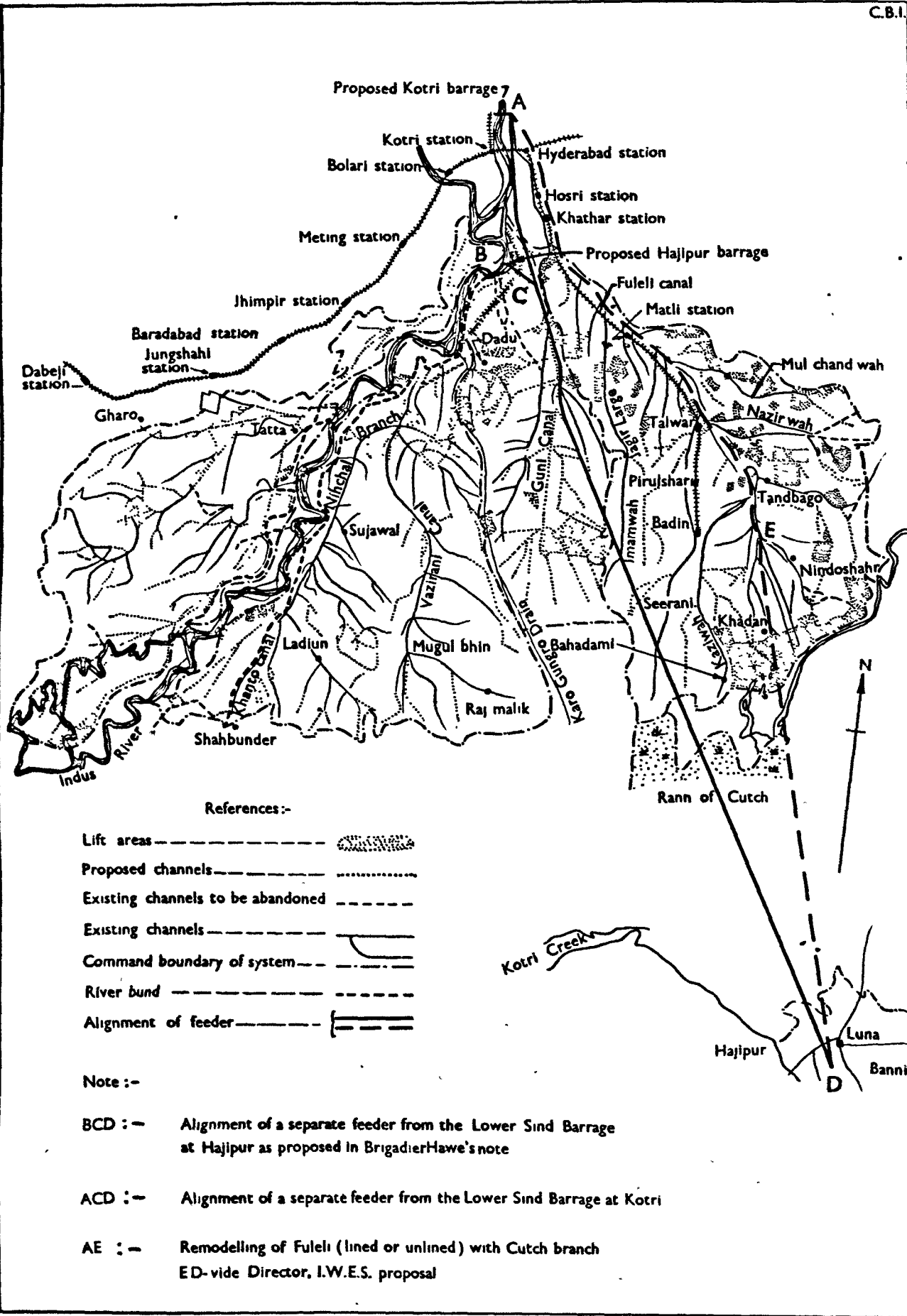
Even with the unlined Fuleli Canal, in addition to lower first cost and a superior financial forecast, there would be the following advantages:—

(a) Brigadier Hawes' proposal of a direct Cutch Feeder from the Barrage would not give flow irrigation when the Barrage would be at Kotri while this proposal will.

(b) This proposal would not entail transit losses otherwise necessary in a highly banked separate Feeder.

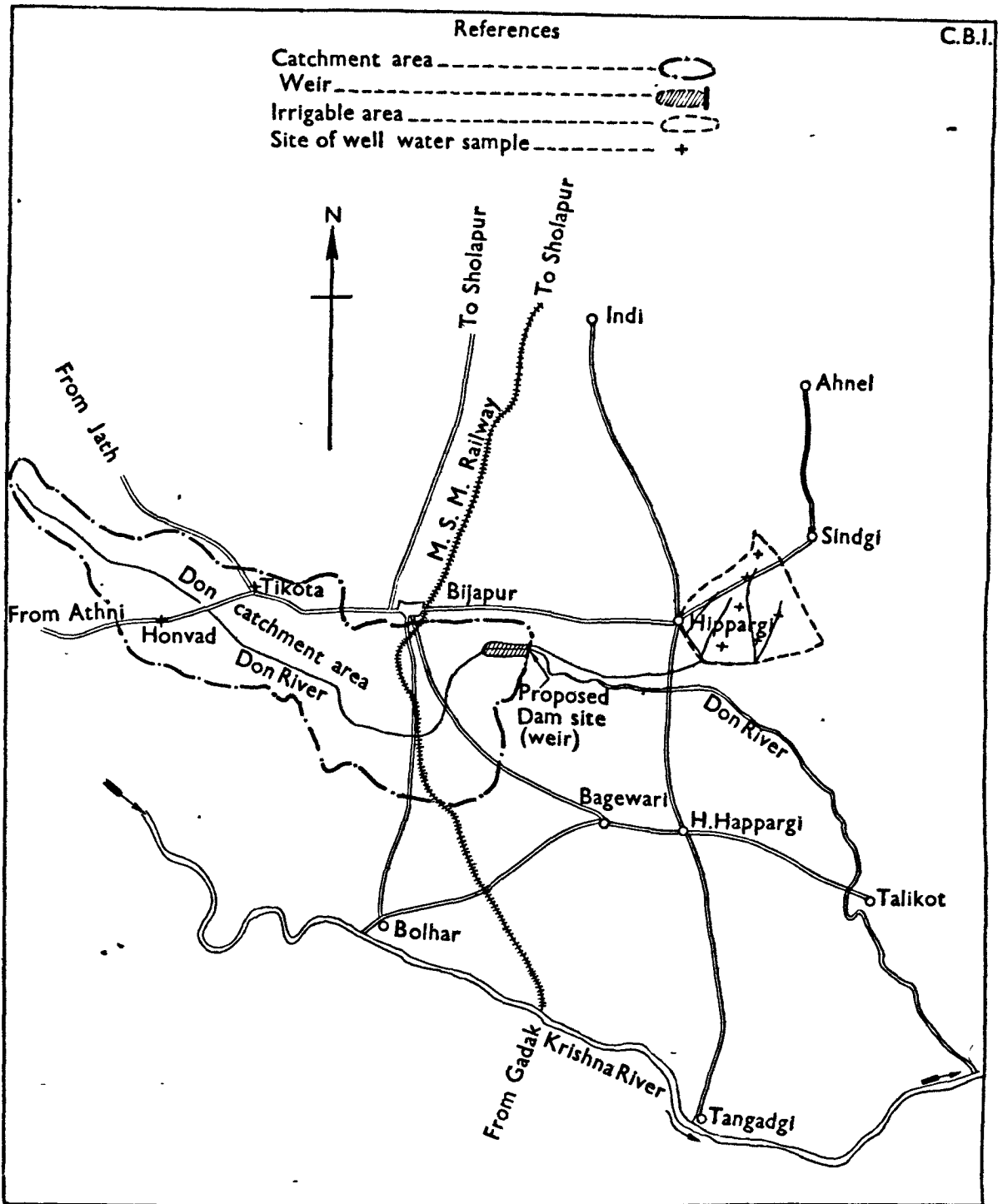
(c) The duplication of canals, cross drainage works, cross regulators, bridges, protective works, service roads would be avoided.

(d) It would avoid the undesirable necessity of truncating the command of the Sind channels and/or providing siphons.



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Figure 1F.5:- Showing lift areas and area commanded by Vazirani, Guni and Fuleli canals



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Figure 1F.6:- Part plan of Bijapur district showing the position of the Don catchment, weir and irrigable area

Scale 10 5 0 10 20 30 Miles

The cost of this proposal of a branch from the tail of the unlined Fuleli Canal has worked out to rupees 1.5 crores.

As the first proposal would require raising of the water level in the Fuleli by two feet (which would be opposed by Sind), though more expensive the alternative proposal of a lined Fuleli Canal was considered more attractive. The merits claimed for it were as under :—

(a) The proposal would benefit Sind as their lands would not be damaged by water logging, while Cutch would not be required to pay heavy compensation which might otherwise be claimed by Sind.

(b) Transit losses and Pocket withdrawals from the Kotri Barrage would be reduced by 1,000 cusecs as a result of the lined Feeder and thus sand exclusion difficulties would not be enhanced.

(c) It would enable flattening of gradients to the full extent necessary to give the Cutch lands the water levels required by them.

(d) This would be the only method by which it would be possible to give supplies saved by lining to Cutch during the crucial months when river supplies are essential but would otherwise be short of Sind requirements.

The total cost of this alternative proposal has worked out to rupees 4.5 crores.

It would, in any case, be an undertaking financially very difficult for Cutch ; but if the unassessable, indirect returns of giving irrigation supplies to Cutch would be of sufficient value to an otherwise arid and parched area, it would be a project worthy of Cutch's consideration.

(3) THE DON RIVER IRRIGATION PROJECT IN THE BIJAPUR DISTRICT⁽⁵⁾

INTRODUCTION

The Bijapur District is a tract of deficient rainfall, regularly visited by scarcity and often by severe famines. There are hardly any irrigation works worthy of name in this District. Government has been anxious since long to give this district the benefit of irrigation wherever possible. The Don River Irrigation Scheme has been talked of for over last fifty years. It appears that the scheme was investigated a couple of times and was abandoned without recording proper reasons for taking such a decision. The question regarding the feasibility of the Scheme was raked up again a few years ago and the project has also been included in the Post-War Reconstruction Plan.

⁽⁵⁾ Poona Irrigation and Research Division, Public Works Department Bombay, Poona, Annual Report, 1947, pages 70—75.

PROJECT

The Don river rises in the Bijapur District 40 miles west of the city of Bijapur, flows eastwards to a distance of about 30 miles east of Bijapur and then takes a turn and flows in the south east direction to meet the river Krishna in the Hyderabad State, the catchment of the river lying wholly in the Bijapur District. The dam of this river for impounding the shortage is proposed at a site about 12 miles east-south-east of the city of Bijapur. A left bank canal takes off this storage for irrigating about 12,000 acres of land in the Sindgi Taluka and lying wholly in the Bhima valley. The lands in the Don valley are excluded as they are saline, clayey and very sticky and are not fit for irrigation. Figure 1 F. 6 shows the lay-out of the project. The catchment above the dam which is expected to impound a gross storage of about 1,650 million square feet is 460 square miles. The net storage that will be available for irrigation after allowing for the dead storage and evaporation and percolation losses is about 940 million cubic feet. The water-spread at the full supply level is 5.7 square miles. The dam will be 8,000 feet long and its maximum height in the gorged portion will be 55 feet. The length of the main canal is 16 miles and that of the minors 14 miles. The entire storage is expected to be used for irrigating *Rabi* seasonal crops only.

RAINFALL AND RUNOFF

There is not a single rain gauge station established in the catchment of the Don river. The nearest rain gauge stations are at Bijapur and Athni and the average annual rainfall calculated over a period of 40 years recorded at these stations is about 20 inches only, Table 1 F. I. The rainfall in the Don catchment must be also of the same order and cannot be expected to be any higher. Figure 1 F. 7 gives a graph showing the distribution of rainfall in the normal years. The rainfall in June, July, October and November is about the same, *viz.*, 2.7 inches. The month of August is marked by absence of rain. September receives the most rain *viz.*, 6 inches and is responsible for causing floods in the Don river. The annual run off in a normal year in this catchment is expected to be of the order of eight per cent. as has been found in other similar catchments in the district. The Don river is in spate two to three times in July about six times in September and a couple of times in November in a normal year. The average flood discharge is of the order of 1,000 to 2,000 cusecs and the flood lasts from 24 to 48 hours. In the non-flood periods during the months from June to November the discharge in the river is about five cusecs only.

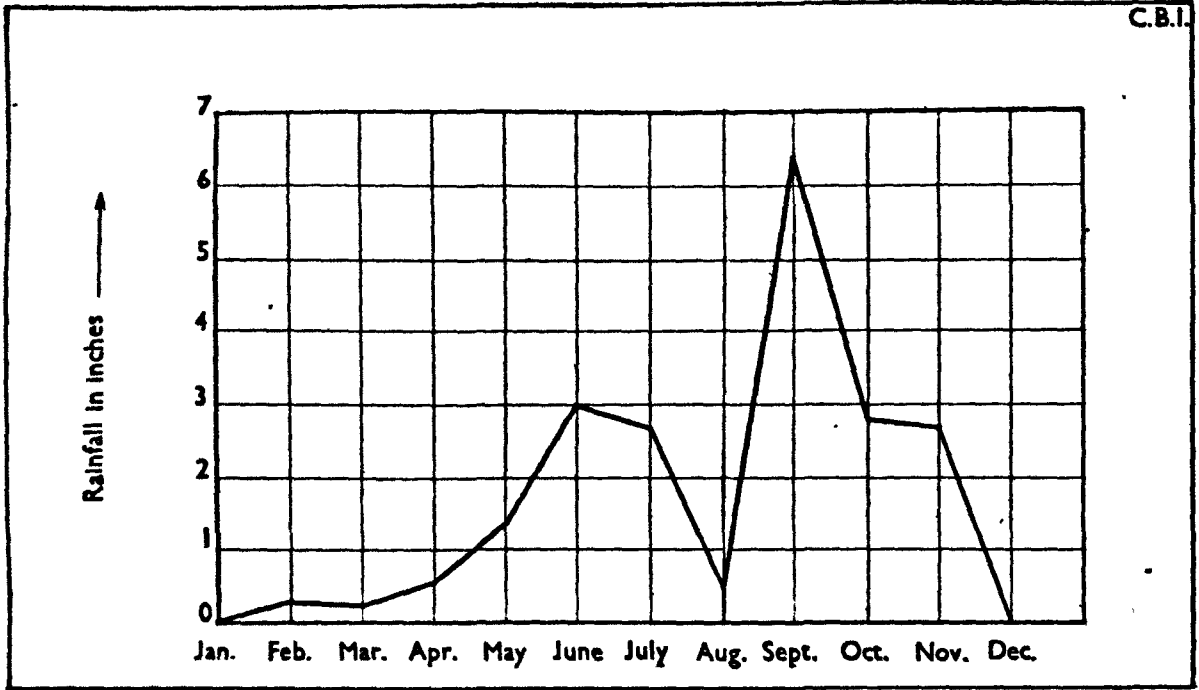


Figure 1 F.7:-Don River scheme-Showing average rainfall at Athani(average of 1921,27,28,36&44)

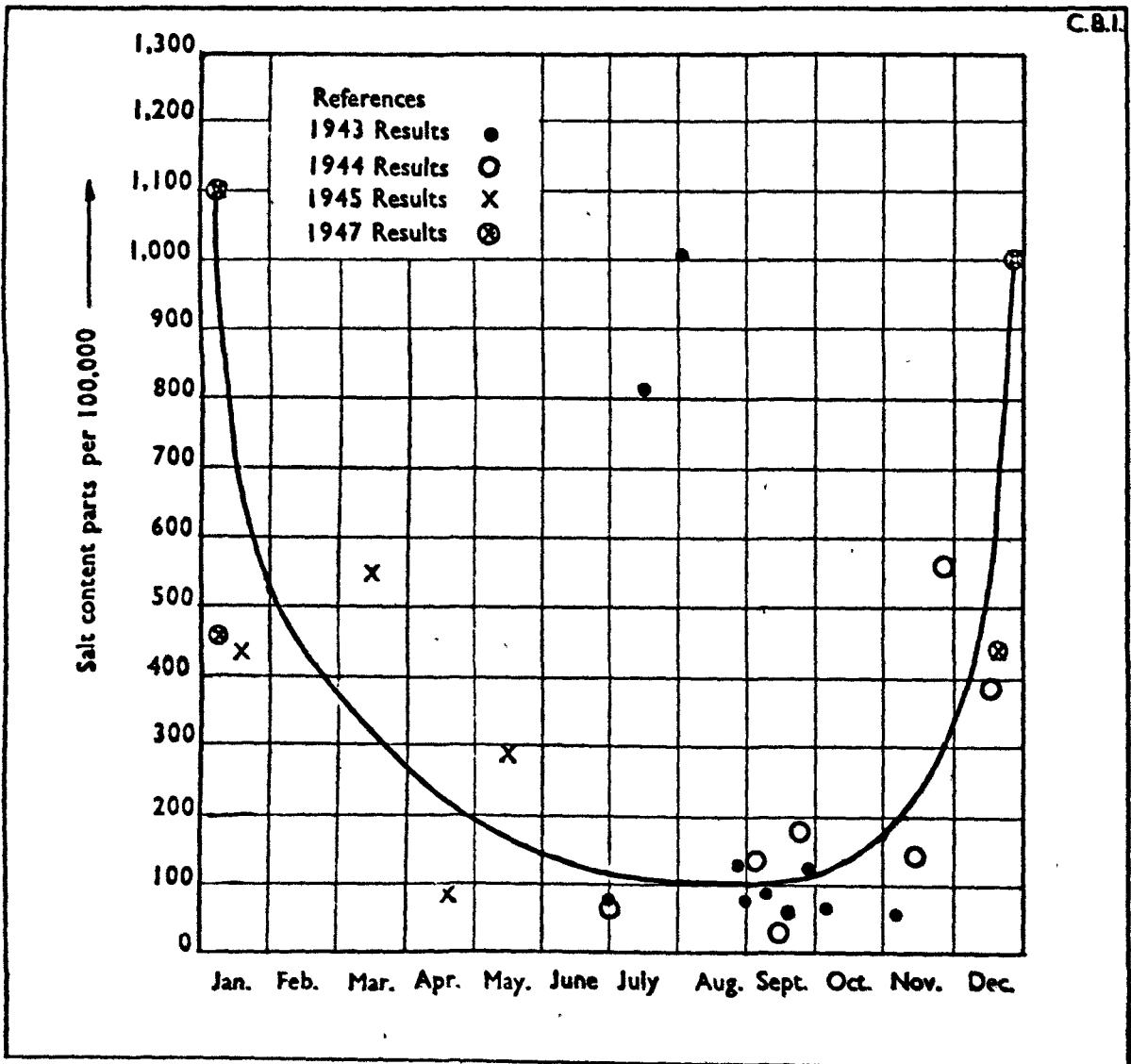
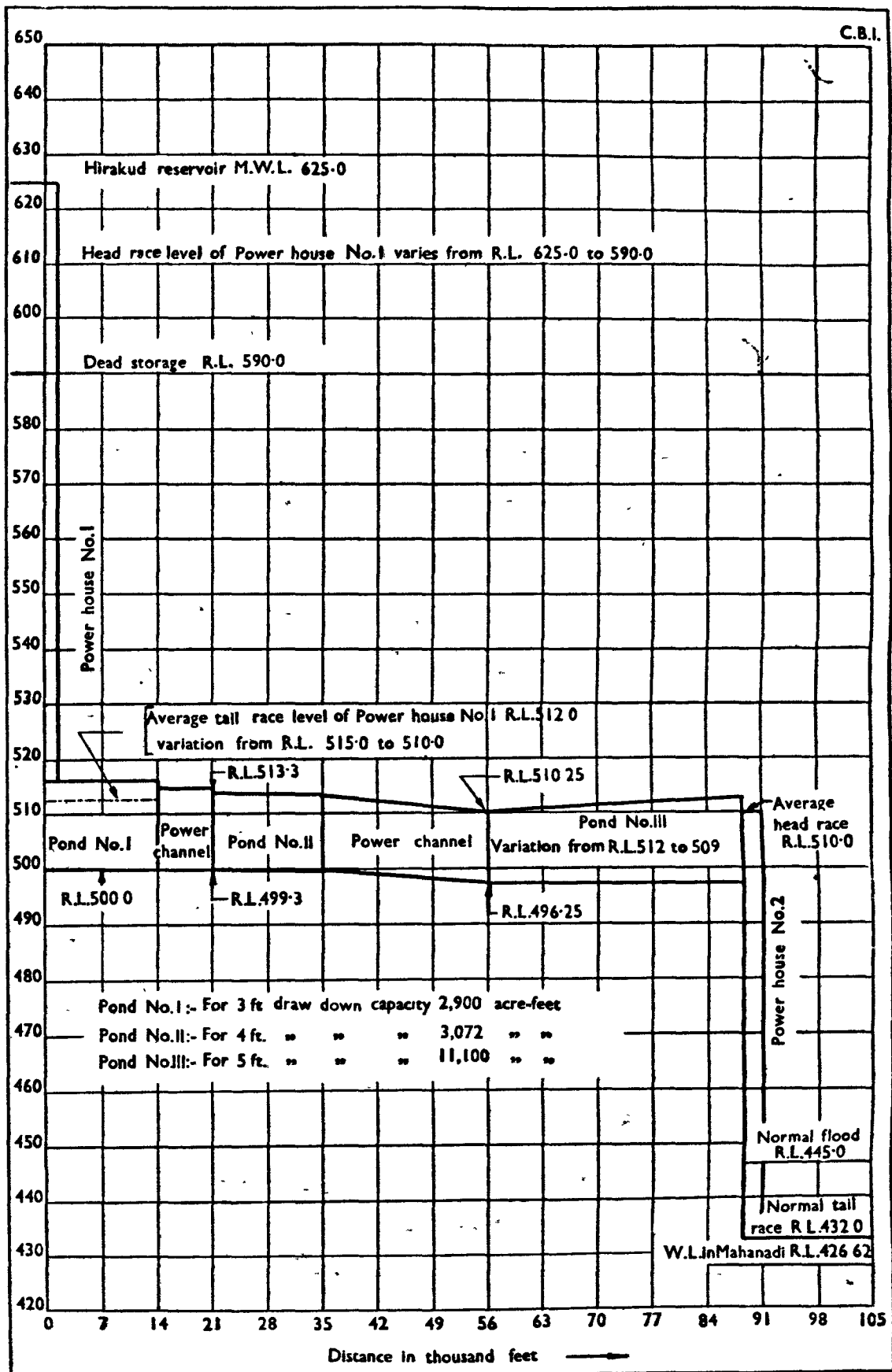


Figure 1 F.8:- Showing salt content in Don River water above Dam site



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Figure I.F.9:- Showing pictorial representation of the power channel
(Hirakud dam project)

TABLE IF. I

wing the rainfall registered at Bijapur, Sindgi, Bagewadi, Athni for Don Irrigation Scheme.

| Year | Bijapur | Sindgi | Bagewadi | Athni |
|--------------|---------------|---------------|---------------|----------|
| | (Inches) | (Inches) | (Inches) | (Inches) |
| 1917 | Not available | Not available | Not available | 18.34 |
| 1918 | " | " | " | 14.88 |
| 1919 | " | " | " | 30.04 |
| 1920 | 12.24 | 13.72 | 10.06 | 13.41 |
| 1921 | 17.56 | 27.21 | 20.98 | 21.45 |
| 1922 | 22.11 | 13.57 | 12.26 | 16.47 |
| 1923 | 11.09 | 14.36 | 13.74 | 12.52 |
| 1924 | 15.16 | 22.75 | 16.98 | 19.58 |
| 1925 | 19.94 | 19.65 | 16.87 | 14.06 |
| 1926 | 14.80 | 17.06 | 12.82 | 12.94 |
| 1927 | 19.97 | 27.46 | 24.04 | 20.29 |
| 1928 | 29.39 | 25.82 | 35.29 | 20.17 |
| 1929 | 26.18 | 13.65 | 18.27 | 32.54 |
| 1930 | 19.76 | 21.41 | 24.62 | 21.87 |
| 1931 | 25.20 | 16.47 | 19.56 | 22.23 |
| 1932 | 27.86 | 28.61 | 30.77 | 31.11 |

TABLE IF.I—*contd.*

Showing the rainfall registered at Bijapur, Sindgi, Bagewadi, Athni for Don Irrigation Scheme.

| Year | Bijapur | Sindgi | Bagewadi | Athni |
|---------------|----------|---------------|---------------|---------------|
| | (Inches) | (Inches) | (Inches) | (Inches) |
| 1933 | 29·10 | 33·94 | 40·77 | 32·94 |
| 1934 | 20·35 | 20·51 | 9·20 | 13·71 |
| 1935 | 24·02 | Not available | Not available | Not available |
| 1936 | 10·47 | .. | .. | 19·66 |
| 1937 | 12·51 | .. | .. | 11·99 |
| 1938 | 29·40 | 31·68 | 25·69 | 32·80 |
| 1939 | 22·47 | 18·82 | 24·44 | 26·91 |
| 1940 | 18·09 | 16·16 | 22·23 | 17·98 |
| 1941 | 17·50 | 11·68 | 14·99 | 24·99 |
| 1942 | 17·22 | 15·70 | 17·28 | 17·29 |
| 1943 | 31·73 | 30·27 | 26·96 | 24·00 |
| 1944 | 18·94 | 20·34 | 20·89 | 19·95 |
| 1945 | 13·05 | 18·63 | 17·35 | 12·93 |
| 1946 | 21·34 | 23·40 | 25·74 | 23·05 |
| 1947 | 19·25 | 27·27 | 26·02 | 26·77 |
| Total .. | 566·70 | 530·14 | 527·82 | 626·87 |
| Average | 20·48 | 21·20 | 21·11 | 20·87 |

QUALITY OF THE DON RIVER WATER FOR IRRIGATION

The river water is excessively saline during the major portion of the year. Figure IF. 8 gives a graph showing the amount of salt in the water during the year. The graph is plotted from the data collected during 1943, 1945 and 1947. The average quantity of salt during the rainy period from June to November is about 100 parts per 100,000 in the flood water. In non-flood water during the period the salinity is still higher. The salts increase five to ten times after November. Even during monsoon, it will be seen that the quantity of water as regards its suitability for irrigation borders on the danger limit. The water during fair season is definitely injurious for irrigation. Table 1 F.II shows the average composition of flood and non-flood waters collected during the rainy season of 1944.

TABLE IF.II
Average Composition.

| Average composition | Flood water | Non-flood water |
|-------------------------------------|-------------|-----------------|
| Total salts per 100,000 parts | 83.5 | 317.20 |
| Containing principally— | | |
| $CaCO_3$ | 15.20 | 18.34 |
| $MgCO_3$ | 1.69 | 23.60 |
| $CaSO_4$ | 3.27 | 10.37 |
| $MgSO_4$ | 8.84 | 43.03 |
| $NaCl$ | 29.10 | 111.17 |
| Na_2SO_4 | 18.78 | 103.63 |
| Na_2CO_3 | 2.12 | .. |

Excess of sodium salts, and magnesium sulphate exceeding calcium sulphate, make the water unsuitable for irrigation,

If the flood water is impounded with the idea of using it for *rabi* irrigation, all the flood water itself may be just suitable for irrigation of *rabi* crops, the addition to it of highly saline non-flood discharge and to some extent evaporation in the tank, area, however, calculated to raise the salinity of the storage to about 140 parts per 100,000 rendering the storage unsuitable for irrigation.

SALINITY SURVEY OF THE CATCHMENT

The catchment of the Don river lies in the zone of deficient rainfall and high temperature. Besides, it is much flatter than a Ghat catchment. Under these conditions the trap decomposes and gives rise to saline salts which are not leached away owing to inadequate rainfall. Hence the soils in this area are calcareous and saline. It is the alternating light showers of rainfall followed occasionally by a torrential down pour which brings salts into the Don waters. The light showers instead of leaching the salts away bring them to the surface by evaporation and they are washed away in the river by occasionally heavy rains. The river discharge picks up more salt and gets saline as it approaches the weir site. The sample collected from the river in its different reaches above the weir site gave the results given in Table IF.III.

TABLE IF.III

| Place | Distance above storage site in Miles | Total salts parts per 100,000 | |
|----------------------------|--------------------------------------|-------------------------------|---------|
| | | 1943-45 | 1947-48 |
| Bannur | 39 | .. | 330 |
| Honwad | 52 | 317 | 436 |
| Sarwad | 19 | 560 | .. |
| Bijapur Hubli Road | 10 | 940 | 1055 |

This shows that practically most of the catchment is saline and not any particular sub-catchment or sub-catchments thereof. This goes to prove that the detailed salinity survey as suggested by the Agricultural Department with a view to locating the weir suitably so as to exclude highly saline sub-catchment or sub-catchments, is not necessary. Further the location of the weir on the river is fixed within reasonable limits and it is not possible to achieve the intention with which the salinity survey was suggested by the agricultural Department.

Analysis of (a) the surface water during flood periods, (b) the spring water during non-flood periods and (c) the sub-soil water in the catchment gave the results given in Table I F.IV.

TABLE I F.IV

| Composition | Flood or rain water | Non-flood or spring water | Sub-soil water (well in S. No. 249 Honwad) |
|---|---------------------|---------------------------|--|
| Total salts, Parts per 100,000 | 88 | 284 | 150 |
| Containing principally— | | | |
| <i>CaCO</i> ₃ | 19.28 | 20.50 | 18.50 |
| <i>MgCO</i> ₃ | 1.93 | 23.60 | 0.70 |
| <i>MgSO</i> ₄ | 11.14 | 25.74 | .. |
| <i>NaCl</i> | 28.83 | 113.19 | 20.14 |
| <i>Na</i> ₂ <i>SO</i> ₄ | 15.33 | 109.10 | 85.32 |
| <i>Na</i> ₂ <i>CO</i> ₃ | .. | .. | 13.25 |
| <i>NaHCO</i> ₃ | .. | .. | 13.05 |

It will be seen that surface water contains more *NaCl*, spring water contains equal quantities, of *NaCl* and *Na*₂*SO*₄ and sub-soil water contains *Na*₂*SO*₄ in predominance as well as alkali carbonates. All these results tend to show the saline nature of the catchment.

SUITABILITY OF THE SOILS TO BE IRRIGATED

The area proposed for irrigation lies in the Sindgi Taluka in the Bhima valley and comprises of seven villages of—Hippargi, Mannur, Ibrahimpur, Kokatnocr, Bammanjogi, Kannoli and Budhihal. The average area of crops grown on rains in these villages during the last five years (1942 to 1946) was

2,045 acres *Kharif* (Mainly *Bajri*),

3,257 acres *Rabi* (*Jawar*),

297 acres eight-months crops.

There was no perennial irrigation as the supply of sub-soil water from the wells fail in hot weather.

The soils proposed for irrigation consist of :—

- (a) Coarse soil on ridge slopes,
- (b) Retentive medium black soils, on upper slopes,
- (c) Impervious ' *Karal* ' soils on lower valley sides,
- (d) Deep soils in the valley.

The black soils, although of moderate depth (four feet to five feet) on well drained *murum*, contain a large amount of soluble salt as a result of meagre rain fall and deficient leaching. The soils contain soluble salts of sodium and have themselves actually become sodiumised in certain areas. They contain about 50 per cent. of clay and 0.3 to 0.5 per cent. of salts and are highly retentive, impervious and heavy. Such soils are called 'Karal' soils. They do not yield crops properly if rainfall is above or below the optimum. Results of analysis of a typical profile in an open pit in a field of 'Karal' in the Kannoli village are given in Table 1F.V.

TABLE 1F.V.

| Depth in inches | Description | Soluble salts % | pH | Exchangeable bases mill-equivalent % | | | | Capillary rise in 24 hours Cms. |
|-----------------|---|-----------------|------|--------------------------------------|------|---------------|-------|---------------------------------|
| | | | | Ca | Mg | Na+K | Total | |
| 0-4 | Loose black soil | 0.14 | 7.65 | 40 | 4.0 | 3.2 | 47.2 | 12.3 |
| 4-24 | Stiff soil with wide cracks | 0.85 | 9.98 | 30 | 10.8 | 7.6 | 48.4 | 2.5 |
| 24-40 | Compact layer with prismatic structure. | 1.125 | 8.8 | 22 | 13.8 | 9.6 | 45.4 | Nil |
| 40-48 | Lime kankor, in cavities | 0.65 | 9.8 | .. | .. | Not estimated | | |
| 48 | <i>Murum</i> | .. | .. | .. | .. | " | | |

The results given in Table 1 F.V show how the profile gets impervious below four inches owing to a high percentage of Na + K.

Analysis of well waters in the area to be irrigated shows that the sub-soil water on the ridge line is sweet and fit for irrigations, but that in the valley contains increasing amount of salts making it unsuitable for irrigation. Sub-soil water from wells in Hippargi, Mannur and Kokatnoor which are situated on the ridge show the salinity of 60, 38, and 50 parts respectively per 100,000 parts. Well waters of Ibrahimpur, Bammanjogi, Kannoli and Budhihal situated in the valley showed a salinity of 122, 138, 114 and 160 parts respectively. This indicates that the rain water absorbed in the elevated—*murumy* and course soil in the upper lands, has travelled through the sub-soil towards the valley

and got contaminated with salts. The composition of well waters collected from Hippargi (on ridge) and Kannoli (in valley) is given in Table 1 F. VI.

TABLE 1 F.VI

| Composition | Hippargi (Ridge) | Kannoli (valley) |
|---|------------------|------------------|
| Total salts, Parts per 100,000 | 60 | 114 |
| Containing principally-- | | |
| CaCO ₃ | 13.75 | 20.75 |
| MgCO ₃ | .. | 5.67 |
| NaHCO ₃ | 11.55 | .. |
| Na ₂ SO ₄ | .. | 16.24 |
| NaCl | 5.9 | 8.76 |
| Na ₂ CO ₃ | 2.65 | .. |
| CaSO ₄ | 4.75 | .. |
| MgSO ₄ | 19.06 | 25.7 |
| MgCl ₂ | 2.31 | .. |

These waters are totally unsuitable for irrigation as they contain $MgSC_4$ in excess, and if used would spoil the land by making it impervious and saline.

CONCLUSION

It has been long pronounced by many that persennial irrigation is out of question in this project. Many have expressed hopes that *rabi* irrigation may be possible and may bring some relief to the famine stricken agriculturists. The tillers of the soil of the area concerned have always looked askance at this scheme and have often expressed doubts whether the application of saline water of the River don to their lands would make the soils saline or not. The Executive Engineer's (Mr. J. P. Naegamavala) opinion on recommendations about the suitability of this scheme is a definite "NO". This scheme according to him is third rate, full of risk and of doubtful beneficence and should be abandoned. Besides, the scheme is a very costly one. The storage is so situated that it will soon get silted up. The waste weir is likely to be expensive. The scheme was estimated to cost Rs. 34,00,000 before the last war, and was expected to yield only one per cent. gross revenue; that means it could not even repay the interest charges. Due to inflation, the same scheme may cost nearly a *crore* of rupees now. The cost of maintenance and management will also be fairly high. The water rates have, however, not increased in the same proportion and the scheme may barely yield any revenue at all, not even a part of the interest charges. Instead of sinking a good *crore* of rupees in this scheme, it will be wiser to have lift irrigation schemes at suitable places on the banks of the other four perennial and sweet water rivers with which the Bijapur District is blessed. They will be more reliable and we shall know where we stand instead of hitting in the dark on the Don Scheme which has to deal with saline waters and which has an uncertain catchment in a scarcity tract.

(4) HYDRO-ELECTRIC POWER DEVELOPMENT—THE MAHANADI HIRAKUD SITE

by

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INTRODUCTION

The design features of a hydro-electric generating station will vary very considerably depending upon the volume of water to be handled, working head available, the variation in head from month to month, storage capacity, etc. Therefore each such project will have its own special features and it is proposed to deal with the Mahanadi, Hirakund site, Project in this paper. Incidentally this would also bring out the method of our working and would give opportunities to other engineers to make their contribution on the subject, by way of comments and suggestions based upon their practice in handling the same subject.

GENERAL

The basic factors for the determination of potential water power are (1) stream flow and (2) available head or fall through which the stream flow may be utilized for the development of power.

Determination of head is a simple matter as it only means correct contour survey of the site. However, determination of stream flow to be taken as the basis for estimating power potential is often a complex matter requiring a detailed study in hydrology.

Stream flow, or run off, at any site depends upon many factors such as precipitation, extent of catchment area, condition and quality of soil in the area, temperature, evaporation, percolation, vegetation, slope of the ground etc.

Stream flow depends largely upon precipitation, its intensity, distribution over the catchment area, the total amount and the extent of the catchment area. Therefore, it is necessary to know rainfall gauge readings over the entire catchment area, if direct stream flow readings are not available over a period of several years. Conversion of rainfall into stream flow readings involves many approximations and naturally the results estimated are liable to great variations. It is beyond the scope of this paper to describe the various methods and formula employed by different engineers, in different countries, to arrive at the estimation of average mean monthly flow, at any given site from the data available under varying conditions such as (1) a very limited data for the site selected, (2) data applicable to a similar site somewhere else, (3) data available on the same river but several miles away, etc.

SCOPE OF THE PAPER

This paper really begins where average monthly run-off for the 'design year' is finally arrived at. For the Mahanadi (Hirakud) Project, such design year figures are given in Table 1F.VII. Other relevant data obtained for use on this project is recorded in Tables 1F-VIII to 1F.XII. This ends with the determination of Generator and Turbine capacities and their characteristics as required for the Mahanadi (Hirakud) Project.

TABLE 1F-VII

| Month | Inflow during the month. (Million acre feet) |
|-------------------|---|
| November | 1.01 |
| December | 0.57 |
| January | 0.45 |
| February | 0.35 |
| March | 0.33 |
| April | 0.23 |
| May | 0.10 |
| June | 0.73 |
| July | 10.93 |
| August | 18.02 |
| September | 20.66 |
| October | 4.09 |

IMPORTANCE OF THE COLLECTION OF DATA

Before we proceed with the subject proper, it is desirable to record, that situated as we are in India, with immense power potential spread over the entire length and breadth of this vast subcontinent, our National Government must undertake from now on, at least, to start providing means on all important rivers, to record stream flow data at all prospective power generation sites. Without such power development, industrialization of the country and its agriculture on modern lines will not be possible. Nor we will be able to raise the standard of living of our people without providing them with cheap and abundant supply of electric power, spread over the entire length and breadth of our country. Keeping this most important national factor into account, our governments must take a long view of the future and incur expenditure on the collection of such data by such means as necessary on all major rivers of India. Small extra cost involved now will work out to a trifle percentage of total cost on any one project on the river.

This question is also directly linked up with the question of making a fresh hydro-electric power survey of India and determination of prospective power generation sites so that future generations might not be handicapped for want of dependable hydraulic data to plan their power development schemes in the interest of the country as a whole.

IMPORTANCE OF THE ACCURACY OF THE DATA COLLECTED

It is well to remember that all our calculations of potential waterpower are dependent for their accuracy on the correctness of the mean monthly flow as assumed for the design year and secondly to the extent to which this mean monthly flow coincides with the reality in any given year. Therefore it is most important that the design year data should be first arrived at with as much care as possible.

As for the record limitation given above, we have to recognise the fact that the nature follows no fixed known lines either in rainfall intensity or frequency over a given catchment area and, therefore, the stream flow is never exactly alike, with reference to time in any two years. So it is futile to expect scientific accuracy, and yet, a reasonable accuracy is necessary if our projects are not to be a mere guess work based on hit and miss method. If any project is so much on the border that even a variation of 10 to 15 per cent. between the design year data and the actual, frequently obtained, is likely to make it an un-economic one ; then it should not be recommended unless there are other known counterbalancing factors justifying the same.

Similarly, no such project would be based on absolute minimum possibilities, extending over a period of 30 years or more as we would thereby be losing good deal of our natural advantage and would not be utilizing our natural resources to our best interests. It is here that we have to estimate 'mean monthly flow' for the 'design year' as accurately as we possibly could. Then the subject should be restudied by assuming say 15 to 25 per cent. variation between the design data and the actual results. If this study still indicated an economic proposition, an engineer is working within safe limits and there should be no hesitation in undertaking the implementation of such a project.

DETERMINATION OF MEAN MONTHLY FLOW FOR THE DESIGN YEAR

In keeping with the above principles, normally the following two methods are employed in arriving at the mean monthly flow to obtain as close a figure as possible, with reference to the actual figures likely to be obtained in practice for most of the years.

(i) *Calendar year method.*—In this method, monthly records of each year are arranged in order of magnitude, beginning from the driest month. There are thus twelve readings, for each year, in order of dryness covering the entire period of all the years for which data is available. Then an average or mean of each month in order of dryness is arrived at to form the design year with twelve monthly readings. It is obvious from the above that each month now represents in order of dryness an average based not on the average readings of any particular month of different years but an average of corresponding dry month in each year. This definitely gives far more possibility of reproducing in actual practice than the ordinary—monthly average mentioned above. Here month is taken as a time unit. If daily or weekly figures are available, different time unit may be used. Still, the method will be the same.

TABLE IF.VIII—*contd.*

| R.L. | Million acre feet |
|------|-------------------|
| 602 | 3.27 |
| 603 | 3.37 |
| 604 | 3.47 |
| 605 | 3.57 |
| 606 | 3.67 |
| 607 | 3.77 |
| 608 | 3.87 |
| 609 | 3.97 |
| 610 | 4.07 |
| 611 | 4.18 |
| 612 | 4.29 |
| 613 | 4.40 |
| 614 | 4.51 |
| 615 | 4.63 |
| 616 | 4.75 |
| 617 | 4.87 |
| 618 | 5.00 |
| 619 | 5.13 |
| 620 | 5.26 |
| 621 | 5.40 |
| 622 | 5.54 |
| 623 | 5.68 |
| 624 | 5.83 |
| 625 | 5.98 |
| 626 | 6.12 |
| 627 | 6.27 |
| 628 | 6.43 |
| 630 | 6.73 |

TABLE 1F. IX

| Month | Quantity required for irrigation. (Million acre feet). | Evaporation losses (Million acre feet). |
|-----------|--|---|
| November | 0.37 | 0.04 |
| December | 0.15 | 0.03 |
| January | 0.15 | 0.04 |
| February | 0.13 | 0.03 |
| March | 0.15 | 0.05 |
| April | 0.10 | 0.05 |
| May | 0.10 | 0.07 |
| June | 0.15 | 0.05 |
| July | 0.44 | 0.06 |
| August | 0.33 | 0.06 |
| September | 0.43 | 0.07 |
| October | 0.44 | 0.05 |

BASIC HYDRAULIC DATA (POWER HOUSE NO. 2)

TABLE 1F.X

| | |
|---|-------------------|
| Maximum pond level | R. L. 512 |
| Minimum pond level | R. L. 509 |
| Normal tailrace level | R. L. 432.0 |
| Normal flood level | R. L. 445.0 |
| Water level in Mahanadi below Power House No. 2. | R. L. 426.6 |
| Length of power channel | 91,000 feet. |
| Capacities of ponds No. 1, 2 and 3, as per Fig. 1 F. 9 (reproduced on the back of Fig. 1 F.8) | 17,072 acre feet. |

TABLE IF. XI

| Month | Absorption losses in power channel | Irrigation requirements in power channel |
|-----------|------------------------------------|--|
| November | 124 | 1,456 |
| December | 109 | 552 |
| January | 110 | 560 |
| February | 113 | 560 |
| March | 118 | 560 |
| April | 122 | 392 |
| May | 130 | 392 |
| June | 140 | 591 |
| July | 164 | 1,676 |
| August | 156 | 1,231 |
| September | 156 | 1,676 |
| October | 139 | 1,676 |

TABLE IF. XII,

Mahanadi River Data at Hirakud, Tikarpara and Naraj.

| Serial No. | Item | Hirakud | Tikarpara | Naraj |
|------------|---|------------|--------------|--------------|
| 1 | Catchment area in sq. miles | 32,000 | 48,000.00 | 51,000.00 |
| 2 | Maximum annual rainfall in inches | 71.21 | 77.80 | 74.00 |
| 3 | Mean annual rainfall in inches | 56.88 | 55.85 | 53.17 |
| 4 | Minimum annual rainfall in inches | 37.02 | 22.80 | 21.70 |
| 5 | Maximum annual run-off in m.a.ft. with reference to rainfall. | 69.90 | 102.72 | 103.67 |
| 6 | Mean annual run-off in m.a.ft. | 50.00 | 73.37 | 74.05 |
| 7 | Minimum annual run-off in m.a.ft. | 20.61 | 30.09 | 30.37 |
| 8 | Average maximum annual discharge in cusecs. | 95,000.00 | 140,000.00 | 141,000.00 |
| 9 | Average mean annual discharge in cusecs. | 68,000.00 | 100,000.00 | 101,000.00 |
| 10 | Average minimum annual discharge in cusecs. | 28,000.00 | 41,000.00 | 42,000.00 |
| 11 | Minimum discharge of river in cusecs | 900.00 | 1,350.00 | 1,500.00 |
| 12 | Maximum flood discharge in cusecs | 942,000.00 | 1,270,000.00 | 1,571,000.00 |
| 13 | River bed level above M.S.L. | 492.53 | 140.67 | 41.02 |
| 14 | Low water level above M.S.L. | 503.00 | 168.47 | 68.62 |
| 15 | Maximum flood level above M.S.L. | 535.00 | 205.25 | 101.96 |
| 16 | Percentage of mean run-off to mean annual rainfall. | 51.50 | 51.50 | 51.00 |

DESCRIPTION OF THE MAHANADI PROJECT

Before the hydraulic data recorded above, is examined a general description of the Mahanadi river development will not be out of place.

The Mahanadi, the biggest river in Orissa, carries annually 74 million acre feet of water which is almost five times that of the Colorado river in the U. S. A. at the site of the highest dam in the world, the Boulder dam. The mean annual run-off of the Indus in the Punjab, Columbia in the U. S. A. and the Nile in Egypt are 87, 80 and 66 million acre feet respectively. Less than about 5 per cent of this mean annual run-off of 74 million acre feet is at present being put to beneficial use for purposes of irrigation. The rest of the water is at present running to waste causing untold damage and destruction by floods in their passage to sea. The scheme for the unified development of the Mahanadi Valley is designed to put a stop to this colossal waste of natural resource and to control, conserve and utilise the waters of the Mahanadi river for purposes of irrigation, hydro power generation and flood control *etc.* This scheme will comprise three units, namely the Hirakud Dam Project, the Tikarpara Dam Project and the Naraj Dam Project, each one with its own canal system and hydro-electric power installations. These three units will be individually capable of independent developments, irrespective of whether the other two are constructed or not, and of forming an integral part of the basin wide plan. The best overall results will obviously be obtained if and when all the three projects have been completed. As a first step, it is proposed to make a start with the construction of the Hirakud Dam Project which work has already been taken in hand by the Central Waterpower, Irrigation and Navigation Commission. This project lies uppermost in the Mahanadi river.

The Hirakud Dam Project comprises :—

(a) the construction of a dam across the Mahanadi about nine miles upstream of the town of Sambalpur. The dam will be nearly three miles in length across the main channel with 19 miles length of low dykes on the two sides. The dam will submerge an area of about 150,000 acres. Figure 1F.10 shows the layout plan of the dam and appurtenant works and Figure 1F.11 section of the concrete dam.

(b) Gravity and lift canals on either side.

(c) Construction of two generating stations—one at the main dam at Hirakud to utilize the fall created by the construction of the dam and the second at the subsidiary dam forming the balancing reservoir at the end of the power channel (280 feet wide and 16.5 feet deep from the upper power house, to utilise the steep slope in the river below Hirakud. Figure 1 F.12 shows the longitudinal section of the power channel.

IMPORTANCE OF MAXIMUM FLOOD LEVEL AND MINIMUM TAILRACE LEVEL

It is very necessary to know maximum flood level at the power plant because on it will depend location of generator floor level. Equally important is the minimum tailrace level as this fixes the setting of turbine (vertical unit), which in turn determines the amount of excavation required in the tailrace. In the setting of the turbine, elevation of the unit above sea level should be taken into account specially at high altitudes which involves low pressures in the draft tube.

STUDIES OF STORAGE EFFECT

It is common knowledge that stream flow varies from day to day, between maximum and minimum limits of the year, while load requirements keep on changing from hour to hour on each working day, and fall off substantially during holidays. Thus, if power generation is based only on stream flow, there is a colossal wastage of water during hours of light load. Storing of water, therefore, during hours of light load and its utilization during hours of peak load provides the most economical arrangements.

Storage permits holding back in reservoir, excess flow available in times of high water, and using it more or less regularly according to requirements during the dry period of the year.

Storage helps in filling in gaps of unevenness of stream flow from day to day. It also helps in reducing the variation between the design year flow and the actual, particularly if the storage is a substantial one as in the Hirakud Project. Power generation is dependent only partly on the run of the river during dry period, and therefore, percentage error between actual and the design year flow has correspondingly less adverse effect on power generation.

Storage for power generation can also be utilized for flood control when the wet season is well demarcated as on the Mahanadi. During the rainy season the quantity of water available due to run-off of the river is so immense that it is not economical to utilize it for storage scheme. Therefore, storage capacity is utilized to reduce the crest intensity of flood discharge by spreading it over a long period and thereby reduce flood damage while power generation can depend on the run-off of the river during this period quite safely. When the wet season is approaching its end and the discharge of the river still exceeds power generation requirements, the storage of the reservoir is filled to its capacity and then begins to operate in the interest of power generation during the remaining dry period of the year. In this method of use of storage the reservoir is usually pulled down to a safe minimum at the end of the dry period to get maximum primary power with the storage effect added to the estimated run-off of the river. This method has been utilized on the Mahanadi Hirakud project.

Yet another use of storage is to equalise, or at least, to minimise effect of variation in total water available from the stream of the river. In this method the reservoir is not pulled down to safe minimum but certain quantity of water is allowed to be carried over to the next year as a margin of safety for steady generation of power of safe yield as it is sometimes called.

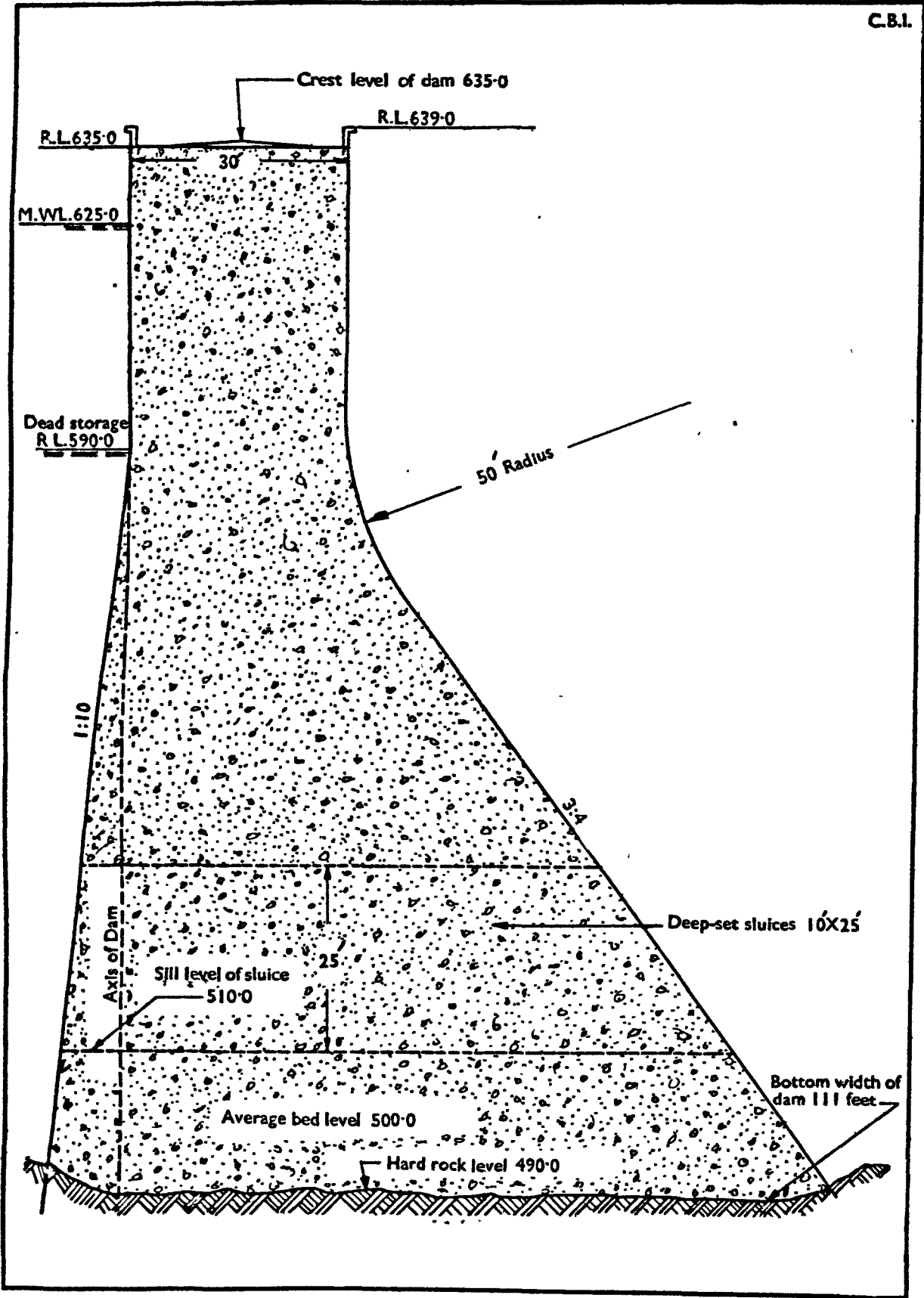


Figure 1F.11:- Showing concrete dam section-straight gravity non overflow type-[Hirakud dam project]



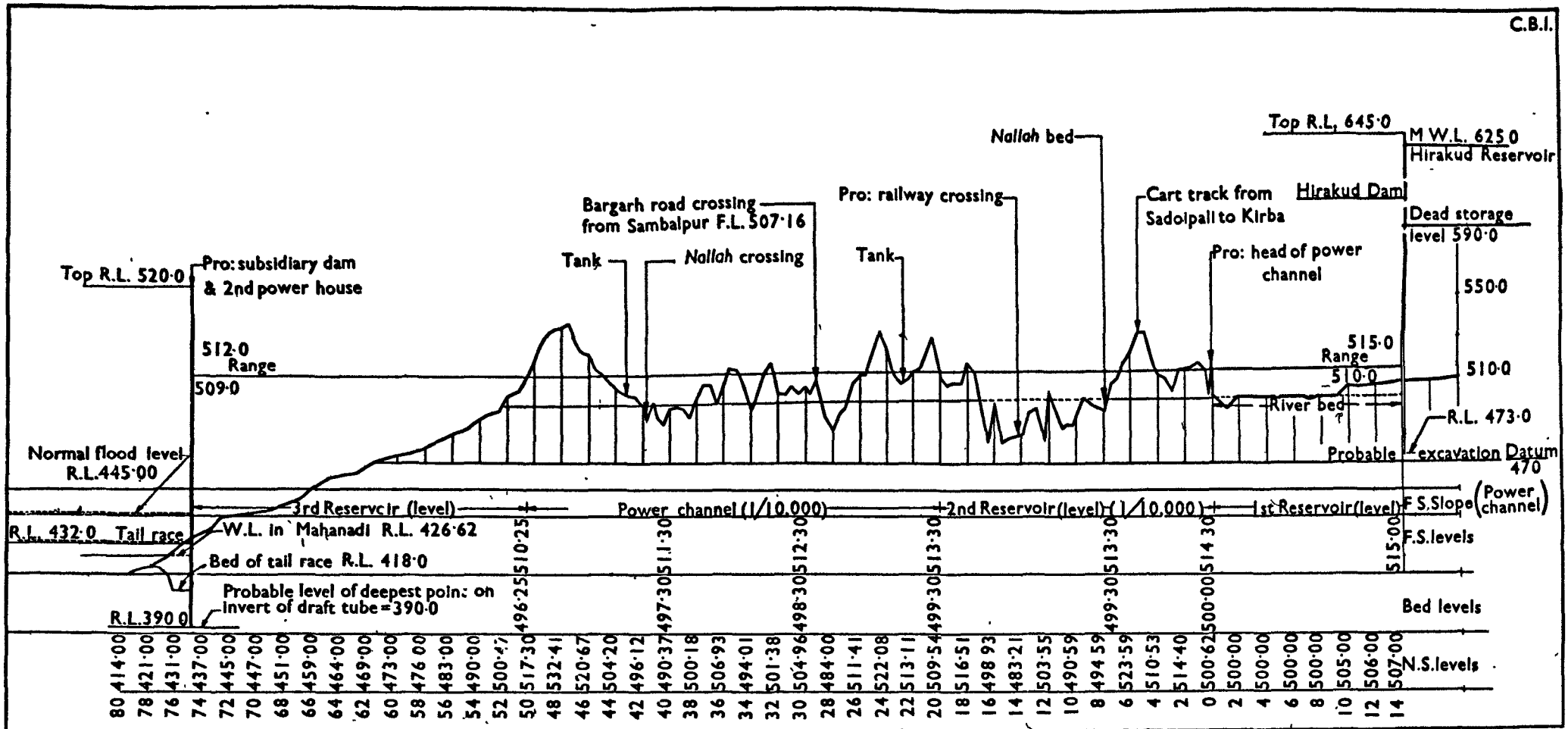


Figure 1F.12:- Showing longitudinal section of power channel (Hirakud Dam Project)

This method is particularly used when the dry years are too frequent, say after every three or four years and the wet years when they come are generally devastating in their flood effect.

On the Mahanadi Hirakud reservoir storage capacity of the reservoir is given as 5.98 million acre feet at R. L. 625.00 the normal reservoir level when it is full. In case of necessity in an unusually dry year it can be raised to 6.73 million acre feet at R. L. 630.00. Because of other requirements, such as silting provision, evaporation and seepage losses, *etc.* minimum level to which storage can be safely reduced at the end of the dry period is fixed at R. L. 590.00 with a reservoir capacity of 2.24 million acre feet. This leaves $5.98 - 2.24 = 3.74$ million acre feet storage for power generation during dry period. During the period of 8 months, namely 1st of November to 30th of June of the following year, water available due to the run-off of the river is estimated at 3.77 million acre feet according to the design year data. After deducting losses and irrigation requirements amounting to 1.66 million acre feet the net addition due to run of the river is $3.77 - 1.66 = 2.11$ million acre feet. So the total quantity of water available for power generation is $3.74 + 2.11 = 5.85$ million acre feet.

Assuming that our design year flow does not materialise in practice and falls short by say 25 per cent. in any year, then the actual shortage would be $3.77 \times \frac{1}{4} = 0.94$ million acre feet. In such a year if R. L. 630 capacity of the reservoir is used we get an addition of $6.73 - 5.98 = 0.75$ million acre feet.

This would reduce net loss to $0.94 - 0.75 = 0.19$ million acre feet. This forms 3.2 per cent. of the total water available for power generation. Therefore, reduction in power up to 3.2 per cent. may be anticipated if the design year stream flow proves to be overestimated by 5 per cent.

It is clear that 25 per cent is a very high variation, and therefore, assumption of still higher variation is not justified.

All this effect is due to the storage effect of the reservoir as planned.

EFFECT OF DRIEST YEAR ON POWER GENERATION

Now taking an extreme case of a driest year one in 20 years as stated in the Mahanadi Report 1947, we get the following results:—

Water available in eight months of dry period by the run of the river is given as 1.74 million acre feet. This will give shortage of $3.7 - 1.74 = 2.03$ million acre feet.

By raising the reservoir level from R. L. 625.00 to R. L. 630.00 at the beginning of the season, we can add 0.75 million acre feet to the storage. This will reduce the net shortage to $2.03 - 0.75 = 1.28$ million acre feet. So the percentage shortage will be:

$$\frac{1.28 \times 100}{5.84} = 22 \text{ per cent.}$$

We have, therefore, to expect a shortage of 22 per cent. in kWh generation once in 20 years. Obviously it is not desirable to reduce our primary power generation permanently based on such an extreme case likely to

occur after long intervals. It is obvious that if such a driest year were to appear before both the power houses are loaded below 78 per cent, it will have no adverse effect.

If one more hydro power station series is in operation by this time, then again there will be no adverse effect until the second series of power houses is also fully loaded.

Normal possibilities are that when one series of power houses is 50 per cent. loaded, it would be time to undertake the construction of second series, and the process is likely to be continued for a very large number of years, and, therefore, there is no occasion to entertain any fear over the condition of developed load during the period of driest year on any one particular project.

However it need be, the following methods can be adopted for tiding over the difficulty without permanently reducing the normal power potential of the project.

(i) Control over consumption of water should be brought into effect sufficiently earlier to spread the shortage over a maximum period, thereby reducing its intensity.

(ii) Water for irrigation can also be reduced proportionately for one season.

(iii) Load could be staggered to reduce the peak demand but as shortage of water affects K. W. hour consumption, proportionate restriction in consumption can be affected without much inconvenience to the public.

(iv) Certain types of load, which do not form part of most essential services can be easily stopped, as is usually done during the war years, thereby affecting a substantial saving.

These and some other methods can safely be used without adversely affecting the interest of the consumers for one season in 20 years.

DETERMINATION OF MAXIMUM POWER POTENTIAL

The water available as per design year data, with the head available in Power House, No. 1 and 2, has a definite maximum power potential. After deducting the inevitable loss, and after making provision for irrigation requirements *etc.*, the remaining power potential must be utilized to our best advantage by converting this power potential into power available at the generator busbars. This power at the busbars can be a combination of primary and secondary power. Primary power is one that can be made available all the year round, and the secondary power is one that can be made available only during certain periods of the year. To be of any practical use water power must generally be available all the year round, and throughout the whole of each day, although the actual demand may vary from hour to hour. There can be an exception to this when some other source of supply, such as thermal power, is also available in conjunction with hydro power, and yet the primary object would be to create maximum primary power by the combination of such sources of supply. Therefore, on the Mahanadi Project the problem is how best to convert all the available power potential into steady maximum power for sale. If during the dry period of the year any secondary power is generated from this available power potential, it must necessarily mean that maximum primary power is

reduced correspondingly. This would mean that we have not made most economical use of our available power resources by converting it into maximum primary supply. Ideal condition would be when we have utilized all the water available in both the Power Houses under the conditions given, and that it would produce some steady primary supply for sale without any extra water going to waste or without coming across any shortage at the tail end of the dry season. In other words, this means that the sum total of power put up for sale, as it is generated, in both the Power Houses working under varying conditions from day to day and from month to month must be a constant figure for all the period of the year. Then alone we can say that we have succeeded in utilizing our available power potential to our best advantage.

In attempting this conversion from available power potential into steady constant supply all the year round we come across many variables. Each variable has the effect of producing either more power or less power for some period of the year, with the result that some primary and some secondary power is generated making up the sum total over the year equal to the available power potential.

For instance, head in Power House No. 1 keeps on changing from day to day during the 8 months of dry period. If we were to utilise water on constant head drop basis, power to be generated will keep on varying as the head decreases. The water so released will vary in quantity as the head goes down. This will produce varying power in Power House No. 2, which would go on decreasing as the quantity of water keeps on reducing. The net result will be that substantial portion of secondary power will be produced, and therefore, primary power is correspondingly reduced, total potential being constant.

If we were to base our draw down from the reservoir on constant power basis, then the quantity of water consumed for generating the same power at lower head will keep on increasing. This varying quantity of water will produce varying power in Power House No. 2 and the sum total cannot be constant or approximately constant figure.

Then again in Power House No. 2 all the water released by Power House No. 1 will not be available for power generation. There is a gravity canal taking out from power channel requiring varying quantity of water each month. The head will fluctuate more violently only during the rainy season when tail-race level will rise in the Mahanadi. But during this period hydraulic efficiency will be of no consequence as a very large quantity of water will be passing over the weir at Power House No. 1 without generating any power.

So some mean has to be struck, and generation of power in each Power House has to be allowed to vary from month to month, but the variation under the given conditions has to be so synchronised that the sum total available for sale, after making the required special provision for lift irrigation load which forms part of this project, will remain constant.

Such an attempt has been made and ultimately Table 1F.XIII has been produced which gives the desired result.

TABLE NO. 1 F. XIII

Working Table for Hirakud Reservoir

(Average inflow 1938-39).

| Year | Month | Reservoir level at beginning of the month R.L. | Capacity of reservoir at the beginning of the month M.A. ft. | Inflow during the month M.A. ft. | Total quantity available M.A. ft. | Evaporation losses M.A. ft. | Quantity required for irrigation M.A. ft. | Quantity available for power M.A. ft. | Total draw-off from reservoir M.A. ft. | Net capacity at the end of month M.A. ft. | Reservoir level at the end of month (R.L.) | Discharge available for power generation cusecs | Head at first fall ft. | Power generated at 1st fall at 100 per cent. load factor K.W. in thousands | Power generated at 1st fall at 56 per cent. monthly load factor K.W. in thousands. | Absorption losses in power channel. | Irrigation requirements in power channel | Net quantity available at second fall cusecs. | Head at second fall ft. | Power generated at second fall at 100 per cent. load factor K.W. in thousands | Total power generated at 100 per cent. load factor K.W. in thousands. | Total power generated with P. H. I. taking the peaks at 56 per cent. M.L.F. K.W. in thousands. | Power required for pumping K.W. in thousands. | Net primary power available for marketing K.W. in thousands. |
|------|----------|--|--|----------------------------------|-----------------------------------|-----------------------------|---|---------------------------------------|--|---|--|---|------------------------|--|--|-------------------------------------|--|---|-------------------------|---|---|--|---|--|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 1938 | Nov. .. | 625 | 5.98 | 1.01 | 6.69 | 0.04 | 0.37 | 0.74 | 1.15 | 5.84 | 624.0 | 12,400 | 113 | 103 | 184 | 124 | 1456 | 10,841 | 75 | 60 | 163 | 244 | 16+26 | 202 |
| | Dec. .. | 624 | 5.84 | 0.57 | 6.41 | 0.03 | 0.15 | 0.68 | 0.86 | 5.55 | 622.0 | 10,900 | 111 | 89.5 | 160 | 109 | 552 | 10,239 | 75 | 57 | 146.5 | 217 | 16+16 | 201 |
| 1939 | Jan. .. | 622 | 5.55 | 0.45 | 6.00 | 0.04 | 0.13 | 0.68 | 0.67 | 5.13 | 619.0 | 11,050 | 108 | 88 | 157 | 110 | 560 | 10,380 | 78 | 69 | 148 | 217 | 16 | 201 |
| | Feb. .. | 619 | 5.13 | 0.35 | 5.48 | 0.03 | 0.13 | 0.63 | 0.79 | 4.69 | 615.0 | 11,350 | 104 | 87.5 | 156 | 113 | 560 | 677 | 78 | 62 | 149.5 | 218 | 16 | 202 |
| | Mar. .. | 614 | 4.69 | 0.33 | 5.02 | 0.05 | 0.15 | 0.73 | 0.93 | 4.09 | 610.0 | 11,850 | 99 | 86.5 | 154 | 118 | 560 | 11,173 | 78 | 64 | 550.1 | 218 | 16 | 202 |
| | April .. | 610 | 4.09 | 0.23 | 4.32 | 0.05 | 0.10 | 0.74 | 0.89 | 3.43 | 604.0 | 12,250 | 93 | 84 | 150 | 122 | 392 | 11,736 | 78 | 68 | 152 | 218 | 16 | 202 |
| | May .. | 604 | 3.43 | 0.10 | 3.53 | 0.07 | 0.10 | 0.80 | 0.97 | 2.56 | 594.0 | 13,000 | 85 | 82 | 146 | 130 | 392 | 12,478 | 78 | 72 | 154 | 218 | 16 | 202 |
| | June .. | 594 | 2.56 | 0.73 | 3.29 | 0.05 | 0.15 | 0.81 | 1.04 | 2.25 | 590.0 | 14,000 | 79 | 82 | 146 | 140 | 591 | 13,269 | 78 | 72 | 154 | 218 | 16 | 202 |
| | July .. | 590 | 2.25 | 10.93 | 13.17 | 0.06 | 0.44 | 1.02 | 1.52 | 3.08 | 600.0 | 16,400 | 83 | 101 | 180 | 161 | 1,676 | 14,560 | 65 | 70 | 171 | 250 | 16+36 | 202 |
| | Aug. .. | 600 | 3.08 | 18.02 | 21.10 | 0.06 | 0.33 | 0.97 | 1.36 | 3.08 | 600.0 | 15,600 | 88 | 101.5 | 181 | 156 | 1,231 | 14,213 | 65 | 69 | 170.5 | 250 | 16+32 | 202 |
| | Sept. .. | 600 | 30.8 | 20.66 | 23.74 | 3.07 | 0.43 | 0.97 | 1.47 | 3.24 | 602.0 | 15,700 | 88 | 102 | 182 | 156 | 1,676 | 13,868 | 65 | 67 | 169 | 249 | 16+32 | 201 |
| | Oct. .. | 602 | 3.24 | 4.09 | 7.33 | 0.05 | 0.44 | 0.86 | 1.35 | 5.98 | 625.0 | 13,900 | 101 | 103 | 184 | 139 | 1,676 | 12,085 | 75 | 66 | 169 | 250 | 16+32 | 202 |

Note.—With 56 per cent. monthly load factor in No. 1 Power House operating in parallel with 100 per cent. load factor on No. 2 power House system load factor works out to 70 per cent. which is a very reasonable possibility with heavy industrial load connected to the system.

EXAMINATION OF TABLE 1 F.XIII

Examination of the Table will indicate the following :—

(1) Reservoir level has been held down at R. L. 600.00 even during rainy season as required to provide for heavy floods. Reservoir will be filled up only when the danger of heavy flood is over.

(2) Inflow during the month of October is shown as 4.09 million acre feet, while the total requirements for the month are 1.35 million acre feet.

Capacity required to fill reservoir from R. L. 600 to R. L. 625 is $5.98 - 3.08 = 2.90$ million acre feet. This gives the total requirement to 4.25 million acre feet as against 4.09 million acre feet available for filling the reservoir. It will, therefore, be necessary to start filling in of the reservoir in the latter part of September.

(3) We can get constant primary power maximum demand of 218 M. W. all the year round at the load factor assumed during eight months of dry year with a variation not more than 1 in 218. Even this variation is for two months only as table has been prepared. In practice even that too can be eliminated by finer adjustment on daily basis instead of monthly basis as taken in calculations in preparing this paper.

In brief the distribution of water from the reservoir shown in the table gives practically ideal conditions visualised earlier in this paper.

(4) Monthly load factor of 70 per cent for the system has been assumed. This is regarded as a practical proposition and a reasonable one with heavy industries such as aluminium, iron and steel, cement factories etc. that are contemplated in this project area. With the above assumption and Power House No. 2 operating at 100 per cent. load factor, Power House No. 1 will operate at 56 per cent. monthly load factor.

(5) There is special provision of 16 M.W. for pumping load in dry period. If it were not to materialise, this being primary power, it can be released for sale.

(6) There is a provision of seasonal power for lift irrigation as required in the regional report (1947). If it were not to materialise, additional machinery to be provided in the Power House No. 1 for seasonal use and also as additional spare for seven months in a year will not be installed. This provides complete flexibility if the lift irrigation load were not to materialise in practice as visualised in the Project for some years to come.

(7) It may be noted that this maximum primary power generation calculations are quite independent of the size of the unit or the number of units to be used in any power house. These designed calculations are based strictly on the hydraulic and other data supplied to us on this project and is aimed at utilising available power potential by converting the entire maximum primary power to be made available for sale and therefore for revenue.

FUNDAMENTAL BASIS OF ECONOMIC OPERATION OF POWER HOUSES NO. 1 and 2

Power Houses No. 1 and 2 are hydraulically connected as the water released from Power House No. 1 is to be re-used in Power House No. 2. It is most essential that the electrical operation of the two power houses must be such that the pondage required between the two power houses should be as little as possible and that water utilized over a given period in Power House No. 2 should be equal to the water released from Power House No. 1. There must be no wastage of water without power generation at Power House No. 2, nor should there be any shortage because of the time lag for the water to travel from No. 1. to No. 2 Power House. Secondly, it is to be kept in mind that the synchronous stability both under steady state and transient conditions between the machines in both the power houses operating in parallel can only be achieved when the active and the reactive kVa is shared between the machines in proportion to their capacities. Thirdly, any power house taking the peak load should operate at as high a load factor as possible to get best hydraulic efficiency and to get maximum use of the capital invested.

Possible methods of operation are—

- (i) No. 1 Power House runs at base load station and No. 2 takes the peak.
- (ii) Both the Power Houses take fluctuating load and a share of peak demand, and
- (iii) Power House No. 2 works as a base load station and Power House No. 1 takes the peaks.

When all the three above mentioned criterions are applied to each of this case, it is obvious that alternative No. (iii) viz. Power house No. 2 taking the base load and No. 1 taking the peak load is the best solution.

This method of operation will have an additional advantage that during hours of very low load and on holidays when the load is normally very much less, water not used on average monthly load basis will remain stored in the main reservoir where there will be ample capacity and would help in providing higher head during working days. If this had not been the case all this water temporarily saved would need extra storage between No. 1 and No. 2 Power Houses involving additional unnecessary expenditure.

DETERMINATION OF GENERATOR CAPACITY

Factors to be taken into account for the determination of the generator capacity at any power station after power potential has been estimated are :—

- (1) Maximum estimated peak demand should be evenly distributed over a minimum number of units.
- (2) Size of each unit should fit in with the practical consideration of size of penstock, weight of unit and its single heaviest component part, transport limitations, operating facilities, *etc.*
- (3) Smaller the number of units to generate a given power, less is the cost per kilowatt of installed capacity and hence the overall cost. Usually, if other conditions permit, three units with one spare or in power stations with large generating capacities six units with two spares should be the very maximum. This should give satisfactory operating facilities. This is for isolated power stations. In the case of power stations interconnected through transmission line network, the question of spare capacity should be determined keeping in view the installed capacity and the operating conditions at individual stations covered by this network.

Taking the case of the Hirakud Dam Project again and keeping in view the above basic principles, the generator capacity at Power House No. 2 has been fixed at 37,500 kW. A reference to column No. 16 in the table would show that average peak output from January to June works out to 151 M. W. when distributed over three machines, it would give a generator size of 50 M.W., with a corresponding maximum turbine output with movable blade propeller type turbines about 88,000 H.P. This size goes beyond the limit of recognised satisfactory operation with the heads available. Cavitation problem also becomes serious and, therefore, it is not recommended by leading manufacturers. Therefore, this size may be passed over as unsuitable. The next convenient size is obtained by using 4 machines instead of three. This works out to generator capacity of 37.75 M.W.

Examining the same data from a different angle it is found that the maximum peak load of 184 M. W. when divided into five machines in the rainy season, gives a generator capacity of 36.8 M.W. If the average size required for dry and monsoon seasons is taken into account, the size of individual unit works out to 37.275 M.W.

Considering all the above and remembering that actual working conditions can only be visualized at present, as best as possible, a size of 37.5 M.W. appears to be a most reasonable choice for the generator capacity. 37.5 M.W. generator rating corresponds with 66,500 maximum output of the turbine which size is within the practical limits of successful operation under the heads to be encountered at site. Cavitation problem also is within safe limits for this size. Four machines will be required to take the peak load for nearly seven months in a year, and five machines for the remaining period. If heavy repairs are concentrated in a period when only four machines are required, it should be possible to operate the power house successfully with only one machine as spare, when five machines are in operation. On such an arrangement, it should be possible to carry out minor repairs, adjustments, routine maintenance works with one spare machine which could be put back into service within a short time after the occurrence of an emergency. So, the installed capacity for primary power should be five units. However, space will be provided in the power house for two more units, as possible extension for secondary load and an additional spare machine, if at all necessary, at any future date.

SELECTION OF TYPE OF TURBINE, ITS CAPACITY AND CHARACTERISTICS

There are two types of turbines that can be used, namely movable blade propeller type (Kaplan) or Francis type. Before we proceed to work out details of water turbine, it is necessary to decide which of the above two types should be used in Power Houses No. 1 and 2.

On detailed consideration it is found desirable to use movable blade propeller type turbine, as it will provide the following advantages as compared with the Francis type :—

- (i) Higher efficiency over a wide variation in head.
- (ii) Higher specific speed, and, therefore, less cost for a generator.
- (iii) Overall efficiency will be higher under part-load operating conditions. This would give most economical use of water, *i.e.* more average output with the same quantity of water.
- (iv) Physical dimensions comparatively smaller.
- (v) Weight will be comparatively less.
- (vi) Saving in power house building cost, as the space taken by the machine will be less.

- (vii) Crane capacity will also be less thereby introducing saving in crane cost, supporting structure *etc.*

In Power House No. 2 fluctuation in head during dry period is comparatively minor and that the power house machines also are expected to run at full load capacity. Therefore, it is not very necessary to have movable blade propellor type turbines. Francis type turbines can be considered as an alternative, if it were to provide any substantial advantage. Otherwise uniformity in type is likely to be helpful in training the personnel and providing operation and maintenance facilities common to both the power houses. Incidentally, use of movable blade propellor turbine might make it possible for the manufacturers to provide almost the same turbine as for Power House No. 1, because in both the cases critical heads are the same and part gate opening operation will have almost similar effect as in one case it will be guided by higher head requirements and in the other lower output requirements. However, it is best to leave this point to the designers of the leading manufacturers of such machines, for advice.

As for the capacity of the turbine, it is dependent upon the capacity of the generator to which it is directly coupled. When the generator rating is expressed as "Maximum Continuous Rating", the turbine is required to develop this maximum capacity under all conditions of operation. The chief factor in the design of turbine is the critical head or the design head. At this head of water, turbine has to produce an output equal to the generator M.C.R. rating at its best efficiency. In the particular case under consideration critical head will have to coincide with the minimum head as it provides complete and satisfactory operation from the cavitation point of view when operated at the maximum head. There is no advantage what-so-ever in fixing the critical head higher than the minimum as the cost of the turbine is practically the same whether turbine is called upon to handle little more or little less quantity of water at full gate opening. So far as the strength of the machine is concerned, it must naturally depend upon its output which cannot exceed the M. C. R. rating of the generator. By fixing a higher critical head say corresponding to the average head, we would be introducing a disadvantage that when the head is lower than the average, generator output would be reduced correspondingly. In other words, installed capacity will have to be increased to keep up the same maximum demand as given in Table 1F. XIII.

CONCLUSION

It may be stated in conclusion that the above is only a brief outline of the power generation aspect of the project. Detailed technical work is still in progress. It is hoped that it will be possible to bring this paper up-to-date as the work advances, so that ultimately it may record a good deal of useful data of this first project of the Mahanadi.

(5) PIPRAI DAM

by

B. P. Saxena, I. S. E.,*Superintending Engineer, IV Circle, Irrigation Works, U. P., Jhānsi.***INTRODUCTION**

Piprai Dam is situated in a narrow gorge formed by laminated sandstone hills of Vindhyan ranges on Narayan River which forms the boundary between the United Provinces and the Central Provinces. It is an all earthen dam, 6,740 feet long, rising 100 feet in the bed of the river, with flood spillways of Volute and Saddle siphons on the flanks. The object of the Dam is two-fold, (i) to provide water for irrigating 116,000 acres food crops annually in Jhānsi, Jalaun and Hamirpur districts and in the adjoining territories of Bundelkhand States where the spring level is generally below 30 feet and the subsoil strata does not ordinarily permit the construction of wells; and (2) to give a steady daily water supply on the existing Dhukwan masonry dam for generating about 2500 K.W. firm power.

CATCHMENT AND RUNOFF

The catchment contains two raingauge stations for which record of rainfall for 16 consecutive years is available. After excluding years of heavy rainfall, and dividing the catchment into six different types, run-off has been calculated according to Strange's diagrams. Average run-off is 13,842 million cubic feet. whereas storage capacity has been provided for 11,600 million cubic feet only on a conservative estimate. This is equivalent to 23 million cubic feet per square mile of catchment.

SUBMERGED AREA

The submerged area of the Lake is 10,000 acres at Full Supply Level 1310.0 comprising of 6,000 acres of forests and waste land, 2,000 acres pasture land and 2,000 acres cultivated land. Some ten small village hamlets get submerged affecting about 500 persons only. But the distress is insignificant, considering that new hamlets shall be established within half a mile of the old site, and emerged land will be available for cultivation, more enriched by submergence. Cases of dispossession of land by cultivators will be rare as enough culturable area is available on the fringes of the lake.

DESIGN

The essential features of the earth fill dam area (a) base on firm rocks, (b) masonry corewall in the whole length, (c) fill of impervious soil laid with earth moving mechanical equipment, moisture content and compaction being determined by Laboratory tests at site, (d) eight feet freeboard and 35 feet top width, (e) 3:1 upstream slope protected by 1.5 feet deep stone pitching, (f) 6:1 downstream slope ending in a strong filter toe of graded sand and stone in the river section, and 4:1 downstream slope in other parts.

Maximum net flood discharge for escapes is 1,36,000 cusecs of which 36,000 cusecs will pass over 1,000 feet long open spillway on the extreme right flank, provided with three feet high drop shutters. The balance will be passed by saddle siphons and partly by Volute siphons.

Gross capacity of the reservoir is 12,400 million cubic feet at R. L. 1311. Allowance for silting is 800 million cubic feet equivalent to 1.5 million cubic feet per square mile of catchment for 100 years. Effective storage is 11,600 million cubic feet.

IRRIGATION

Area to be irrigated lies in two separate tracts, namely, (1) Betwa Canal Doab and (2) Betwa Shahzad-Sajnam Doab. In former case, water will be passed through river sluices into Betwa River over Dhukwan dam for use on the existing Betwa Canal system which will be enlarged by 200 miles of additional channels in Jalaun and Hamirpur districts, and also it will help to generate about 2500 K.W. firm power on 50 feet head water turbines at Dhukwan. In the latter case, a two mile tunnel will be cut through the hilly ranges of the right flank of the gorge for the irrigation of Betwa—Shahzad doab by 260 miles of new channels.

Anticipated water consumption will be :—

| | | Million cubic feet |
|--|---|--------------------------|
| 77,000 acres Rabi | Three Watering—at 14 acres per million cubic feet | 5,500 |
| 25,000 acres early Rice | Two waterings—at 12½ acres per million cubic feet | 2,000 |
| 14,000 acres Sugar | Three waterings—at 7 acres per million cubic feet | 2,000 |
| Village tanks for drinking water during summer | | 300 |
| Reserve for fish culture | | 100 |
| Losses by evaporation and in transit | | 1,700 |
| | Total | 11,600 |

CAPITAL OUTLAY

Estimated cost of works is Rs. 1,72,29,760, Direct Charges, Rs. 9,69,620 and Indirect Charges Rs. 3,92,298. Total cost of the scheme is Rs. 1,85,92,000 approximately.

Annual working expenses are estimated as Rs. 1,63,750. Annual Revenue Rs. 6,87,450, and Net Direct Return on Capital Outlay is 2.8 per cent. The construction is being started this year and is expected to be completed in four years.

(6) YAMUNA HYDRO ELECTRIC SCHEME

by

A. C. Mitra*Superintending Engineer, Project Circle West, Irrigation Works, United Provinces.***ABSTRACT**

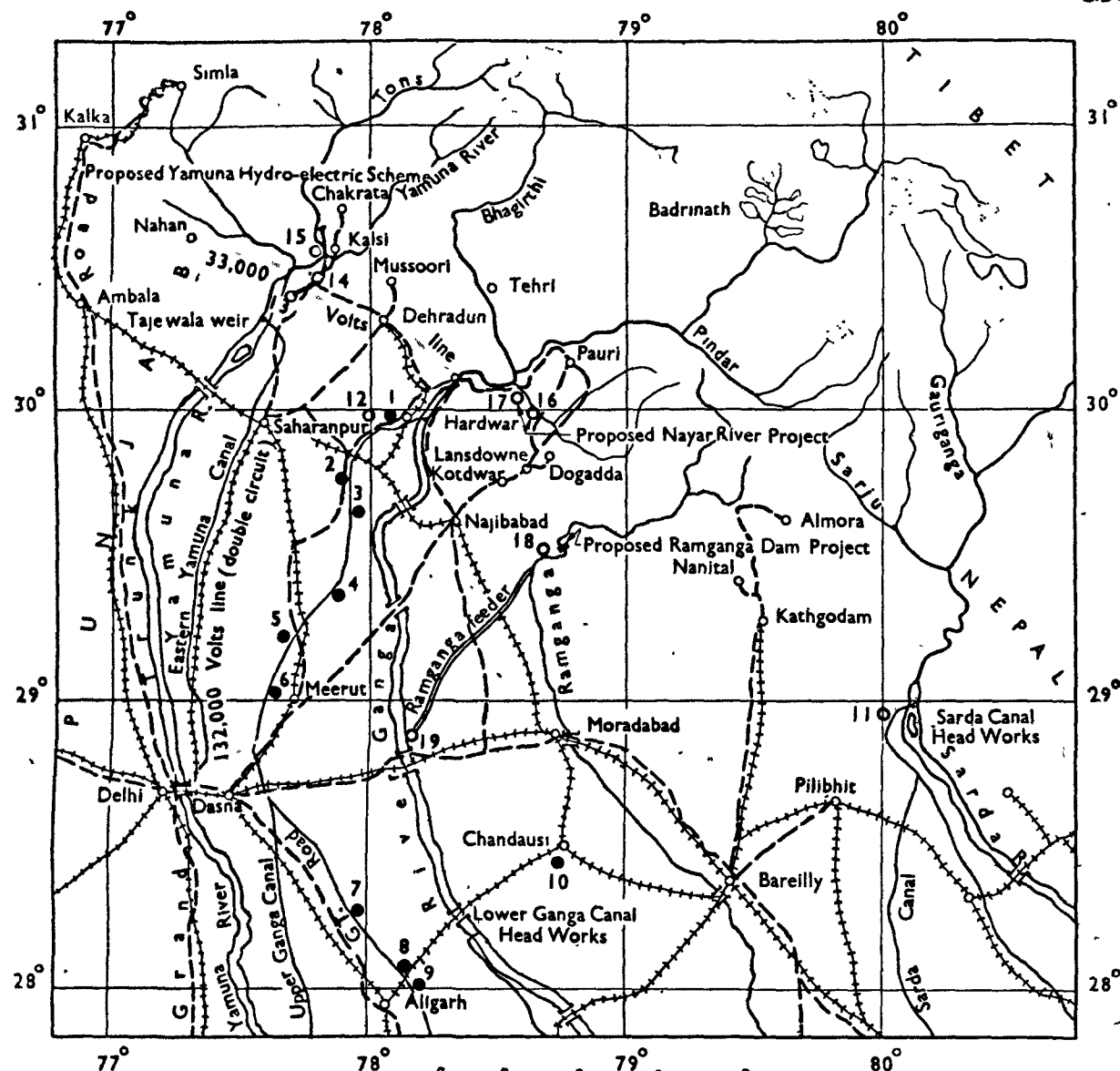
Construction work has commenced this year, on the Stage I of the Yamuna Hydro-Electric Scheme, which will be developed in two stages. This stage comprises (i) 2,000 feet long barrage, (ii) eight miles of open concrete lined channel with a carrying capacity of 4,600 cusecs (iii) two power houses 50 and 100 feet head respectively. Stage II will comprise (i) in the narrow gorge of the river Tons a 70 feet high concrete dam (ii) a 6.75 mile long concrete lined tunnel in two sections with (iii) a double, 14 feet diameter, steel pipe siphon aqueduct. The scheme will increase production of water power for industrialisation of the United Provinces six fold, as compared to the present power output. The two power houses of the first stage will ultimately contain eight kaplan type, 8,500 kilowatts, turbo-alternators, whilst in the single power house of the stage II will be installed six Francis type 30,000 kilowatts turboalternators.

INTRODUCTION

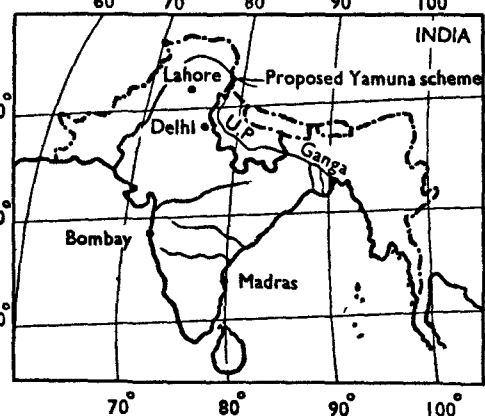
The United Provinces is not rich in coal or fuel oil resources. Whatever coal there exists must be reserved for manufacturing processes instead of being used up for power production. The Province, however, has a large potentiality, for the development of Hydro-electric power in the waters of its rivers hurtling down from the Himalayan Heights into the Gangetic plains. The energy of these flowing waters can be converted into cheap hydro electric power, without in any way depleting the supply.

So far, however, only a very small fraction of these water resources has been utilised for the generation of electricity, by the installation of power plant on a number of falls on the Upper Ganga Canal in the Western United Provinces. The entire output of 19,900 kilowatts from the scheme was fully utilised long ago. Thermal Stations of 19,600 kilowatts capacity, which had to be installed to supplement hydro-power, are also over loaded.

Several new schemes for the development of Hydro-Electric power are contemplated in Western United Provinces, Figure 1F. 13. Amongst these, the Mohammadpur Power Station, on one of the few remaining falls on the Upper Ganga Canal, which will generate 7,000 kilowatts of firm power, is nearing completion. The construction of Pathri Power Station to utilise the last of the available falls on the same canal has just been commenced. It will increase the firm power generating capacity of the grid by 15,100 kilowatts. These stations are, however, expected to be loaded up immediately on their completion of construction, as applications for power, exceeding the total output of both stations are already registered.



| No. | Names of power houses (Existing) |
|-----|----------------------------------|
| 1 | Bahadarabad |
| 2 | Mohammedpur |
| 3 | Nirgajni |
| 4 | Chitaura |
| 5 | Saiawa |
| 6 | Bhola |
| 7 | Palra |
| 8 | Sumera |
| 9 | Qasimpur |
| 10 | Chandausi |



| No. | Names of power houses (Proposed) |
|---------|----------------------------------|
| 11 | Sarda |
| 12 | Pathri scheme |
| 13 | Yamuna scheme |
| 14 | Yamuna scheme |
| 15 | Yamuna scheme |
| 16 | Marora |
| 17 | Byasghat |
| 18 & 19 | Ramganga scheme |

References :-

- Proposed Yamuna Hydro-electric works
- Existing power houses
- Proposed power houses
- Proposed transmission line
- Railways
- Canals
- Roads

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Figure 1F.13:- Regional map showing location of Proposed Yamuna Hydro-electric Scheme in Western United Provinces

Scale 50 40 30 20 10 0 50 Miles

Some of the more ambitious schemes to develop large block of power in the Western United Provinces are as follows :—

- (a) The Nayar River Project in district Garhwal, of the United Provinces, would store, by the construction of a 600 feet high concrete dam, 1.06 million acre feet (46,000 million cubic feet) of water in the valley of the Nayar River, a minor tributary of the River Ganga. This Scheme would generate 1,81,700 kilowatts of power during the dry weather *i.e.* November to May and 52,800 kilowatts during the remainder of the year. In addition, it would provide irrigation to 2,38,000 acres of new area, and would improve irrigation facilities on 10,68,000 acres of area at present inadequately irrigated by the Upper Ganga Canal system. The Project is under the consideration of Government at present.
- (b) The Ramganga River Project, also in Garhwal District, would store, by the construction of a 340 feet high earth and rockfill dam, 1.78 million acre feet (77,000 million cubic feet) of water in the Ramganga valley near Kalagarh. This scheme would generate 83,000 kilowatts of power during the dry weather. Irrigation would be provided to 4,68,000 acres of new area and improved irrigation service to 7,78,000 acres at present irrigated by the Lower Ganga Canal. Detailed surveys and subsurface exploration of the dam site is in progress and the project is expected to be finalised by April, 1949.
- (c) The Yamuna Hydro-Electric Scheme, which forms the subject matter of this article, would generate 82,560 kilowatts of power during the dry weather and 1,98,620 kilowatts during the rest of the year. Its power output would thus be complementary to the storage schemes mentioned above, and when run in conjunction, the entire outputs of all these schemes will be mutually firmed up.

The Yamuna river is one of the most important tributaries of the Ganga, Figure 1F.13. Its source lies in the snow capped peaks of the Himalayas in the extreme northern parts of Tehri Garhwal. It thence drops in a succession of water falls and steep rapids, first along the boundary of Tehri Garhwal and the United Provinces and then inside United Provinces territory, down to Kalsi, where it emerges into the Doon valley.

Near Kalsi, the Yamuna is joined by the Tons which drains the major portion of the snow catchment of the system. The Tons too has its source in Tehri Garhwal. In its lower reaches it winds its way, in steep rapids and through narrow gorges, Figure 1F. 14 along the western boundary of the United Provinces. Two other tributaries, the Assam from the east and the Giri from the west join the Yamuna before it leaves the Doon valley. At Paonta the river enters the Shiwaliks and emerges into Gangetic Plains at Faizabad.

The Eastern and Western Yamuna Canals, taking off from the river at Tajewala, two miles down stream of Faizabad, divert most of its dry weather flow, for the irrigation of crops in the United Provinces and the Punjab respectively. Continuing along the western boundary of the United Provinces the Yamuna, passes Delhi and thereafter enters United Provinces territory in Mathura District. It turns eastwards near Agra and ultimately joins the Ganga at Allahabad.

Proposal for the construction of a storage dam on the Tons at Kishau, 13.5 miles upstream of Kalsi, to improve irrigation facilities in the two Yamuna canals mentioned above, was made by the Punjab Government some years back. The scheme, however, is held in abeyance at present.

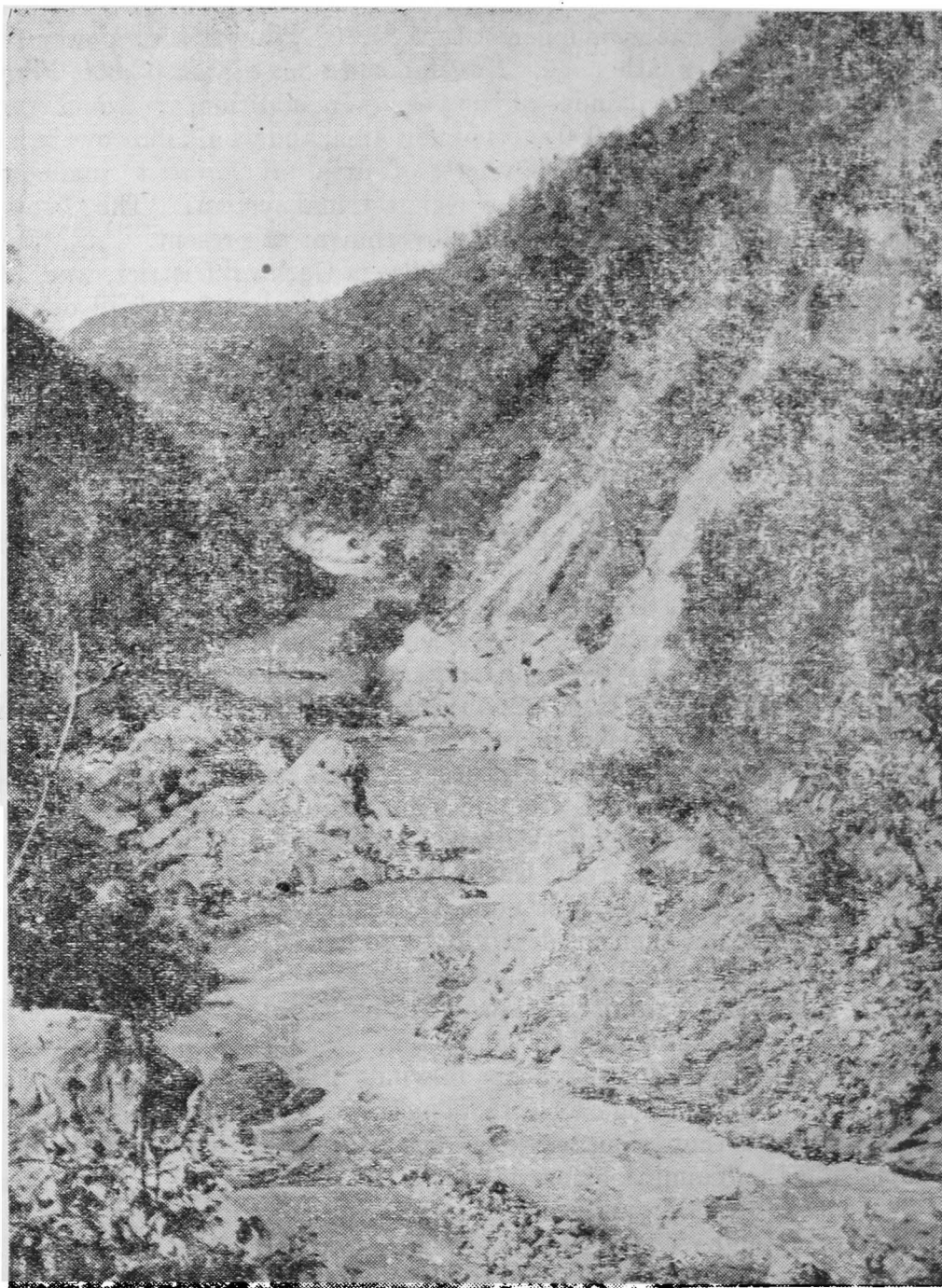


Figure 1F.14 : *Tons Valley*

The drop of about 750 feet, between Kishau on the River Tons and Paonta on the Yamuna, is now to be utilised for the generation of a large block of power

by the Yamuna Hydro-Electric Scheme, which can be constructed in two separate stages. The scheme is very important on account of the large block of cheap power which it can make available in shortest possible time with possibility for a large increase in output as the demand increases. It is expected to start earning revenue for the Province before a major portion of the capital cost has been spent.

COMMUNICATIONS

The nearest rail head, is Dehradun, on the 5 feet 6 inches gauge of the East Indian Railway, which is about 30 miles away from the site of works of stage I and 50 miles on the average from the site of works of Stage II.

Dehradun Chakrata metalled road runs within two miles from the site of works, of stage I, which will be connected to this road by means of metalled approach roads.

When the stage II of the Project is taken up for construction approach roads connecting the sites of works with Dehradun Chakrata road, will be constructed.

HYDROLOGY

By correlating the discharges of the Yamuna at Tajewala with observed discharges of the Tons at Kishau, and of the Yamuna at Kalsi it has been estimated that except for a few weeks, in years of drought, 2,000 cusecs will be available for power generation, from Stage I of the scheme, between 1st week of October and middle of May and 4,600 cusecs during the rest of the year, Figure 1F.15.

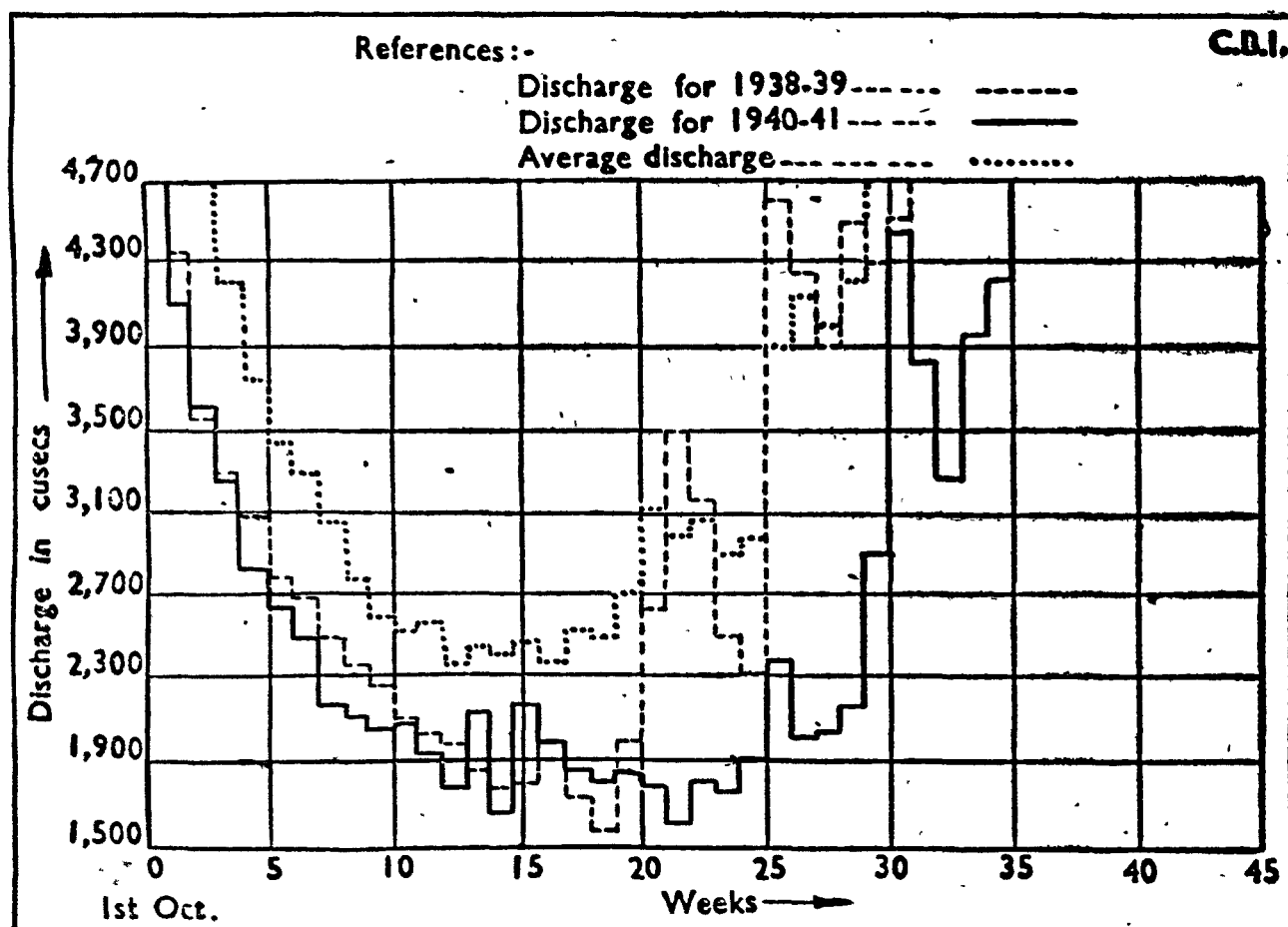


Figure 1 F.15

The corresponding figures of discharge of the Tons at Kishau available for power generation in Stage II of the scheme are estimated to be 1,400 and 3,800 cusecs respectively.

PROJECT FEATURES—STAGE I.

General Description

This stage of the scheme will utilise a total drop of 150 feet available between Dakpathar, Figure 1F. 16 about two miles downstream of the confluence of rivers Yamuna and Tons, and the junction of the rivers Ahsan and Yamuna.

A barrage 2,048 feet long, having 30 bays of 60 feet clear, span each, each with a control gate varying in height from 13 feet on the left end to 5 feet on the right end, will be constructed, across the river Yamuna, at Dakpathar. This will divert the waters of the river through a regulator into a concrete lined power channel with a full supply capacity of 4,600 cusecs. There will be two drops of 50 feet and 100 feet respectively in the channel.

The Barrage

A bridge across the Yamuna has to be constructed for the National Highway and the most economical arrangement is to have it over the barrage. A barrage with gates along its entire length has been decided upon. This will give best possible control, over the river flow, which is essential in view of the necessity of continuously training the water supply of the river from the right flank, on which side it has a natural tendency, towards the power channel regulator on the left bank. In order to help the formation of low level supply channel, through the undersluices during receding floods, the barrage will be stepped up from the left flank to the right, Figure 1F. 17. The main force of the floods will, however, be spent on the rock abutment on the right flank away from the regulator.

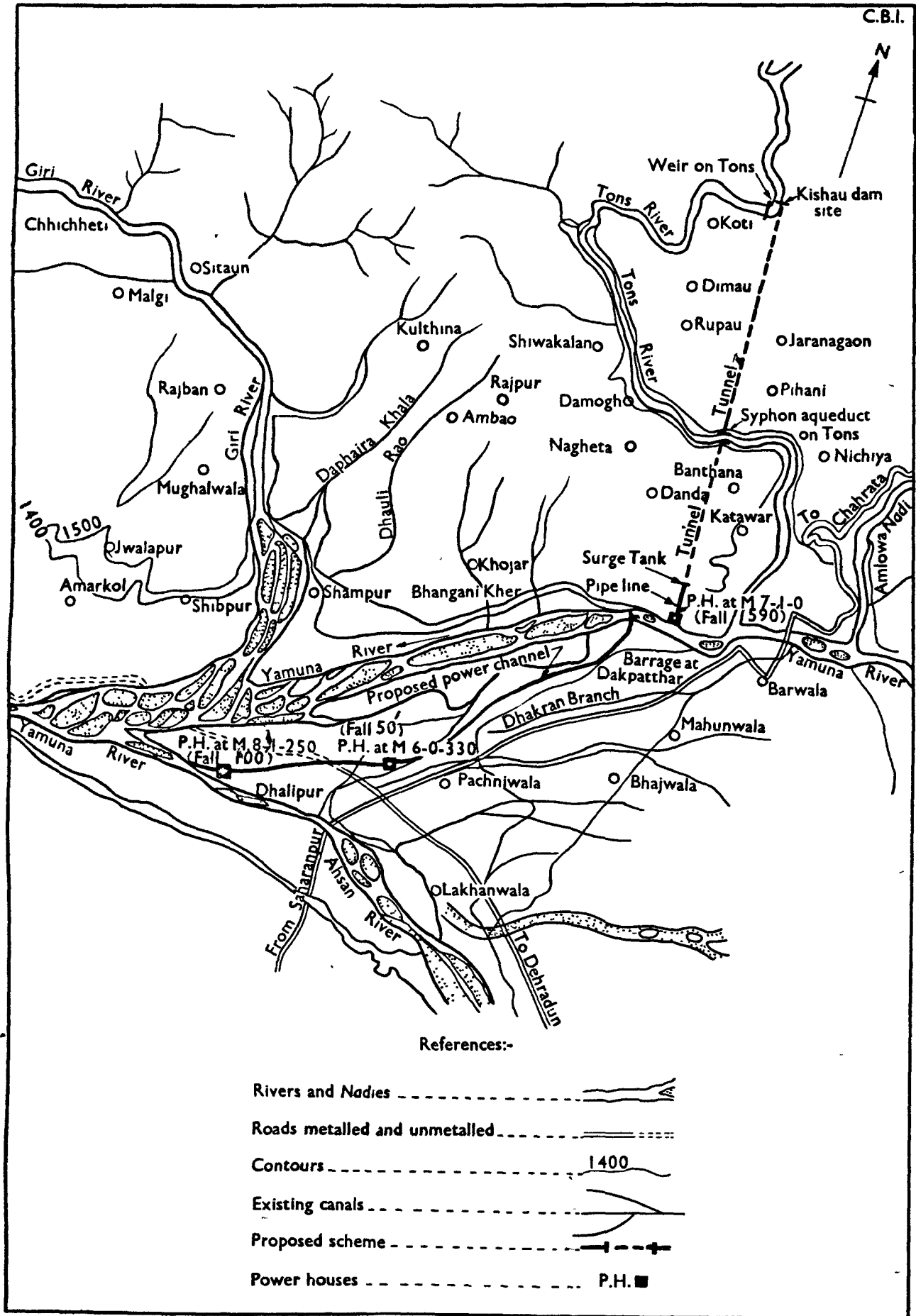
The section of the barrage, Figure 1F. 18, is the usual glacis crest type which has been designed so that the standing wave for all conditions of flow is formed on the downstream slopes of the glacis whilst the downstream floor thicknesses are sufficient to withstand the uplift pressure of water. Three main lines of cutoffs will be provided to guard the floor against scour. The pond level upstream of the barrage will be maintained at an elevation of 1472 to enable the channel to have a supply of 4,600 cusecs. Extra discharge of 1,000 cusecs, needed for the silt extractor, will be passed into the channel by raising the pond level to an elevation of 1472.5.

The Head Regulator

Six bays of 25 feet each will be provided in the regulator having crest elevation at 1467 so that a discharge of 4,600 cusecs can be passed into the channel with pond elevation at 1472.

The Channel

The channel will be 8 miles $5\frac{1}{2}$ furlongs long and will provide two drops, Figure 1F. 19. The first fall of 50 feet will be sited at Mile 5-0-330 of the channel, where the full supply elevation is 13.44 feet above ground level and the second fall of 100 feet will be at Mile 8-1-250, near village Dhalipur where there



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Figure IF.16:- Index map of Yamuna Hydro-electric Project showing the proposed power channel and tunnel

Scale 0 0.5 1 2 3 4 5 Miles

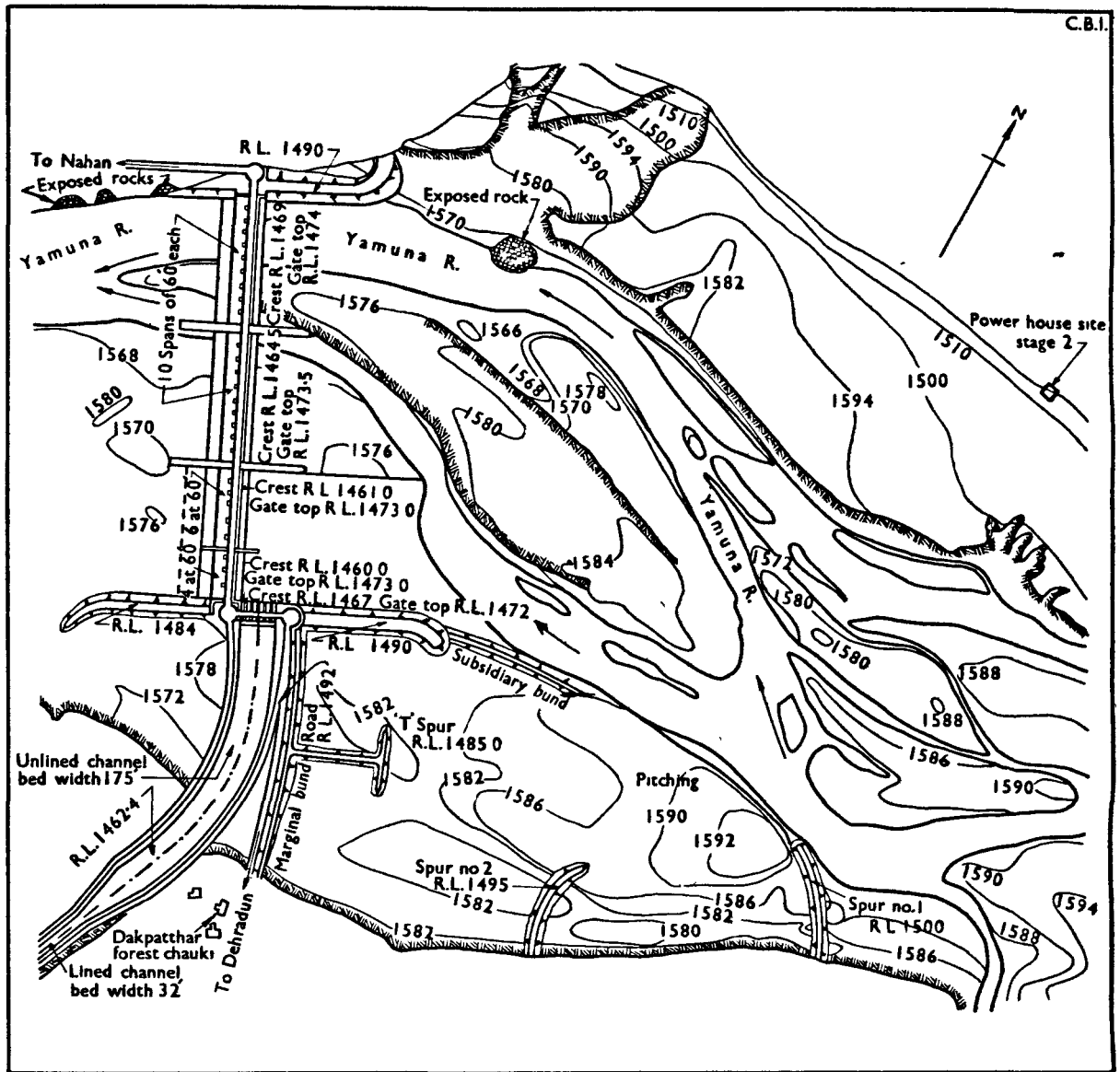


Figure IF.17:-Showing layout of the headworks of the Yamuna Hydro-electric scheme

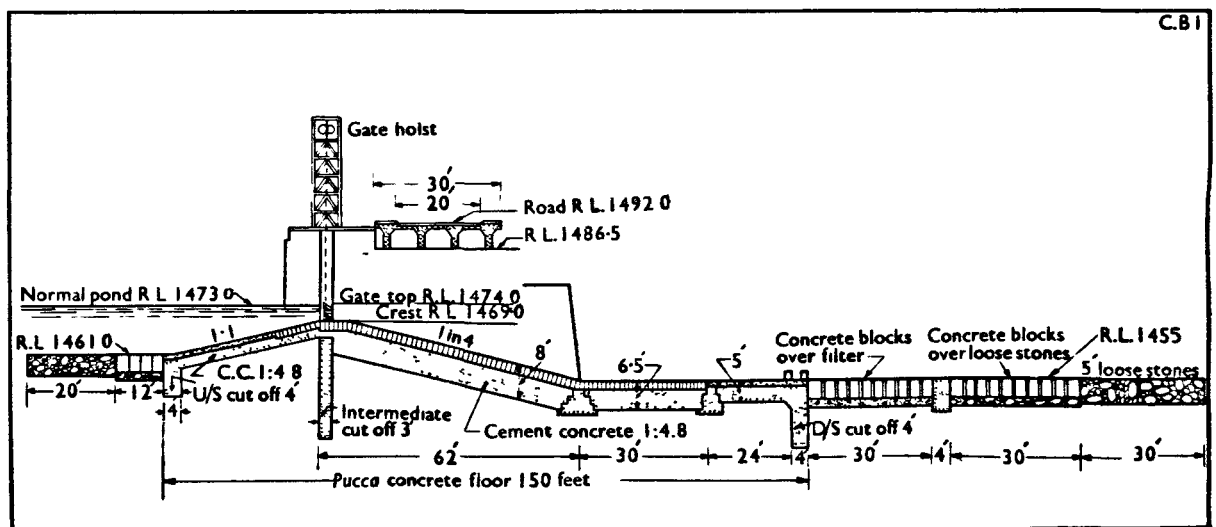


Figure IF.18:- Showing typical cross section of the barrage

is an abrupt drop of over 60 feet along the bank of the Ahsan river. The channel finally meets river Ahsan at Mile 8-5-250.

In the first $2\frac{1}{2}$ furlongs of the head reach the channel will be 175 feet wide and will not be lined as the spring level is expected to be high. After $2\frac{1}{2}$ furlongs the bed width of the channel will be gradually reduced, to 32 feet, providing 0.56 foot per mile bed slope and 15 feet water depth for 4,600 cusecs. This is the most economical section for the channel for an average depth of digging of 16.5 feet. For deeper excavation, the most economical section would have been narrower but in order to provide sufficient space for working mechanical excavators, 32 feet wide section has been adopted throughout.

The channel will have side slopes of $1\frac{1}{2}$ to 1 and will be concrete lined, Figure 1F. 20. A steeper side slope of $1\frac{1}{4}$ to 1 would have been possible but has not been proposed as the concrete lining in this case will have to be done by manual labour. A 16 feet wide roadway along the right bank and 20 feet wide along the left will be provided all along the channel.

Expansion joints will be provided at intervals of 33 feet and will be supported on stone masonry bars to be constructed along the side slopes and across the bed. The expansion joints will be grouted with water proof bituminous mixture. In embanked reaches, the lining will be reinforced with $\frac{1}{4}$ inch bars placed one foot apart in both directions, so as to prevent cracking by any local settlement of the fill.

Downstream of the first power house, the channel will be 150 feet, wide, to suit the power house dimensions, but will gradually narrow down to the usual section of 32 feet bed width. Downstream of the second power house, the channel upto its outfall into river Ahsan, will not be lined with concrete and will be 170 feet wide having a bed slope of 1.0 foot per mile.

The silt Extractor

Quite a high percentage of suspended silt is likely to enter the canal during the monsoon which must be extracted to prevent the runner blades of turbines from wearing out excessively. This will be accomplished by providing a silt extractor at Mile 0-6-330 of the channel. During the monsoons the channel will be fed with 1,000 cusecs extra discharge, in addition to the discharge required for power generation; in order to work the silt extractor.

The Power Plant

Hydro-electric power plant comprising two vertical shaft, adjustable blade, propeller turbines directly coupled to a 8,500 kilowatts, 11,000 volts, 3 phase, 50 cycles alternator each, will be installed at the first fall, whilst four turboalternator sets of similar type and 8,500 kilowatts capacity each will be installed at the second fall, near the end of the channel, where it outfalls into Ahsan river.

Each power station will have space for the installation of a spare set, similar to the ones initially provided, which will be required when any storage scheme such as the Nayar, Ramganga or Kishan dam project comes into operation.

. PROJECT FEATURES—STAGE II

The river Tons brings in the greater portion of the supplies of the river Yamuna below the junction of the two rivers. This stage of the project will utilize a total drop of about 590 feet in the Tons river from the Kishau dam site to Dakpathar, by short circuiting the double loop of the river, by means of a tunnel to be driven through the intervening hills.

A 70 feet high concrete dam will be constructed across the gorge in the river Tons, at the point of commencement of the first loop, about one and a half mile downstream of the proposed Kishau dam site. This will raise the water level to the tail water elevation of the proposed Kishau dam and will divert the waters into a 20 feet internal diameter, concrete lined tunnel, Figure 1F. 21. The tunnel will be in two sections 4 miles and $2\frac{3}{4}$ miles long respectively. Between the two sections, the Tons river will be crossed by a double 14 feet diameter steel pipe siphon aqueduct, the aqueduct portion of which will be supported above the highest flood level of the river by suspension cables, which will also carry a light roadway, Figure 1F. 22.

The tunnel will finally feed into a double 14 feet diameter steel pipe penstock which will carry the water to the power house, to be sited near village Khadri on the right bank of river Yamuna, about 4 furlongs upstream of the barrage of Stage I. A surge tank will be installed at the junction of the tunnel and the penstocks. At the power house, five generating units of 30,000 kilowatts each will be installed initially but space will be left for the installation of a sixth similar set. The sixth set will be installed later when any storage scheme, such as the Nayar River Project, comes into operation, in conjunction with which, the entire power output from Stage II of the Yamuna Hydro. Electric Scheme will become firm power.

A highway bridge will be constructed across the Yamuna over the barrage at Dakpathar as soon as the construction of Stage II of the project is approved. This will provide communication facilities to the Khadri Power Station and tunnel outlet works. It will also carry the Doon-Simla National Highway, providing a most vital road link between the United Provinces and the Himachal Pradesh.

CONSTRUCTION FEATURES

The construction of Stage I of the scheme is not likely to present any serious difficulty. The excavation of the power channel will have to be done by power shovels and trucks, as it involves a deep digging to gravel and boulder, forming a large proportion of the material to be excavated. Excavation of the top layers consisting mainly of soil can, however, be started by manual labour pending the arrival of mechanical excavators. Power shovels of $2\frac{1}{2}$ cubic yard and $1\frac{1}{2}$ cubic yards capacity with 12 cubic yards End Dump trucks will be used for the excavation.

The construction of this stage is expected to be completed in $4\frac{1}{2}$ years *i.e.*, by the first half of the years 1953.

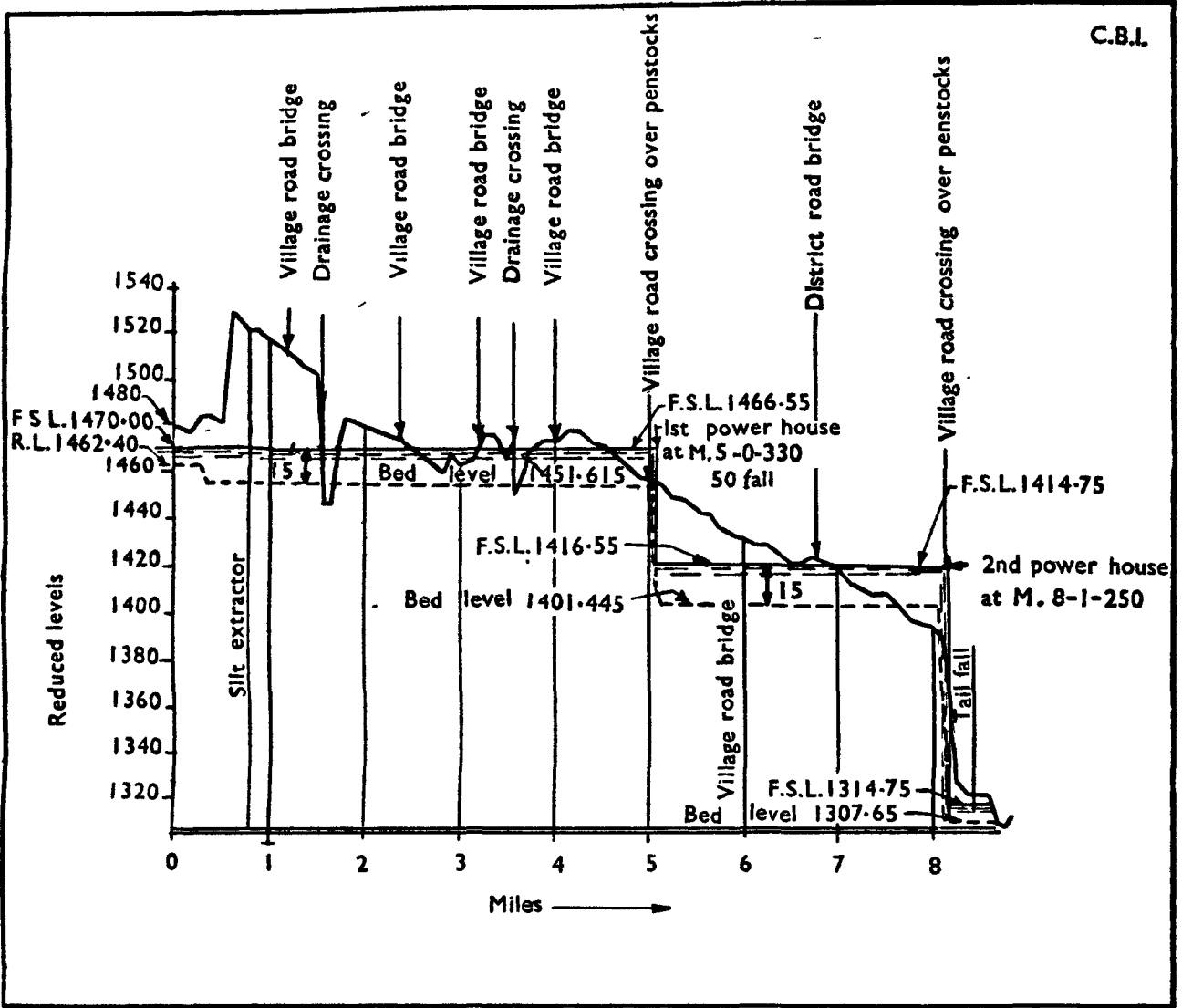


Figure 1F.19:- Showing longitudinal section of power channel

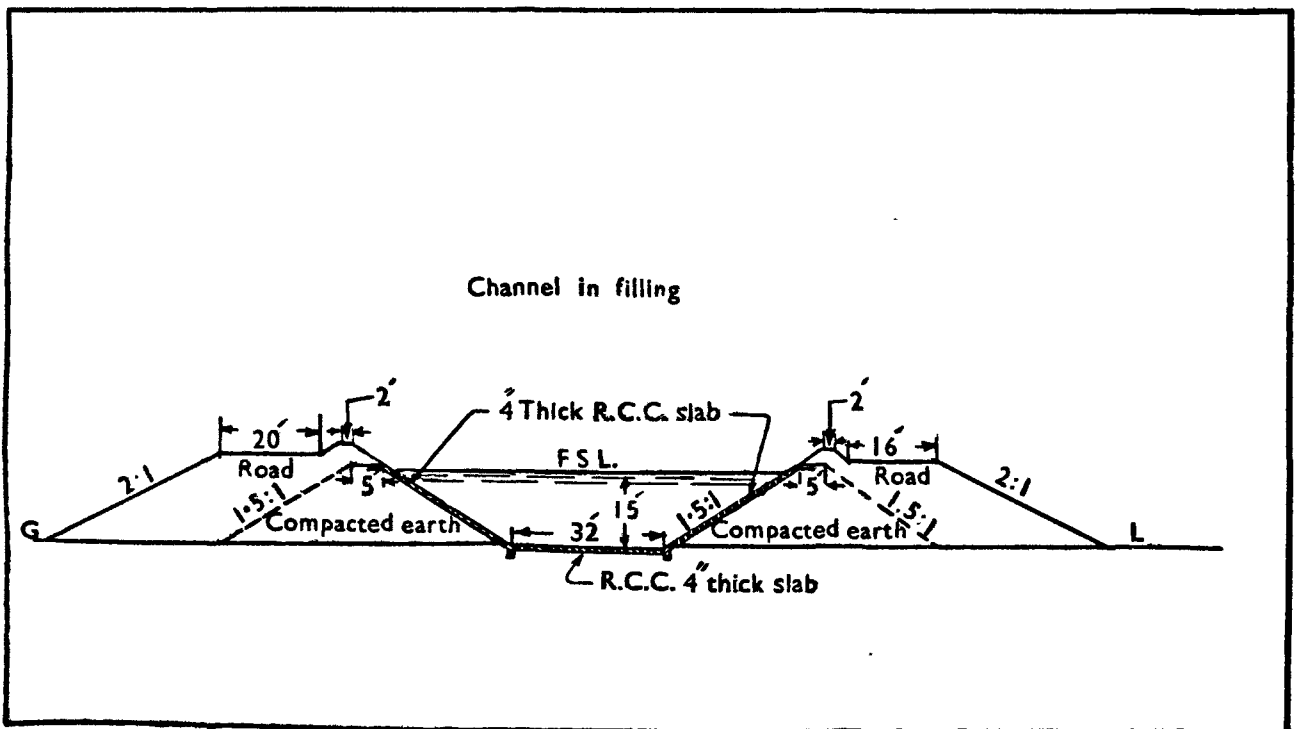


Figure 1F.20:- Showing typical cross section of power channel

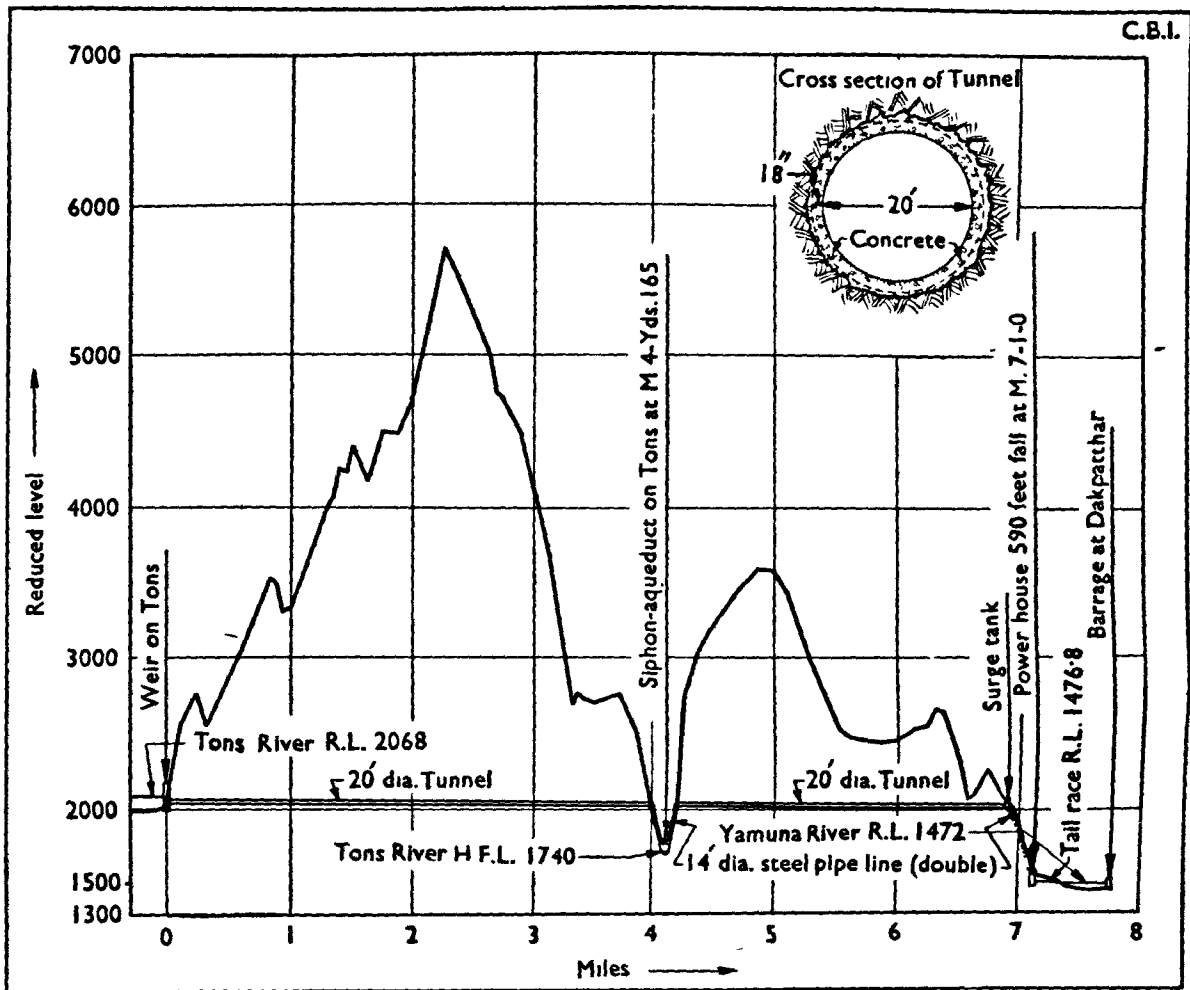


Figure 1F.21 :- Showing longitudinal section of Tunnel

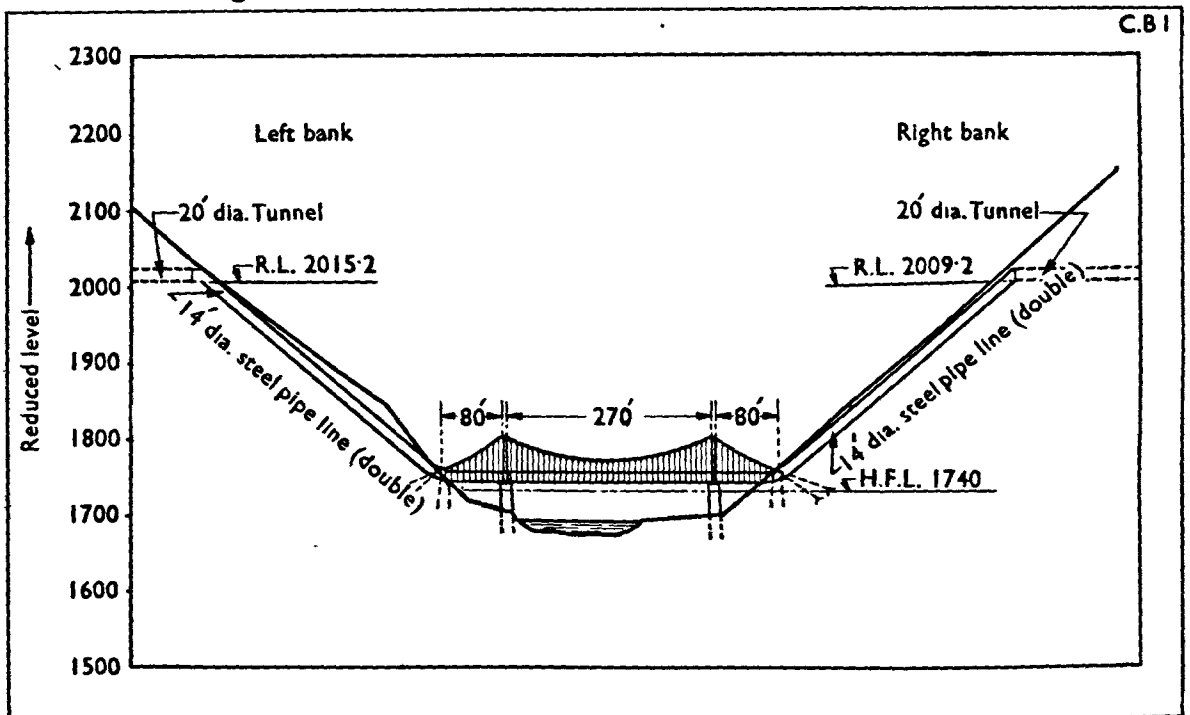


Figure 1F.22 :- Showing Siphon-aqueduct

Scale 200 100 0 200 400 Feet

Mechanical tunnelling equipment and about 3,000 kilowatts of power will be required for the construction of Stage II. Its construction can, therefore, be taken up shortly before, or immediately after, the completion of Stage I, from which the power for construction will be available. If demand for power justifies it, the construction can be commenced earlier by installing a 3,000 kilowatts thermal station. The construction of this stage is expected to take about five years.

POWER OUTPUT

It is estimated that 22,560 kilowatts of firm power from the first stage and 60,000 kilowatts from the second stage, would be available throughout the year. In addition 28,360 kilowatts of seasonal power from Stage I and 87,700 kilowatts from Stage II would be available in the period from middle May to first week of October, Figure 1F. 23.

Discharge in many weeks will be more than that required for firm power output. The power generated in excess of the firm output during the period first week of October, to middle of May will be secondary power. The average secondary power output is estimated to be 50.8 million kilowatt hours annually from the first stage and 153.4 million kilowatt hours from the second stage.

All the seasonal and secondary power output will, however, become firm power when any storage scheme such as the Nayar or Ramganga Project comes into operation in conjunction with the Yamuna Hydro-Electric Scheme.

Although, the average, minimum output from the two stages of Yamuna Scheme would be very much more than the figures of firm power mentioned above, yet in a few weeks of very dry years the output may fall below the limit. The storage will, however, be inappreciable, being less than 0.5% of the total power output, and will be made up by the existing thermal plants without any difficulty.

POWER UTILISATION

The power to be generated from the first stage of the scheme is expected to be utilised as given below :—

| | | |
|---|----|--|
| (i) Himachal Pradesh (Sirmur State) .. | .. | 4,500 kilowatts firm power to be delivered at the power station. |
| (ii) Dehradun - | .. | 3,000 kilowatts firm power to be delivered at the Dehradun sub-station. |
| (iii) Rishikesh, Narendra Nagar (Tehri Garhwal) area. | | 500 kilowatts firm power to be delivered at Narendra Nagar or Rishikesh sub-stations. |
| (iv) Industrial area round about Ghaziabad .. | .. | 9,000 kilowatts firm power and 4,650 kilowatts seasonal power. |
| (v) Delhi. (In case this block of power is not required by Delhi it will be utilised, in full, on existing Ganga Canal Grid). | | 5,000 kilowatts firm power and 20,000 kilowatts seasonal power delivered at Ghaziabad sub-station. |

The distribution of power from Stage II will depend on the development of industries in western United Provinces and the neighbouring Provinces and States.

TRANSMISSION

Power is proposed to be transmitted on 33,000 volts lines to Himachal Pradesh, Dehradun and Narendra Nagar. A 132,000 volts double circuit transmission line will carry the power to Ghaziabad and Delhi.

At Ghaziabad sub-station it will be stepped down to 66,000 volts at which the power will be available for Delhi. For the United Provinces industrial area, 66 KV transmission lines and 33 and 11 KV distribution systems will be constructed to suit the nature and location of industrial installations. A link with the 66 KV Ganga Grid transmission line will be provided at Dasna or Moradnagar for interchange of power between the two systems. Figure 1F. 13.

FINANCIAL

Capital Cost

Power Generation.—The initial capital costs of the Stages I and II of the project work out to Rs. 498.32 and Rs. 884.42 lakhs respectively. If, and when, any storage scheme, such as the Nayar, or Ramganga Dam Project comes into operation in conjunction with this scheme, one spare generating set will have to be installed at each of the power stations. The ultimate capital cost of the two stages will then be Rs. 564.02 lakhs and Rs. 927.22 lakhs respectively.

Transmission.—A complete project for the transmission lines is under preparation. On the basis of a preliminary estimate, however, the cost of transmission lines to bulk supply points and sub-stations for Stage I, is expected to be Rs. 300 lakhs, approximately, whilst the corresponding figure for the second stage is expected to be Rs. 839 lakhs.

The cost of 132 KV double circuit transmission line to Ghaziabad and the sub-station at Ghaziabad is estimated at Rs. 167.40 lakhs.

Cost of Generation.—

The cost of generation for firm and seasonal power from the two stages of the scheme is expected to be 1.98 pies and 1.24 pies per kilowatt hour respectively. The corresponding figure for the two stages combined works out to 1.43 pies per kilowatt-hour.

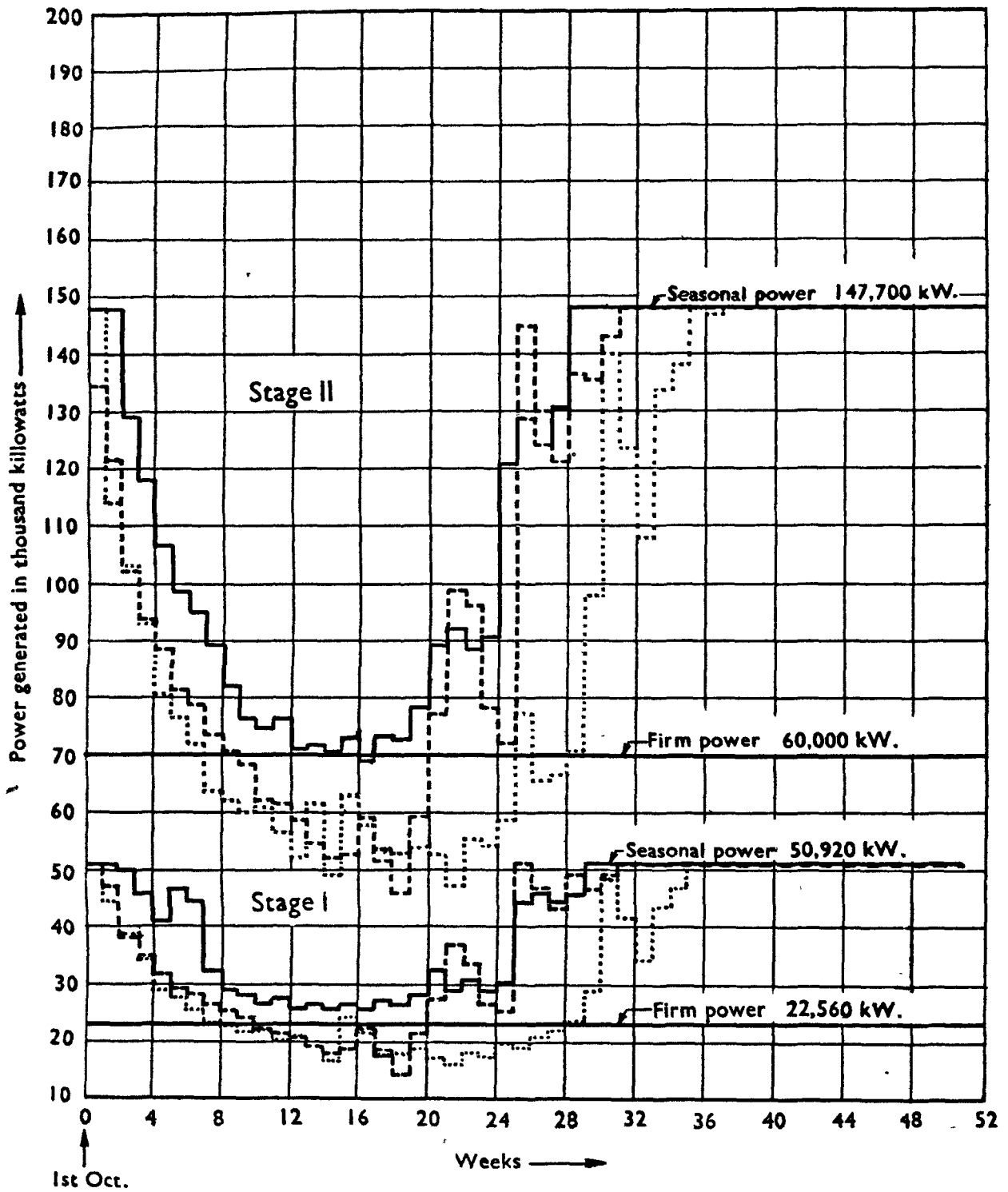
Cost of power delivered from the first stage, at 66,000 volts at Ghaziabad sub-station is estimated to be 3.39 pies per kilowatt hour as compared to 10.08 pies per unit, the average selling rate of power from Ganga Canal Hydro-electric Grid.

These figures also compare very favourably with those of other existing power plants and most of the proposed power plants.

Percentage Return—

Revenue from the project has been calculated assuming a selling rate, at the generating station, of 2½ pies per kilowatt-hour for firm power, 1½ pies per Kilowatt hour for seasonal power and ½ pie for secondary power.

The percentage return on capital cost of Stage I of the scheme, excluding transmission lines, is expected to be 3.3 percent whilst from Stage II it would be 5.93 percent. The percentage return for the two stages combined would be 5.00 percent.



References

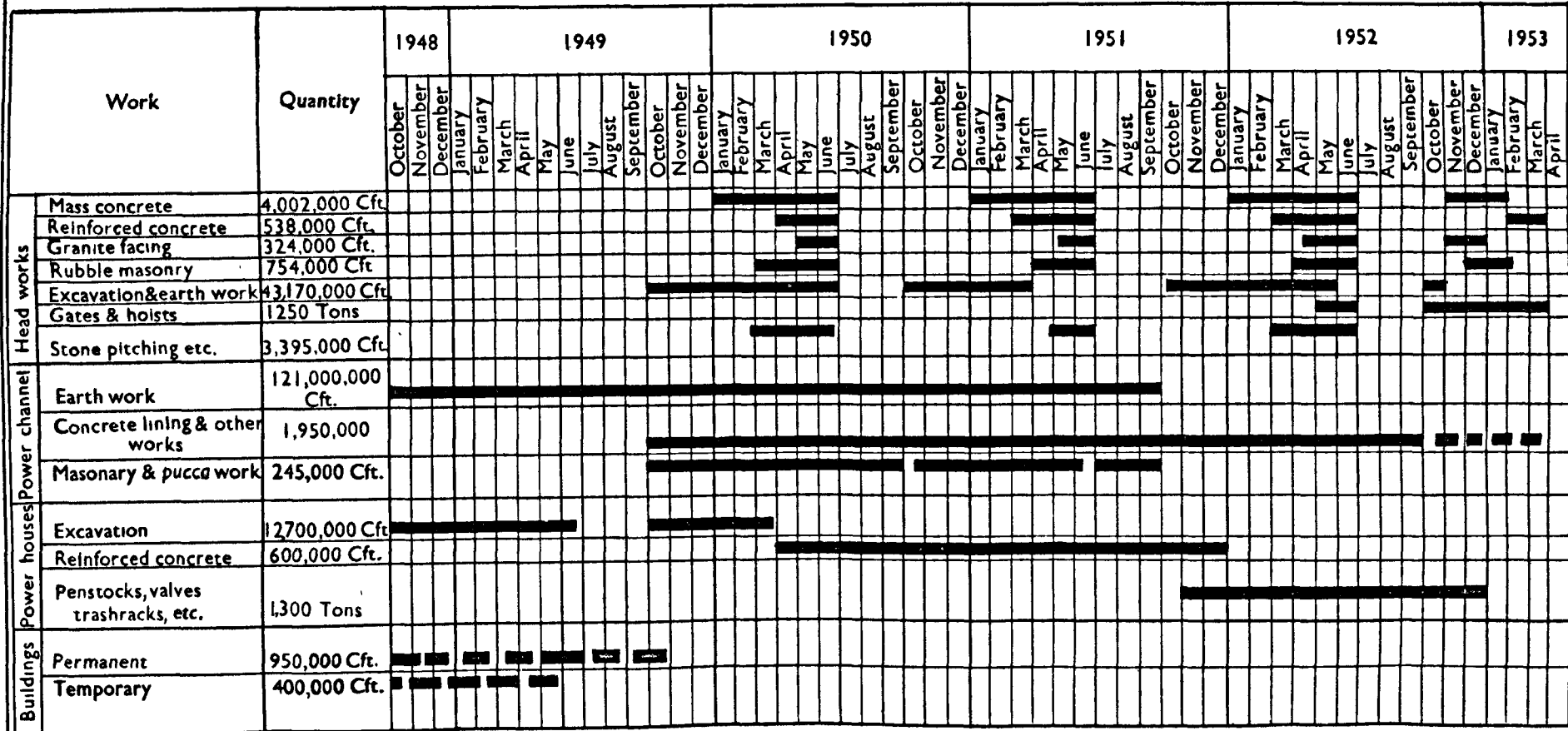
Stage I

Stage II

- Average (1934-35 to 1946-47) —————
- Worst year (1938-39) needing peak support - - - - -
- Worst year (1940-41) needing maximum over all support

- Average (1934-35 to 1946-47) —————
- Worst year (1938-39) needing peak support - - - - -
- Worst year (1940-41) needing maximum over all support

Figure IF.23:- Showing weekly power output, stage I and stage II



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Figure 1F.24:- Showing the scheduled quantities of important works (Stage I)

The return will be very much increased by the construction of either the Nayar or Ramganga River Projects.

The Yamuna Hydro-electric Scheme will, in addition, yield considerable indirect revenue by the industrialisation of country as the result of the availability of cheap power.

PROGRAMME OF WORKS

It is obvious that Stage II of the scheme is much more remunerative and will yield a larger block of cheap power than Stage I, but this stage cannot be taken in hand for construction immediately, as it would require tunnelling machinery, power for construction and trained personnel for tunnelling work. Stage I is a straight forward scheme independent of Stage II. It does not require special construction machinery which would take time to be procured and has, therefore, been commenced already.

The construction of this stage of the project is expected to be completed by the middle of the year 1953. Orders have been placed for the construction equipment required for the scheme, whilst contract for the turbines, generator switchgear and other auxiliary equipment will be let by the end of this financial year so that the power plant is received in time for installation in accordance with the programme.

The quantities of the important works of Stage I are given in the schedule in Figure 1F. 24.

Work on the Head works will not be possible for three months in the monsoon season due to heavy discharges in the river Yamuna.

The annual requirements, of the critical materials, for the period of construction of the first stage are given in Table 1F. XIV.

TABLE 1F. XIV

| Name of material | Quantity in tons required during the year | | | | | | Total Tons |
|------------------|---|--------|--------|--------|--------|-------|------------|
| | 1948 | 1949 | 1950 | 1951 | 1952 | 1953 | |
| Steel .. | 250 | 1,200 | 1,200 | 2,000 | 1,600 | 500 | 6,750 |
| Cement .. | 700 | 20,000 | 25,000 | 25,000 | 25,000 | 5,000 | 1,00,700 |
| Oil .. | 20 | 5,000 | 6,000 | 7,000 | 7,000 | 3,000 | 28,020 |

In the tunnel of Stage II, 1,59,18,000 cubic feet of excavation and 47,21,000 cubic feet concrete lining will be required. The pipe line siphon crossing and the penstocks of this stage will require about 3,000 tons of steel.

Preparations for the construction of Stage II such as (a) survey and investigations, (b) training of personnel in tunneling work, (c) finalisation of the detailed project are being continued and are expected to be completed in time for the Stage II to be taken up for construction immediately after the completion of Stage I, or earlier, if power demand warrants it.

SUMMARY OF PRINCIPAL FEATURES

HEAD WORKS

The Barrage :—Located near village Dakpathar, about two miles downstream of the confluence of the rivers Tons and Yamuna.

| | | |
|-------------------------------|----|---|
| Maximum anticipated flood | .. | 410,000 cusecs. |
| Highest flood elevation | .. | 1478.0. |
| Normal Pond elevation | .. | 1472.0. |
| Length | .. | 2048 feet comprising 30 bays of 60 feet clear span each. |
| Crest Elevation | .. | From left flank to right. 4 bays crest elevation 1460.0. 6 bays crest elevation 1461.0. 10 bays crest elevation 1464.5. 10 bays crest elevation 1469.0. |
| Number and size of gates | .. | Four of 60 feet × 13 feet. Six of 60 feet × 12 feet. Ten of 60 feet × 9 feet. Ten of 60 feet × 5 feet. |
| Road Width (National Highway) | .. | 20 feet plus two '5 feet' side walks. |

Head Regulator.

| | | |
|----------------------------|----|---|
| Length | .. | 175 feet comprising six spans of 25 feet clear. |
| Crest elevation | .. | 1467.0. |
| Elevation for top of gates | .. | 1472.0. |

POWER CHANNEL

| | | |
|----------------------------------|----|------------------------------|
| Maximum discharge | .. | 4,600 cusecs. |
| Bed width | .. | 32 feet. |
| Side slope | .. | 1½ to 1. |
| Depth of water | .. | 15 feet. |
| Total length | .. | 8 miles 5 furlongs 250 feet. |
| Length of concrete lined channel | .. | 7 miles 6 furlongs 580 feet. |

POWER PLANT

| | | |
|-----------------------------------|----|---|
| <i>Power Station I</i> —Location | .. | Mile 5-0-330 of the power channel. |
| Installed capacity | .. | Two Kaplan turbo-alternator units of 8500 kW. each rated head 48.5 feet. Provision for one spare set. |
| <i>Power Station II</i> —Location | .. | Mile 8-1-250 of the Power Channel. |
| Installed capacity | .. | Four Kaplan turbo-alternator units of 8500 kW. each rated head 97 feet. Provision of one spare set. |

STAGE II

| | | |
|--|----|---|
| <i>Dam on Tons River</i> | | |
| Height | .. | 70 feet straight gravity concrete structure. |
| Elevation of top | .. | 2,068.0. |
| <i>Tunnel</i> | | |
| Length | .. | 2 sections 4 and 2¼ miles respectively. |
| Type | .. | 20 feet internal diameter concrete lined circular. |
| Thickness of concrete lining | .. | 18 inches average. |
| Maximum discharge | .. | 3,800 cusecs. |
| <i>Tons crossing between the two sections of the tunnel.</i> | | |
| type | .. | Combined siphon and aqueduct, comprising double 14 feet diameter pipe line laid along the hill sides and then suspended across the river by cables 10 feet above the highest flood elevation of River Tons. |
| Span of suspension bridge | .. | 270 feet central span and two 80 feet side spans. |
| <i>Power Plant</i> | | |
| Installed capacity | .. | Five Francis type units of 30,000 kW. each at a rate head of 575 feet. Provision for a spare set. |

DISCUSSION BY THE RESEARCH COMMITTEE

THE SECRETARY said that subjects No. 1F, 2F and 3F were generally discussed at the Board meeting, and suggested that these be reserved till then unless Research Officers desired to discuss any item in particular.

MR. NAEGAMVALA referred to item (3) and said that unfortunately, waters of this river were saline. The salinity during the rainy period from June to November was about 100 parts per 100,000 in the flood waters. The analysis was given on page 431 both for the flood season and for the winter when salinity was still higher. He requested for suggestions to remove this salinity.

DR. HOON said that there were two points worth examination :

- (i) did the water have a permissible salinity for irrigation purposes ?
- (ii) how would the soil stand irrigation with that type of saline water ?

He said that in the Punjab they had fixed an upper limit for salinity in irrigation water at 120 parts per hundred thousand parts of water. It would have to be investigated what sort of limit could be fixed for water in other parts of the country.

DR. RAO said that a similar problem had been discussed in Sacramento. He suggested, Mr. Naegamvala might get in touch with that literature.

DISCUSSION BY THE BOARD

MR. S. A. GADKARY in introducing item (4) said that he had two objects in contributing this paper ; firstly to persuade other experienced engineers to contribute to the subject by giving more detailed technical information on the various Hydro-electric projects which they had completed or on which they might, be working now. Secondly, he wanted this paper to act as an introduction to the bigger paper which he had promised earlier to present at the next meeting and in which he would like to give detailed technical data, photographs and tests taken on the plant and equipment to be employed on the Hirakud Project. He appealed to the Hydro-electric engineers in the country to associate themselves more actively with the work of the Central Board of Irrigation.

MR. N. N. IYENGAR, Chairman of the Central Electricity Commission in opening the discussion wanted to have all the reasons which led Mr. Gadkary to conclude that alternative No. (iii), viz. Power House No. 2 taking the base load and No. 1 taking the peak load, was the best solution. He suggested a combination of hydro and thermal power for an economical development of the system as a whole and referred to the practice adopted in other countries with good fuel resources and on the Damodar Valley Project. He thought that this should be possible as Orissa was not far from the coal resources. In this way, he said, the installed hydro capacity could be put much more than on the basis of the minimum flows alone. As our fuel resources, however, were not as extensive as we desired, the economics of such hydro-electric power projects could be considerably improved if their construction programmes could be co-

ordinated with constructions of similar projects in neighbouring areas. In the case of the Hirakud Project, there was of course expected to be no shortage of storage supplies, as only a portion of the total flow of the Mahanadi River was impounded. To this extent, there would be no need for any back-up from Thermal power stations. If the generating capacity installations, however, were co-ordinated with power system capacities in neighbouring zones, which could be connected up with transmission lines, installed generating capacities in all the stages of development could be utilized continuously with resulting economics of capital and operating costs. I would recommend that the possibilities of such co-ordinations be examined, when considering the programme of installation of generating capacities in such projects.

Mr. S. S. KUMAR appreciated the lead given by the author in presenting papers on Hydro-electric projects.

He referred to the author's suggestion to use Power House II as a base load station and pointed out that in the earlier stages when the load would be low, it would not be economical to run Power House I without loading it in order merely to run Power House II. Even when load developed, he thought there would be difficulties as due to the taking of irrigation water through the power channel, regular flow of water could not be counted upon to work Power House II.

He referred to the arrangement proposed on the Nangal Power House in this respect.

Mr. KUMAR agreed generally with the principle that smaller the number of units to generate a given power, the less would be the cost per kilowatt of installed capacity and hence the overall cost but there was a limitation to that statement as beyond a certain size it would not be quite economical.

RAO BAHADUR G. SUNDARAM said that he had not exactly understood Mr. Gadkary's remarks regarding 'mean monthly flow' for the 'design year' and that the subject should be restudied by assuming say 15 to 20 per cent variation between the design data and the actual results. In this connection it would appear that in arriving at the 'mean monthly flow' of water to be utilised in a scheme the volume of water available from the power point of view had also to be taken into consideration. Referring to the method by which the seasonal power was converted into firm power, he said that valid consideration should be given to the amount of thermal power that was also available. In his opinion the firm power should be allocated only to first class loads *viz.*, urban loads, and certain industrial loads and large seasonal power should be made available to cover loads of secondary importance. All this, of course, had to be studied keeping in view the local demands and characteristics and also whether possibility of thermal station existed to supplement hydel generation. Possibly some provinces might have to go in for thermal power rather than for seasonal power. Another point to be considered while converting seasonal power into primary load was that supposing it was a grid and the grid happened to have thermal and hydel plants of varying regimes, then greater use of seasonal water could be made use of than was otherwise feasible.

MR. J. C. HARDIKAR said that his experience of combining the irrigation project with the hydel was that the requirements of the two were different. The seasonal variation of water for irrigation did not generally fit in with that for power generation. In some such combined schemes that he had come across he remarked that it was found very difficult to make them run together. Looking at the power requirements of the scheme, he said it would be found that very little water was left for irrigation purposes.

Continuing he said that from Mr. Gadkary's paper, it was not clear how the capital cost would be apportioned between the two benefits—irrigation and power.

MR. S. R. AGGARWAL referred to the need of proper load planning. It was not sufficient to state merely that the full load would be developed in 5, 10 or 15 years. Referring to the United Provinces projects he said that the total generation of electricity was expected to be about five lakhs of kW. These they wanted to install in 10 years. He said that the power planning was not akin to water planning for food because the latter was relatively simpler. The power planning was depended on the economic conditions of the country. Continuing he said that in United Provinces they required huge quantities of cement and iron but they had only limited supplies of these. He believed many of the projects were power projects. He therefore wanted that some principles should be enunciated as to how the power planning should be done and what materials were to be taken into account. He thought they could definitely find out which projects were more important than the others and as such should be taken up first.

MR. R. L. NARAYANAN (Orissa) in thanking Mr. Gadkary for his paper said that the first point he wanted to take up was regarding the running of the lower power house. In the case of this scheme they had two power houses utilising the same water for power generation and this water was being used by the second power house. Besides, there was a storage reservoir of a reasonable magnitude. Regarding the installation of the plant, he said, they should take advantage, of all the circumstances pertaining to the scheme. Continuing he said that the minimum head in the upper power house occurred when that at the lower power house would be a maximum. There would be no water in the river below it and the storage reservoir above would not vary appreciably in level. Under the circumstances the turbines at the Upper Power House would be capable of only the minimum output while the turbines at the Lower Power House would be capable of the maximum output. One should certainly take advantage of the larger capacity of the turbines in the Lower Power House at this time to carry part of the peak load and thereby reducing the demand at peak load time on the Upper Power House. The reservoir above the Lower Power House, he said, was big enough for this purpose. This should mean that part of the increase of load during the peak time would be carried by the Lower Power House and it would work at less than its average load during the off peak load time and correspondingly in the Upper Power House the increase between the low load period and the peak load time would be reduced. He said, one should design the two power houses to be capable of supplementing each other at all times.

Further one should not make the generator suitable for the output at the lowest head only but for a reasonably higher head than the minimum. This could either result in a reduced number of sets for the same load or in the reduced size of the turbines required to carry the load. He was therefore, of the opinion that a reduction in size of the order of even 10 to 15 per cent. would result in a substantial saving in cost considering the present high rates of machinery.

Coming to the question of the size of the turbines he said, it would not be correct to make up the mind for just three or four machines and to base the sizes on this assumption without taking into consideration the fact that this might lead to a side which might necessitate going down in speed, for a larger generator combined with a lower speed would not necessarily mean a reduction in the cost of generating plant per kW. Besides, the heavier and larger parts of a larger but slower machine, would also mean a larger power house, deeper foundations, deeper drought tubes *etc.* It would also mean a larger amount of spare capacity.

Continuing he said that on analysing the installation of a larger number of hydro-electric stations in America, he observed that it was very seldom indeed that the generating capacity was based on the basis of minimum head.

He was, therefore, of the view that—

- (1) the size of the machines should be gone into in much more detail and made to fit the conditions at Hirakud where there were two generating stations with varying heads but where the variation in head did not occur at the same time.
- (2) the size of the set should be fixed with a view not only to having the minimum number of machines but also to having the most economical rate of the generating plant per kW.

Referring to the remarks that during the monsoons the efficiency in the lower power house did not matter as there was plenty of water in the river, he said that no doubt there would be plenty of water going over the dam, but would not be available for No. 2 power house.

Another point was that if they were going to base that load on minimum head, why to have moveable propellor blade turbines at all as they would be more costly. Unless one took full advantage of them the extra cost he said would not be justified. He therefore suggested Kaplan turbines as their efficiency was also fairly high over a considerable range.

Mr. H. R. BHATIA remarked that in a hydro-electric scheme the quantity of water available should be known for an economical design so that the scheme as designed could fulfil the requirements for which it was designed. The most desirable method of determining this in his opinion, was the actual river gauge at site and no formula could be applied. He was very glad to know that Mr. Gadkary had laid stress on this point. Continuing he said that from the development of load point of view a step by step development was more suitable than an overall scheme. The Central Waterpower, Irrigation and Navigation Commission, he said, was making schemes from an All-India point of view. He was not sure if this point was being kept in view. He agreed that the total potential power of supply should be utilized but it did not necessarily follow that the total storage scheme was necessarily the most

economical one. Sometimes one could utilize a fairly large proportion of the total potential power available by providing only a small pondage instead of total storage. This was particularly so when the variations in the stream flow in different seasons of the year were not very wide. Referring to this particular scheme he first pointed out to page 444 and said that it was not clear why one should always go too much on the safe side in every case. Too high a factor of safety at every step would tend to make the scheme less economical. He next referred to page 445 where a reduction had been made of 1.66 million acre feet of storage on account of irrigation requirements. He presumed from this that a channel had been tapped direct from the main reservoir for irrigation requirements and this was not clear from the paper.

With regard to running of the base load station, he thought that before this question could be decided, it was necessary to study the load curves with respect to the water flow. Further, it had to be studied in relation to the capacity of the reservoir as to how much water it could store. Unless this study was made from hour to hour, he did not think that this question could be decided. He suggested that a detailed study should be made on this point. As regards the number of units on the last page of the Paper, he said, Mr. Gadkary had suggested ultimately seven units. He personally felt that this number of units was too high. In his opinion six generating units would be ample, four of which would carry the full capacity, the fifth one could take the peaks and the sixth one would be spare.

Mr. K.L. Vij agreeing with Mr. Bhatia, remarked that it was of great importance to know the correct data on which any hydel project was to be based. For that either one could take the minimum flow that had actually been observed in the past or one could study the cycle of rainfall. Personally he was of the view that one should, in each and every case, see the effect in case the minimum cycle came in after sometime whether the loss of power was such that it could be made up by other practical means. In case it was so found the design need not be based on the minimum flow. In this particular case, as had been shown by Mr. Gadkary, the loss of power in the worst year came to about 22 per cent. So he had a choice between designing 22 per cent. more or 22 per cent. less of power. Now in this particular case the average power which is 22 per cent. more was actually available in 19 out of 20 years. It was only in one year that the power fell short by 22 per cent. Therefore, he said he was personally of the view that it would be quite reasonable in this case to assume the average year flow and design it on that basis. Recently he said, he had a chance to see the Wain-Ganga Project in the Central Provinces. There he found actually that in the worst cycle of rainfall the actual shortage of power over the average year fell by 62 per cent. Certainly in that case the worst cycle of rainfall would have to be taken into account because it might not be possible to make so much shortage by any practical means. The second point, which he thought was a very useful point, and which also had been raised earlier was about the supplementation of the hydel power by the steam power. He said that since a huge hydro-electric programme was envisaged one could not think of thermal supplementations unless all the primary power available from the hydro projects had first been sold out. After the primary power had been sold out, it would be time then to think as to whether the secondary power from any project was available or

not and if so whether it would be economically reasonable to supplement it by steam power. Now, there was shortage of power only once in 20 years. A steam plant to cater for that one year in 20 years would certainly not be economical.

Another interesting point on which he said he would like to add his comments was about the parallel operation of the power houses Nos. 1 and 2. There were two aspects of this case to be viewed. All the water that was released from power house was actually used on power house II. Then there was the second aspect namely the electrical aspect. The question was whether it would be possible to hold the two power houses in parallel operation in the event of any major disturbance on the system because it was most essential that both active and reactive power were shared between the two power houses in proportion to the assignments made to them before hand. Otherwise if there was any disturbance on the system it might so happen that one power house might take far more reactive power than was actually assigned to it. In that case the entire power house would be thrown out of the system. The other station not being able to take up the entire load might follow suit. Therefore both these considerations should be taken into account. Personally he thought that the electrical consideration was as important as the hydel consideration. Between the two power houses he thought, it would be very expensive to control them from a central control by some supervisory means. In his opinion, the best results from the electrical point of view would be obtained by running one power house at fixed load and fixed power factor. Another point which he said he would like to raise was about fixation of critical load. The trouble was that so far no manufacturing facilities were available in this country and for any data or design difference between the turbines themselves one had always to run to foreign countries for advice. Consistent with consideration of economy, it would be ideal to so fix the critical head that an output from the turbine equal to the rated generator output can be obtained at all heads. Previously they were being told all the time that whether the turbine was designed for a head of 78 feet or 88 feet the cost would be almost the same in both cases. If that was correct then he thought that it would be quite reasonable to design for the minimum head of 88 feet so that it was possible to obtain an output equal to the generator output at all heads, otherwise. When the head was low more sets had to be taken into commission. The efficiency of a Kaplan turbine was fairly constant between 25 per cent. full load and 100 percent full load. Referring to Table 1F. XIII, he said, the head varied from 79 feet to 112 feet in the months of June to November. For the three months of May, June and July when the available head would fall short of the design head of 88 feet, spare set would have to take up the additional load. Having recently learnt that the difference in cost between a design head of 88 feet and 78 feet would be by about 10 per cent. and because of the reason that the spare set is not called to run for more than three months, the design head had been raised from 78 feet to 88 feet. Referring to page 453 of the Paper Mr. Vij thought that Mr. Gadkary's intention was probably just to make a sort of a general case as his own experience was that the cost per kW. depended on the diameter of the turbine and the regulationship indicated by Mr. Gadkary, no doubt, held good upto a certain limit of the turbine diameter.

In winding up the discussion Mr. GADKARY felt gratified at the keen interest taken by Power Engineers in his paper. He said that although he had noted the points raised by the various speakers, it would not be possible to complete the discussion within an interval of a couple of minutes then left for closing the discussion. However, he would like to refer to these points by a separate note. The note as received from him is reproduced in the following form :—

With reference to Mr. Iengar's remarks Mr. GADKARY stated that the question of operation of two power houses had been gone into very much in detail, and the reasons for selecting No. 2 (Lower) Power House for base-load operation, when both the power houses were fully loaded, were given on page 451 wherein three basic conditions had been stated for their successful synchronous operation in parallel. To this it might be added that the head in Power House No. 1 was higher than in Power House No. 2, and, therefore, the water required for generating the same power would be less at Power House No. 1 than at Power House No. 2. Therefore, for a given power output, storage reservoir at Power House No. 1 would be less than that at Power House No. 2. Secondly, storage at Power House No. 1 was already existing; therefore, its additional use by storing water for peak load demand would involve no extra expenditure.

It should also be noted that the load factor at Power House No. 2 could be much less than at Power House No. 1, if Power house No. 2 was to take the peak-load.

In the ultimate analysis it was the overall economy that counted and, therefore, when all the variable factors had been taken into account, the proposition in the paper would give the best economy.

With reference to the use of steam power generation to firm up the secondary power from hydro generation, Mr. GADKARY stated that the following need consideration :—

Capital investment would increase when power was generated for part of the year in one power house, and for the rest of the period in another power house. This meant interest and depreciation charges would increase. Interest charges would increase in direct proportion, while depreciation would increase at a comparatively reduced proportion. Still the sum total would be much higher for generating the same units from the combined scheme than from one scheme operating on 12 months basis. This uneconomic proposition could only be taken advantage of if there were other counter-balancing factors of sufficient importance, as were sometimes found in some industrially advanced countries. In India, with the availability of immense firm hydro-power, the combined generation would not be economical as a rule. In this particular case, it would be definitely very much uneconomical.

It was worth noting that even the secondary hydro-power at Hirakud could be converted into primary power when second storage scheme, namely, Tikarpara, downstream the river, came into operation. There was therefore, no case at all for firming the secondary hydro-power by steam generation when the same object could be achieved, when required, by another storage scheme, downstream of the same river.

Referring to Mr. Kumar's remarks, MR. GADKARY pointed out that, when load was not fully developed, hydraulic efficiency was of no consequence, as water had to be wasted for want of sufficient load.

As for use of water for irrigation taken out from the power channel between the two power houses, it was already taken into account under fully developed load conditions as explained in the working Table 1 F. XIII.

Referring to Mr. Sundram's remarks MR. GADKARY added that mean monthly flow referred to the addition of water from month to month to the water available by storage, taken as full, at the end of wet season, percentage referred the mean monthly flow assumed in the design year. This was inevitable because the discharge cycle was not constant in each year. However, some cycle had to be assumed and therefore in this paper the assumed cycle was referred to as design year cycle. The object in restudying the water available for power generation by assuming variations in any particular year with design year data in the inflow, was to bring out its effect on power generation and to examine whether the extent of such a loss could be met conveniently by some other means which had already been dealt with on page 438.

Referring to Mr. Hardikar's remarks he stated that month by month variations of the requirements of irrigation had already been taken into account in detail in columns 8 and 18 on page 448.

As for allocation of cost between irrigation and power in a multi-purpose project, it was a subject by itself and was beyond the scope of the paper.

Referring to Mr. Narayanan's remarks, MR. GADKARY added that the study of tables given on pages 448 would indicate that the variations in head at both the power houses in different months had been fully taken into account in arriving at the power potential available by the combination of two power houses hydraulically connected. No. additional power could be obtained from the same water beyond the limits of its power potential as given in the paper.

Secondly, even in some months, the head at power house No. 1 was higher than that at power house No. 2 and the efficiency of Kaplan turbine was fairly constant with a wide variation in head, therefore, water was being utilised economically.

As for design head, the criterion was economy in first cost, and, therefore, it had already been taken care of, by calling quotations for the design head of 88 feet though the minimum head was 78 feet.

Referring to the question of number and size of units, it was stated that the economy involved in the size and number selected took into account all the factors mentioned by him. The principles laid down were true within certain limits, on the size of turbines diameter and therefore as the size chosen was within this limit, it could be safely taken as an economic proposition as per information supplied by the well-known manufacturers.

Referring to the question of additional water for No. 2 power house during the monsoon period, Mr. GADKARY added that it was not understood what additional purpose it would serve, when all the machines had enough water for full load operation, and yet if for any reason additional water was required, it could be released from power house No. 1 site into tailrace channel, as per design of the power house and sluice gates *etc.* proposed to be provided in the power house section of the dam.

Referring to Mr. Bhatia's remarks, it was stated that the first deduction for irrigation requirements was with reference to the main reservoir upstream of power house No. 1, and the second deduction was on account of gravity channel taken out from power channel in between the two power houses. Both these deductions catered for irrigation requirements as laid down in the design.

Provision for the openings in the Dam for two additional units, was made, only to make it possible for this addition, if required to generate secondary power in the wet season and to convert it at a later date into primary power with the help of Tikarpara storage scheme, as already stated.

In conclusion, Mr. GADKARY expressed his thanks for the interest taken by Power Engineers in his paper and felt that his labours in preparing the paper had been fully justified. However, in a technical paper of this nature, it was not possible to give in detail, several factors that had entered into the calculations and, therefore, if any Power Engineer was interested in elucidating further information on any aspect of the case referred to in this paper, Mr. GADKARY would be extremely pleased to supply such additional information as much as he could.

THE PRESIDENT congratulated Mr. Gadkary on his Paper and on the exact approach that he had brought in for discussion. He said he was sorry that he was not able to give more time to Mr. Gadkary to reply to the discussion, but he felt that this discussion would go on by personal contacts and through correspondence. He however, assured the Members that Mr. Gadkary had spent considerable time on the consideration of this subject and he had been ably assisted by Mr. Vij. He appreciated the results produced by him. The President agreed with Mr. Gadkary in his general ideas about supplementation with thermal power. In this particular case, of course, one need not at all be worried about the thermal power because they were storing only five million acre feet where as 40 million acre feet of water was running through the river. Later on there was going to be another dam namely the Tikarpara dam, and thus storage to the full extent would be possible. It would be possible to develop two million kW. at Tikarpara. Mr. Gadkary's assumption that loads in this case, would be assured from the beginning, he thought that Mr. Gadkary was quite correct because it was felt that a large number of factories would take big blocks of power and they would come in almost simultaneously with the construction of the dam. He once again congratulated Mr. Gadkary on behalf of the Board, for the very good paper that he had put in.

MR. S. R. AGGARWAL introduced item (5) in the absence of Mr. B. P. Saxena, and in answer to questions from members said that the maximum, minimum and the average rainfall for Khorai was 61 inches, 54 inches and 20 inches respectively. Corresponding figures for Lalitpur were 53 inches, 33 inches and 30 inches. The catchment area was 520 square miles. Discharge observations had been taken for the last two years throughout the monsoon. The cost of the tunnel would be rupees 40 lakhs including the main canal, which is 20 miles long. Length of the tunnel would be mile and a half. Diameter of the tunnel would be 10 feet and the tunnel would be in sand stone.

MR. R. CHANDRA (Assam) recommended an earthen dam as that in his opinion, would not require several controlled materials.

MR. A. C. MITRA in introducing item (6) regretted that the note could not be placed in the hands of the Members of the Board earlier. For this reason he read out certain portions of his Note to bring out the salient features of the scheme and requested the Members for advice regarding the river diversion and the best method of lining the channels.

MR. S. A. GADKARY enquired what was meant by cheap hydro-electric power.

MR. A. C. MITRA in reply said that $2\frac{1}{2}$ pies per unit would be the sale price and $1\frac{1}{2}$ pies per unit would be the cost of generation. Explaining this he said that first of all they did not want to go too deep into the foundations and secondly as they were going to use Kaplan turbines on Stage I he had verified from the variation of the discharge, that they did not get low efficiency at any stage. In reply to another question, he said that the size of the Plant Unit was 8,500 kW and that the installed capacity of Stage I would be eight such units.

MR. S. A. GADKARY said that if they had no objection he would examine the scheme and give his considered opinion provided the necessary data and information were supplied to him. Offering his general remarks he said that the size of the units was decided on the water potentiality or on the potential power, which meant the head multiplied by the discharge. After the was decided, it had been found out that the most economical proposition was to have only one unit. For various reasons he said it was an impracticable proposition. In the case of two units one should allow one spare, i.e. 50 per cent spare so that the cost per kW. again went up. By various calculations it had been proved that three units with one spare was the most economical proposition. So as far as possible the entire plant should be sized on the above basis. Of course, if there were more power houses, it stood to reason that no spare was essential. He said when the problem was examined on this basis it would be found that there were other criteria that had to be fulfilled. Incidentally, he thought that on the generation side the scheme was economical. He, however, suggested that details of the scheme should be supplied to him for study.

Referring to page 10 of the Paper, Dr. J. K. MALHOTRA said that for a concrete lined channel, the figures of N given therein appeared to be a trifle optimistic. If this particular value did not materialise in practice, it might reduce the capacity of the channel. The practice in the Punjab he said, was that deterioration should be allowed for.

RAI BAHADUR C. L. HANDA referred to the practical procedure for compacting the banks, and said that instead of compacting soil in horizontal layers as was generally done in this country, he found that in other countries they attached rollers to a tractor and pushed them up and down the slope. He was of the opinion that it was a better method for compacting soil.

Continuing RAI BAHADUR HANDA said that on the Nangal Canal they had lot of shingle and boulders in the soil excavated. When confronted with such soil compositions, he wondered if the most economical procedure to compact such banks had been considered and if so he would like to know as to what proportion of shingle and boulders should be allowed to go in the banks. If boulders had to be sorted out, it meant slowing down the progress. If on the other hand those boulders were allowed to remain above a certain limit they were going to give trouble by way of cracks etc. Dr. Dhawan he said, had carried out some experiments on this problem.

SHRI D. V. JOGLEKAR pointed out that the barrage site on the Yamuna appeared to be wrong. The ideal site he said, was further upstream so that the canal would take off from the concave side of the river and would then draw sand—free water due to favourable river curvature.

MR. T. J. MIRCHANDANI wanted to know the length of the 132 kv. line, the load that it was going to carry, its regulation as well as its cost.

MR. A. C. MITRA in reply said that these had not been worked out yet. In reply to another question, he said that a rate of 3 per cent. had been adopted for interest.

MR. S. A. GADKARY said that he understood that 132 kV. line was only a general suggestion. He enquired if there was any rough idea regarding the distance, cost or even the load to be transmitted.

MR. A. C. MITRA replied that the designed load for the 132 kV. was 50,000 and its distance was 130 miles upto Ghaziabad.

In winding up the discussion, THE PRESIDENT remarked that he would appreciate the idea of provincial Chief Engineers and their *attaches* presenting papers to the Central Board of Irrigation because not only it gave a picture of what was happening in the Provinces, but it also helped the writers to get other opinion about their projects. He further stated Mr. Gadkary as Member of the Central Waterpower, Irrigation and Navigation Commission had volunteered his help to examine the schemes that might be forwarded to him and whatever further information was required would also be given by the Central Electricity Commission. In conclusion, he said that Rao Bahadur Joglekar's suggestion about the barrage site might also be taken into account. Some training works upstream might also be considered.

2F. Financial Aspects of Projects

PRELIMINARY NOTE

(1) The following resolution was passed at the 1945 Annual Meeting of the Board.

“(a) Resolved that the Government of India be requested to form a committee to determine what data should be collected to enable the indirect benefits of irrigation to be assessed. The Committee should consist of:—

The Chairman of the Central Waterways, Irrigation and Navigation Commission (Chairman).

A member of the Central Board of Irrigation.

Secretary, Central Board of Irrigation to act as Secretary of the Committee.

“(b) Resolved further that pending the framing of an accurate estimate of the monetary value of the indirect benefits of irrigation, the Board recommends that, in view of the undoubted fact that this value is appreciable, the criterion for judging whether an irrigation project is productive or not should be that the estimated net revenue shall not be less than the anticipated interest on the sum at charge when the project is fully developed.”

The action taken by various administrations on part (b) of the resolution was reported to the Board at its 1946 meeting when it was decided to await the formation of the committee by the Government of India as recommended in part (a) of the resolution. Decision by the Government of India on this subject is still awaited.

A communication has been received from the United Provinces Government saying that works on the Irrigation Branch of that Government are classified as Productive or Unproductive according as the net revenue, *i.e.* the balance of revenue after meeting working expenses from each work on the expiry of ten years from the date of closing the construction estimate, covers or does not cover the prescribed annual interest charges on the capital invested. If a work classed as Productive fails to yield the prescribed return for three successive years, it is transferred to the Unproductive Class and *vice versa*. The current rate of interest for productivity was four per cent. and had been in force since January 1942. It has also been added that that Government is already following the principle laid down in resolution (b) above.

A note entitled ‘Indirect benefits of Irrigation and a new method of financing irrigation projects’ by Rao Bahadur A. R. Venkatacharya, I.S.E., Chief Engineer for Irrigation, Madras was received and the author at the 1947 Board Meeting explained the results of his study. It was decided that (a) reply from the Government of India may be awaited and (b) in the meantime copies of Rao Bahadur Venkatacharya’s note be supplied to all members of the Board.

It is proposed to put up a separate note of all the replies received at the time of the next Board meeting.

(2) At the 1947 meeting of the Board the question of apportionment of costs into different units of a project was also discussed at some length. It was finally decided that members and other officers interested, be asked to contribute papers on this subject after reading the TVA publications and a discussion be arranged at Roorkee in April. Unfortunately the discussion could not be arranged at Roorkee as desired by the Board.

Recently a progress report entitled "Qualitative aspects of Benefit-cost practices currently in use by the Department of Agriculture, Department of Interior, Corps of Engineers and Federal Power Commission" has been received in the office of the Central Board of Irrigation. A summary extract of the same has been circulated to the members of the Board for their information and also for inviting their opinion if they would like to examine the benefit-cost problems of projects in India.

A paper entitled "Allocation of cost in a multi-purpose project" by Dr. Rao of Madras has been received which is proposed to be discussed at the meeting. Burma Electricity Department, Madras, Orissa, C.P. and Berar and Travancore have intimated that no paper will be contributed by the officers of their respective Provinces. Replies from others are awaited.

(3) The Board at its 1947 meeting considered the question whether where perennial irrigation is made possible by storage (thereby ensuring certainty of water year in and year out), provision should be made that charges for water and rent should be amalgamated (with a corresponding increase in revenue derivable from landlords) so as to ensure so far as this is possible that the water will be used to the maximum extent possible for a double cropping.

The Board accepted Shri M. Narasimhaiya's proposal (that members of the Board should send notes to the Secretary as expeditiously as possible within say, a month and the Secretary should prepare a questionnaire on the subject) and it was decided to discuss the matter further at the informal meeting to be discussed at Roorkee in April. Unfortunately this discussion could not be arranged.

Notes have been received from the United Provinces, Bombay, East Punjab, West Bengal, Central Provinces and Berar and Bahawalpur. Replies from others are awaited. On receipt of replies from all, note will be prepared by the Secretary of the Board and circulated to the Board members.

Recent Literature

1. Voorduin W. L. Multipurpose development of the Tennessee river—*Science and Culture*, Vol. 12, No. 11, May 1947.
2. Procedure for net benefit in cost analysis in Project Planning reports—U.S. Department of the Interior, Bureau of Reclamation, Washington 25 D.C., April 14, 1947.

THE YEAR'S WORK

The following items were presented for discussion at the 1948 Annual Meeting of the Board.

- (1) "Financial aspects of water utilization projects" by Om Perakash Bhasin.
- (2) "Allocation of costs in a multi-purpose project" by Dr. K. L. Rao.

(1) FINANCIAL ASPECTS OF WATER UTILIZATION PROJECTS

by

Om Prakash Bhasin*Irrigation (Hydel) Branch, United Provinces.***ABSTRACT**

The paper deals with the economy of development, engineering control, and economic justification of Water Utilization Projects.

Planning for the proper utilization of the resources of a region should have as its main objective the well-being of the whole. The promotion of the general public interest is the criterion by which the wisdom or futility of a plan must ultimately be measured.

To be justifiable, the total benefits of the project must not only exceed the total cost, but the project must also be less expensive than the most economical alternative schemes which would provide equivalent benefits.

It has been said many times that there is no accepted rule of allocation of common costs flowing from joint use, a position eloquently proved by the litigation arising around this problem of the Tennessee Valley Authority. That body has been charged with the obligations of maintenance of navigation, control of floods, and generation of power on the Tennessee River, a task that by its nature results in certain of its facilities being used jointly for two or more functions. For the solution of that problem at least nine allocation theories have been advanced.

ECONOMY OF DEVELOPMENT

It has not been long since the day when an irrigation dam was designed for no purpose in addition to irrigation; when a structure for the improvement of navigation was designed with only that thought in mind; when a power dam was a power dam and nothing more so far as the designer and the operator were concerned. At that time many structures were built which served well their individual purposes; but failed to develop valuable related uses; structures which will have to be duplicated because the related uses were overlooked.

Mr. Abel Wolman, Chairman of the Water Resources Committee and President of the American Public Health Association observed in a paper delivered before the American Society of Civil Engineers:

"Whether for better or worse, people are beginning to view the control of a stream for flood reduction as an integral phase of the use of that stream for power, navigation, irrigation, public water supply and sanitation. To the writer it is an evolutionary step of merit."

Probably the major problem is the question of planning or the development of a stream so that the water resources available in a region can be conserved and developed to serve not only one need but the various needs of the region to the greatest economical extent.

It has frequently been stated in recent years that the river drainage basin is the logical element for water control planning. This is essentially true, but it is a broad statement. What constitutes a river basin?

There seems to be no basis for fixing a definite rule. The unit should not be so large that the problem is unwieldy, or that the elements are so diverse that they can never be reasonably reconciled. On the other hand, the unit should not be so small that comprehensive development for the immediate region can never be made, or so that the scheme will always operate at cross-purposes with the development of confluent river-systems.

It is believed that a drainage basin should be sufficiently inclusive to embrace an area in which the needs for water are generally common and widely distributed, a system of streams which can feasibly be developed to meet the needs of the area to the fullest possible extent, with due regard to the effect on the large stream to which this system is a tributary.

The most questionable tendency in some recent concepts of water control planning appears to be the idea that a definite plan should be set up for years in the future. It is not believed that any man or body of men are wise enough to predict or to enforce a programme of development for 50 or even 25 years hence nor is it always practical or economical to build for the distant future. Too many things could never be done for practical reasons under this concept.

In reality, a moderate beginning is often required to pave the way for the ultimate end, while the carrying charges saved by the moderate beginning will often amortise the investment by the time it becomes obsolete.

Planning for the proper utilization of the resources of a region should have as its main objective the well being of the whole people. The promotion of the general public interest is the criterion by which the wisdom or futility of a plan must ultimately be measured.

It is clearly recognized that the benefits accruing to the people are not to be measured by financial return on the investment. In addition to direct benefits, there are also at times important indirect benefits that cannot be measured in money. For instance, the storage of water in a reservoir undertaken primarily to increase the low flow of a river may and often does, increase recreational facilities and become a factor in the conservation of bird and fish life. Such a value is similar to these intangible values obtained from the development of national parks or scenic high-ways.

In weighing the economic value of a project, it is necessary that, against the benefits that will be obtained, there be set out very definitely the costs that must be met. Included in these costs are not only the proper interest charges, operation costs, allowances for depreciation, *etc.*, but also damages to existing land values and other charges that are detrimental rather than helpful.

Credits for benefits, such as flood control and navigation, should not be capitalized in any other way than good business practice would sanction and permit. Water-power costs should be compared with the cost of generating and delivering power to load centres by alternate available methods. The economic loss in power plants are power facilities already built and must be taken into account if these plants and facilities are made to stand idle because the market they were built to serve is taken over by power generating stations and facilities built by the Government.

A combined scheme must stand the same analysis and scrutiny as two single schemes ; the cost must be justified by the two kinds of benefits secured.

In the long run, economic considerations must be faced and, in doing so the best method is to make each project to the economic line from its inception. Economic history shows that this has been done only when the penalty for unsound projects has been visited on the projectors immediately and with full force.

Planning for the wise use and development of our water resources requires the cooperation of engineers, other specialists and lay citizens.

Those who know most about the possibilities and methods of using and controlling water must appraise and fit together projects for flood control, navigation, soil conservation, irrigation, water supply, pollution abatement, power development, and other particular water uses, so that an integrated plan for a whole drainage basin can be developed. Many purposes can be served together—protagonists for one use are coming to see their projects as part of a large whole.

Through the democratic process, with participation in planning for the future of the areas in which they live, our citizens have found opportunity to make known their needs and to see how their requirements may fit together in a general plan. Progressive revision of programmes of work and general plans for development is necessary as new problems arise, new standards are recognized, and new methods are found to meet them.

A unified plan of water control and development, in contrast to a medley of unrelated projects, calls for an integrated policy with respect to the various types of water problems in their interlocking relationships in contrast to a collection of more or less unrelated policies.

Coordinated control and development of river systems, it may be noted, means far more than realization of the multiple potentialities of individual projects. As already implied, it means multiple-purpose action on an areal basis as well as on a functional basis. A river system is a natural unit. It presents interconnected problems that extend as a series of unbroken chains from the source of each tributary to the mouth of the master stream. A single project of magnitude may have far-reaching effects upon the regime of a river and upon other projects. Integrated planning, therefore, requires adequate consideration of the effects of each project of large size not only on its own area but also in contiguous areas and perhaps on the entire basin. The need for coordination may extend even to the operation of a system of completed works. Thus unified operation of all the reservoirs in a system designed, wholly or in part for flood control may be essential.

At the risk of some repetition it may be affirmed that substantial progress in dealing with the major water problems of the Nation is contingent upon acceptance of the river basin as the normal unit area in planning and in the execution of plans. This view is now generally held in principle, but in many quarters its implications are not accepted, especially in the case of inter-provincial rivers. Most of the large rivers of the Country cross one or more

province lines. Most major water problems of the country accordingly involve inter-province relationships. This is true of nearly all types of problems and especially of the associated problems of various types that are involved in the integrated control and development of river systems. It is futile to hope that the separate plans of several provinces may fit together into an effective master plan for an inter-province river system. If each province attempts to plan and carry out alone the development of its part of such a system, waste, inequities, and controversies result.

In its report, "Drainage Basin Problems and Programms, 1937 Revision," the National Resources Committee, representing all the Federal Agencies in America, said on the subject of multiple benefits :—

"Not to promote the integrated development and utilization of latent water resources as promptly and fully as all relevant technical, economic, and social conditions warrant is to invite waste of potential wealth and so is incompatible with the public interest."

"Integrated control and use of water implies planning and constructing projects for dual or multiple benefits wherever practicable. Actually, almost every water project of magnitude may be made to contribute to the solution of more than one problem. Not to realize all of its feasible potentialities is inimical to the public interest. A large dam and storage reservoir built and used solely for flood control is a wasteful mal-adjustment, socially if not economically, provided it would have been practicable to design, construct and operate them to regulate the flow of the stream for other purposes as well as flood control, to develop marketable power, or to realize incidental reservoir values in connection with recreation and wild life conservation. Coming years, like the last few years, should witness increasing emphasis on multiple-purpose projects. The regulation and integrated development of rivers for all useful purposes is an attainable goal."

"Conclusions and commitments looking to the solution of water problems should be based on facts, not on mere opinions. Prompt preparation for efficient action, rather than prompt action through unpreparedness is the essence of right procedure. No crises, whether of flood or drought or work relief, should lead to neglect of these precepts. The adoption of a plan for the regulation and development of any large river without a definite study of adequate data on all phases of the physical and human problems involved is illogical, is almost certainly wasteful, is a signal for controversy, and may preclude suitable action later. Such studies take time, of course, but 'time pays little respect to that which is done without it.' Impatient planners and impatient citizens would alike do well to heed this proverb. When the prospective beneficiaries of costly measures of water control or use demand in their impatience that the processes of thorough-going investigation be abandoned, they do themselves and the public at large a disservice."

“The Principle of normally sharing costs according to benefits might be less unpopular in many quarters if the elementary facts were kept firmly in mind that no Federal source of funds exists into which states and local communities can dip without cost to themselves. Any so-called gift from the Federal Government must eventually be paid back by the people of the country in the form of taxes. Moreover, sharing costs has a salutary effect in curbing lavish expenditures. The principle should be maintained and extended in the field of water resources.”

“The relation of costs and benefits is patently a crucial matter in deciding whether or not large water projects should be undertaken and in timing meritorious projects. The wide-spread practice of ignoring general benefits and potential benefits in evaluating certain types of projects is no longer defensible. Social accounting should take its place with economic accounting. The procedure followed by public agencies in these matters should be standardized and modernized.”

In addition to the foregoing considerations, policies for drainage basin development must be related from an overall national viewpoint and to the business cycle. Ability to pay as well as benefits must be reckoned. It is emphasized that both the amount and type of construction and the division of costs among Central, Provincial and Local Agencies should vary with the movements of the business cycle.

ENGINEERING CONTROL

In applying engineering principles to multiple-purpose projects, it becomes more necessary than ever, in view of complexities, to keep one's feet on the ground.

Engineering control is the best utilization of all available means—terrain material, equipment, and personnel. The terrain is usually assigned at the start. Engineering control also involves good business management, technical knowledge, and professional alertness. Good business management is merely the application of common sense and experience to the prevailing problems; technical knowledge relates to specific ability based on knowledge of the natural laws; and professional alertness involves keeping informed of the latest developments in one's field of endeavour.

Engineering and construction is a rapidly changing science and the engineer, to be successful, must keep abreast of the times.

The fundamental objectives of a water control project are two-fold—economy and quality. Modern projects are usually large projects and mass production methods shall be followed whenever practical. Adequate preliminary studies should be made to insure that the project finally selected is the most feasible and gives maximum returns on the investment. There are many ways in which economy may be effected and it is the responsibility of the engineer in-charge to make certain that no *alternative* showing promise of a more economical development is overlooked. That a project will pay is sometimes not sufficient justification. Question is, what is the best.

A project, if undertaken at all, must be of high quality. Improved design and construction facilities are justified because they reduce the first cost or because they reduce operating charges. The present reduction in prevailing interest rates makes possible the use of a higher ratio of initial cost to annual charges than ever before and offers considerable encouragement to the development of higher standards in planning, design, construction and operation.

One of the first steps in the solution of a water control problem is the preparation of a definite and comprehensive statement of the problem. The preparation of an ideal programme covering all of the desirable features and omitting most of the undesirable ones is relatively simple and is perhaps the best initial step. After an ideal programme has been prepared it should be studied carefully with the thought of later perfecting a programme which will achieve the desired objectives in the most practical manner.

The important part in setting up a definite programme, however, is to determine definitely *what* to do, *when* to do it, and *why*. Once a practical programme is outlined, all efforts should be concentrated on attaining its objectives rather than reconsidering those phases of the ideal programme which were abandoned in the establishment of the adopted programme.

Before undertaking a specific programme, all available data bearing on the problem should be assembled, and studied. This material includes all the available information concerning the problem; both physical data such as hydrology, topography, and geology, and cultural data such as the social and economic status and needs of the urban and rural population. It is important that the accuracy and completeness of these data be analysed and recognized. After this available material has been studied, additional investigations are usually necessary to remedy deficiencies in the data in the interest of a better solution of the problem. Then extreme care should be exercised in selecting the methods and programme that offer the most successful solution of the overall problems. This programme should look to the future and consider the probable needs two or three generations in advance, as well as the current needs.

After these studies and investigations have been completed or concurrent with the maturing of such plans, tentative programme for each sub-basin in the drainage area are prepared. These plans should be progressively revised and coordinated so that each will fit logically into the most efficient regional plans, and the benefit values allocated to each sub-basin project can be determined. In this way it is generally possible to outline the most favourable sequence of project development, giving proper consideration to the effect of each project on its own locality and on the integrated system.

The problems involved in planning are legion. One may involve deciding whether to purchase and flood certain valuable areas or to protect them.

In designing a project the aim is low overall cost and necessarily low design cost. Frequently an extra investment in design pays for itself several times over in reduced construction costs and in improvements in the facilities provided. The initial step in the design of a project should include a review of

outstanding similar jobs in order to incorporate the better features of the previous works into the job. The adage:

“Be not the first by whom the new is tried

Nor yet the last to lay the old aside.”

is applicable in design. Radical departures from prevailing methods are permissible only when they have been checked carefully by persons qualified to pass on their merits.

The proper operation of a water control project requires the diligent observation of the limitations and assumptions prepared by the designers. Mistakes in the physical operation of a water utilization project are usually those of omission rather than of commission. Operating crews are frequently reduced in size as much as possible with the result that needed maintenance and repairs are often postponed longer than desirable. Periodic checks on the physical condition of the plant, the methods and procedures followed in operating the project, and on the ability and efficiency of the personnel will ordinarily decrease the average annual costs of the project.

Generally speaking, electric power, irrigation, and water supply are the only revenue-producing functions of a multipurpose development. The other benefits, while just as real, accrue to the public in general and are rarely assessable. If the project is developed by public agencies, these general benefits are just as valuable as the so-called paying functions and should be included in benefit analysis of the project.

In preparing any cost analysis, however, it is important that the general benefits be estimated very conservatively in order to avoid serious mistakes arising from the intangible nature of these items.

An important consideration in the evaluation of benefits for a multipurpose development is that of a social nature.

After a project is completed and put into operation, a careful appraisal should be made. An appraisal differs from a justification study in that the justification is based on estimates of *probable* cost and benefits, whereas an appraisal is an *actual fact-finding* process. A definite appraisal should be made to determine more accurately the cost of the development and the benefits made possible. Such an analysis serves as a check on the justification study and furnishes valuable information for use in operating the project and in planning new programmes. After an appraisal has been made, a proper share of the total expenditures of the multiple-purpose project should be charged to each of the functions served in order to obtain a measure of the economy of the enterprise. Appraisal should include all factors.

An allocation is similar to valuation involving, as all valuation cases, do, matters of judgment. Cost records are nearly always based on certain judgement factors and for this reason detailed cost comparisons should not be made without some knowledge of the construction and accounting conditions involved.

The advantages of multiple-purpose development, unified in design and operation, cannot be over-emphasized. In a properly developed multiple-purpose project, whether it be a single structure or an integrated series of

structures, two or more separate and distinct objectives can be realized. The total cost of providing these objectives is materially less than the total cost of producing equivalent results by the construction of separate single-purpose projects.

ECONOMIC JUSTIFICATION

The subject of economic justification is perhaps the most important as well as the most controversial of all problems with which the engineer has to deal. In fact, it is so controversial that experts do not even agree as to whether or not it is important. In the opinion of most prominent engineers, however, especially those engaged in private practice, economic justification is fundamentally a duty of the engineer and just as much a part of his work as the strictly technical aspects. It is just as important for the engineer to plan and design economically and justify a project by an economic analysis as it is to design safely.

The reason that engineers in private practice are as much more conscious of the importance of economic justification is that their clients usually are more interested in the economics of the project than any other feature. In fact, too often they are inclined not to allow enough time and money for thorough technical studies and investigations, but they always insist on a report as to the economic feasibility of a project before investing their money. This is specially true of consulting engineers in the employ of investment companies whose main duty is to assure their clients that the investment is sound and will be returned with interest.

The engineer in public service, however, does not have the same urge or the same feeling of responsibility for justifying Government projects economically.

In the words of David E. Lilienthal, Chairman of the Tennessee Valley Authority,

“Plans and action are part of one's responsibility. T.V.A. is responsible not alone for plans but for results. If T.V.A. had been a “planning agency” in the sense that its responsibility had been limited to the making of plans—the usual meaning of the term—those plans would probably have met the fate of so many other plans; brochures decorating book-shelves, adornments of the bibliography of a sterile learning.”

“In the T. V. A. the merging of planning and responsibility for the carrying out of those plans forces our technicians to make them a part of the main stream of living in the region or community; this it is that breathes into plans the breath of life. For in the Tennessee Valley the expert cannot escape the consequences of his planning, as he can and usually does where it is divorced from execution. This has a profound effect on the experts themselves. Where planning is conceived in this way, the necessity that experts should be close to the problems with which they are dealing is evident.”

“ In my opinion the idea of planning is still struggling for popular support in America largely for this reason : that the most spectacular plans have been drawn by men who did not have the responsibility for carrying them out. They did not have the salutary discipline which the experts of this valley had who have had to ask themselves : “ Is this a plan that I can take responsibility for seeing carried out ? Will the people help to make it effective ? Will they make the plan their own ? ”

Perhaps one reason why economic justification is so much a matter of controversy is because of the difficulty and uncertainties involved.

Another reason why economic justification is such a controversial subject is because of the lack of basic data required.

A more difficult task in economic justification for a multiple-purpose project is to develop the basis for comparison. For a private enterprise this is a very simple matter since it is only necessary to determine whether or not the revenue will more than balance the operating cost and fixed expenses. In other words, whether the project will make a return on the investment sufficiently great to justify the project.

Dana M. Wood in his paper “ Power Planning in Multiple-Purpose Systems ” prepared for the Seminar on Economics of Multiple-Purpose Projects considered the following points for an economic justification of a multiple-purpose project :

- “ (1) Comparisons should be made between two separate systems of plants, the second to include the project under consideration. In each system, it should be assumed that the necessary power capacity is installed at each project to fully develop the potentialities, with the same relative reserves. This assumes a market for the power developed. In the second system, less capacity may be required at some of the other plants after adding the project under consideration than in the first system. This would result in a credit to the added project by the cost of the capacity eliminated. The same argument may apply in some degree to storage provided for flood control.
- (2) The economics of a project will differ, depending upon the system of projects of which it is considered a part. The planned succession of projects should be followed.
- (3) Possibly serious consideration should be given to a determination of the diminishing value of flood control storage at tributary projects to allow for gradual filling of storage space during the flood season in accordance with prescribed rule curves.
- (4) Economic comparisons will vary, depending upon the emphasis placed upon the various multiple-purposes. “ For example, a practicable amount of flood control development will give a different conclusion as to power benefits than an extreme assumption for flood control like that of empty storage space throughout the flood season, thus affecting comparisons including combined purposes.

- (5) Auxiliary steam plants and inter-company connections effect economies in several ways :
- (a) A saving in combined reserve capacity, permitting sale of more power with a given installation, or requiring less combined new installed capacity for specific loads.
 - (b) Saving due to load diversity in inter-connected systems.
 - (c) Permit economic installation of the largest practical size of units, with resultant lower capital and operating costs.
 - (d) Permit allocation of loads to most efficient plants, using less efficient for reserves or light-loading.
 - (e) Hydro and steam operation can be made complementary to each other, operating steam on base when stream flow is low and on peak when it is high, with corresponding splits during intermediate stages.
- (6) In arriving at any benefit value of a given single purpose, deduction should be made for any tangible economic losses to society.
- (7) In comparing two projects with the same, or nearly the same, total benefits, but one having greatest benefit in, say, navigation or flood control and the other in power, the Government preference in regard to order of priority should govern.
- 8) It has been contended by some that Legislature authorization and appropriations for such projects eliminates the necessity for economic justification.
- (9) Projects economically justified with present conceptions of navigation and flood control values, and with existing power rates, may not be justified with future possible variation in any or all of these factors."

It has been said many times that there is no accepted rule of allocation of common costs flowing from joint use, a position eloquently proved by the literature arising around this problem of the Tennessee Valley Authority. That body has been charged with the obligations of maintenance of navigation, control of floods, and generation of power on the Tennessee River, a task that by its very nature results in certain of its facilities being used jointly for two or more functions. For the solution of that problem, at least nine allocation theories have been advanced.

At the outset of this problem, T. V. A. met with preliminary difficulties. Should their allocation be influenced by the fact that the T. V. A. Act creating the programme gave legal priority to navigation and flood control? The allocation of joint cost must recognize this limitation. T. V. A., however, could not accept this limitation, because they refused to substitute legal folderol for economic realism. Other problems must be faced. Which are the common costs, and which are directly allocable to a single function? Presumably, locks pertain to navigation, and intakes, turbines, and electrical-producing facilities are direct costs of power production. Shall any of the storage space,

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be considered a direct adjunct to one function, or is the use of all such space joint use? For all its difficulties, however, the first step in most allocation theories must be the separation of direct costs attributable to each function, leaving the remainder as the common cost to be allocated.

Before undertaking the discussion for allocation of joint costs in a multiple-purpose project, it will be helpful to formulate a set of preliminary criteria by which the suggested procedures may be appraised. They are as follows :—

- (1) The method should have a reasonable logical basis. It should not result in charging any objective with a greater investment than the fair capitalized value of the annual benefit of this objective to the consumer. It should not result in charging any objective with a greater investment than would suffice for its development at an alternate single purpose site. Finally, it should not charge any two or more objectives with a greater investment than would suffice for alternate dual purpose or multiple-purpose improvement.
- (2) The method should not be unduly complex. In a democracy public agencies should be subject to the understanding scrutiny of the citizen body to the maximum possible extent. The goal should always be presentation of problems and programmes for public consideration in clear and simple terms.
- (3) The method should be workable. It should not be dependent upon estimates which are difficult to prepare, and it should not require the use of data as to actual operation of the project which will not become available until after the passage of a considerable period of time.
- (4) The method should be flexible. It should be equally applicable to an isolated project or a coordinated system. In the case of a system it should be applicable to both the initial and ultimate stages of development. It should be readily adaptable to changing conditions over plant or system life.
- (5) The method should apportion to all purposes present at a multiple-purpose enterprise a share in the overall economy of the operation. The point has two implications. First, no purpose should be assessed costs as great as would suffice for alternate single purpose stream improvement. Second, no purpose should be assessed costs as its capitalised benefit value.

The several methods or theories which have been proposed by engineers and economists for allocating among purposes benefited, that part of the total cost of multiple-purpose water control projects which has joint value for two or more purposes, stem from a concept of the sharing of benefits derived from joint endeavour or joint accomplishment in the final analysis.

Vendibility Theory

This is the method of commerce where under conditions of effective competition, joint products produced in an open market will tend to be sold at

prices which in total will equal this joint cost of production plus a competitive profit but the apportionment of total receipts between them will depend on the relative demand for each.

The difficulty in applying this theory to the T.V.A.'s projects is that of the services rendered by multiple-use dams only two, fertilizer and electric power, are salable commodities. Navigation and flood control are not subject to any system of charges but are regarded as a general cost of government. Even fertilizer produced by the Authority is not sold commercially and will not produce dependable income sufficient to recoup a share of the general cost.

The Vendibility Theory thus breaks down because there is no open market in which the services produced by the Authority under conditions of joint supply can be sold.

The Specific Costs Theory

The proposal was considered that joint costs be apportioned to the several uses in direct proportion to the specific costs incurred for each of the purposes. This procedure needs only to be stated in order to be rejected as irrelevant where the object of the allocation is to impute responsibility for joint costs. Accountants have not been averse to an apportionment of overhead expenditures in proportion to direct expenditures, since administrative expenditures tend to vary with direct expenditures. No such functional relationship exists between direct expenditures for navigation and power and the incurring of joint costs.

Equal Apportionment Theory

It was suggested that the joint cost might be apportioned on the theory that each of the functions served by a multiple-use structure should share costs on the basis of equality. This is equivalent to admitting that no truly scientific basis for apportionment can be found. This method will produce reasonable results, where the representative uses of each function are substantially equal. Such is not the case on many of T.V.A. projects where one of the three functions may become of relatively minor importance. This solution would have satisfied no body.

Bye-product Theory

It appears that while this was never considered as a practical solution of the problem, Counsel for the Authority contended that the theory consistent with the Statute would be to charge directly to power only the cost of power plant and to allocate to navigation and flood control the common costs of the dams excluding the power-house section. This is referred to as the "Bye-product Theory", power being considered as nothing more than a bye-product of the dams which were built to satisfy, the general public by navigation and flood control, as directed in the Statute.

No-Allocation Theory

This theory was advanced by the president of the Edison Electric Institute, C.W. Kellogg, at the hearings of the Joint Committee investigating the Tennessee Valley Authority. Under this theory, all joint costs of a multiple-purpose venture would be charged to the power function, since, in the past, such had

been forced upon the private owners of hydro-power developments. Mr. Kellogg testified that the power developments at Keokuk on the Mississippi, Conowingo on the Susquehanna, and Lock Island on the Columbia had been charged with all costs. He said of the Keokuk plant:

“the company of which I had charge from 1914 to 1919—built the entire navigation improvement, they created a pool 50 miles long on the Mississippi River, they built a lock of the same width as the Panama Canal locks, and even greater lift, although not as long, they built a large dry dock, furnished buildings, and equipment, shops, tools, store-houses for the Government, all of that being furnished by the power company as part of its development cost, and had to be carried by it.”

However, the multiple-purpose dams of the Authority are not comparable to those erected by private companies, the dams are located with reference to the requirements of navigation and flood control, whereas the projects constructed by private companies with regard to the economical generation of power, any expenditures for navigation works being limited to construction of an incidental character. Also the Authority is not permitted to regulate the flow of water primarily for the purpose of producing power. Clearly this theory would impose un-warranted costs upon consumer of power.

This theory, the majority report of the Joint Committee investigating the Tennessee Valley Authority regarded as being not consistent, and not objective, but largely controlled by the desire of its sponsors to show that the yard-stick for power rates was unfair and based on too small an allocation to power, and was, therefore, rejected.

The Incremental-Power-Investment Theory

This theory was advanced by Dean Edward L. Moreland of the Massachusetts Institute of Technology, when a witness for the Commonwealth and Southern Corporation before the Joint Committee. Here again, the allocation principle referred to the common costs; power was to be charged with the balance of total investment, after deducting the estimated cost of the most economical alternative plan for accomplishing the other purposes. The difficulty here was to assign a cost to each purpose subsequently where this had not been done originally, although three or more purposes were taken into account in the original design, construction and total cost. This necessarily involves hypothesis, and the hypothesis can differ very widely, according to the type of navigation or flood control systems that might have been built; so that under this particular method of allocation the costs and valuation might vary enormously even as between different witnesses who accepted it. Furthermore, this method took as its starting point alternative navigation and flood control systems that would not have accomplished the purposes specified in the T.V.A. Statute.

This proposed theory was likewise rejected by the Joint Committee because of its excessive portion to power production.

Use of Facilities Theory

This theory would distribute joint costs upon the basis of the comparative use of the joint facilities. To each single function would be allocated such share of the joint cost as is measured by the extent of its use.

As an example, in the steam railways, the apportionment of common cost between freight, mail, express, and passenger business may be made upon some comparable use units like the car-mile, passenger-mile, or ton-mile measure.

This theory breaks down where there is no common use unit, or where difference in the use units or different basis are so great as to preclude their being reduced to some comparable basis. For the T.V.A. problem it was suggested that an acre-foot of reservoir capacity or an acre-foot of water released might be used as the common unit, but when considering power, head is an essential feature, while for flood control head is not a factor. Furthermore, reservoir capacity for flood control may be considered as a readiness to serve for which an analysis becomes very difficult. This theory was given serious consideration by the Authority but discarded in favour of the ninth on this list.

Benefit Theory

The theory of allocating joint costs of multiple-use dams on the basis of estimated benefits from the completed developments has been strongly urged. Dr. A. E. Morgan, the first Chairman of the Tennessee Valley Authority utilised this theory as the basis of a preliminary allocation which he submitted to Congress at an Appropriation Committee Hearing. Its use has been recommended by the National Resources Board, by the Mississippi Valley Committee, and by various regional planning committees.

The theory is simple, it being asserted that the common expense should be shared on the basis of the benefit accruing to each function. The difficulty in applying this theory lies in the determining of the benefits which are in many cases quite unpredictable and not susceptible of valuation. For example, flood control benefits go beyond any measure of actual property damage which may have occurred in the past or even be contemplated in the future. Protection of human life and health, the promotion of social well being, protection of business and industrial losses by floods, continuance of industrial pay-rolls during periods of floods, stabilization of property values, encouragement of new investments, increase in property values not only in flood zones but in surrounding areas, reduction in cost of local flood protection works, all must be considered in any estimate which purports to measure benefits to be gained from flood control.

Navigation benefits from the T. V. A.'s programme are numerous and far-reaching. There may be direct savings on freight shipped by water at rates lower than those available from land carriers and also on freight shipped by truck or rail at rates influenced by the existence of water competition. There may be market extensions for materials which cannot move profitably under existing rates, and extensions of markets for products now limited by freight rates. Industrial growth may be encouraged through growth of established industries, establishment of new industrial development or industries whose

selection of sites is influenced by availability of water transportation, stimulation of the building industry by reason of the general development of the region. Increased recreational activities will inevitably follow the development of the waterways. The adverse effect of waterways, competition on existing means of transportation, such as the rail roads, where these form a necessary part of the regional transportation facilities should also be considered.

The difficulty is to estimate the total benefits tangible and intangible. Such estimates as have been made indicate that the value of benefits is materially in excess of the cost of construction of a single-purpose navigation development on the river. Accordingly, this low dam cost has usually been taken as the measure of the benefits to be derived from the navigation programme.

The benefits resulting from the development of power by the T.V.A.'s programme has been variously estimated. The simplest, and perhaps the most logical basis is to estimate that the power development should produce power at no greater cost than could be obtained by equivalent steam generation.

Ingenious as this theory is, its great difficulty is the highly hypothetical, imaginary result of the attempt to evaluate benefits. It seemed desirable, therefore, to develop a simpler theory of allocation, if such can be found.

Alternative-Justifiable-Expenditure Theory

The T.V.A. working through an expert committee of public utility economists, rejected all these methods as unworkable in practice, and used as the principal guide to its final decision the "Alternative-Justifiable-Expenditure Theory". This theory was generally approved by the Joint Committee. This theory assumes that each of the principal purposes—navigation improvement, flood control, and power development—is equally important, and that each should carry a share of the common costs equivalent to the savings which each purpose enjoys through combination in multiple-purpose enterprise.

It is based on the fact that river dams and works can be built for a single function, though the aggregate of the estimated costs of such single works would ordinarily exceed the cost of actual multiple-purpose dams and works. Thus, it is possible "to use the ratio in which these higher expenditures are avoided by joint action as a basis for allocating joint costs."

This may be restated as "under which the joint costs are shared in proportion to the difference between the estimated *justifiable* costs and the actual costs incurred specifically for each of the purposes."

In applying this method, it is necessary to secure estimates of the lowest alternative cost by means of which substantially the same quantity and quality of service for each separate function can be obtained. The fundamental assumptions which underlie the cost estimates for single use structures must be as reasonable and practical as they can be made and must be based upon experience and after adequate investigation.

This method was suggested for allocating joint costs between navigation and power for the St. Lawrence River Project on the international section of that stream. It has also been used as a basis for allocating the common capital costs of the distribution system of water utilities as between commercial service and fire-protection service. In the latter case it should be noted that a distribution system for fire protection would in most respects parallel one for commercial service, alone.

Following is an illustration of application of this theory to a simple hypothetical case :

Assumed allocation of Rs. 1,00,00,000

Assumed direct costs

| | Rs. |
|-----------------------|-----------|
| Navigation | 15,00,000 |
| Flood control | 10,00,000 |
| Power | 25,00,000 |

| | Rs. |
|----------------------|-----------|
| Total .. . | 50,00,000 |
| Common costs | 50,00,000 |

Total projects costs .. 1,00,00,000

Assumed alternative costs

| | Rs. |
|-----------------------|-----------|
| Navigation | 40,00,000 |
| Flood control | 30,00,000 |
| Power | 60,00,000 |

Total .. 1,30,00,000

ALLOCATION (See next page)

The alternative-justifiable-expenditure theory affords a justifiable basis for the allocation of the investment costs.

ALLOCATION

| | Alternative costs | Direct costs | Remaining alternative costs (1-2) | Percentage | Allocation of common costs | Direct costs added to allocated costs (5+2) | Percentage |
|-----------------------|-------------------|--------------|-----------------------------------|------------|----------------------------|---|------------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| | Rs. | Rs. | Rs. | % | Rs. | Rs. | % |
| Navigation | 40,00,000 | 15,00,000 | 25,00,000 | 31.4 | 15,60,000 | 30,60,000 | 30.6 |
| Flood control | 30,00,000 | 10,00,000 | 20,00,000 | 25.0 | 12,50,000 | 22,50,000 | 22.5 |
| Power | 60,00,000 | 25,00,000 | 35,00,000 | 43.7 | 21,90,000 | 46,90,000 | 46.9 |
| Total .. | 1,30,00,000 | 50,00,000 | 80,00,000 | 100.0 | 50,00,000 | 1,00,00,000 | 100.0 |

SUMMARY

A unified plan of water control and development, in contrast to a medley of unrelated projects, calls for an integrated policy with respect to the various types of water problems in their inter-locking relationships in contrast to a collection of more or less unrelated policies.

Drainage basins normally should be treated as units in planning and carrying out the control and development of their river systems, for the cogent reason that a chain of connected problems extends from the source of each tributary to the mouth of the main river.

A number of fundamental economies result from the development of an entire watershed by a local public agency.

Economic justification of a project is fundamentally a duty of the engineer and just as much a part of this work as the strictly technical aspects.

The several methods or theories which have been proposed by engineers and economists for allocating among purposes benefited, that part of the total cost of multiple-purpose water-control projects which has joint value for two or more purposes, stem from a concept of the sharing of benefits derived from joint endeavour or joint accomplishment in the final analysis.

Two theories stand out among those which have been proposed as being of greatest validity in evaluating the returns from navigation and flood control projects, first the benefit theory, and the second, the alternative-justifiable-expenditure theory.

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(2) ALLOCATION OF COSTS IN A MULTI-PURPOSE PROJECT

by

Dr. K. L. Rao**INTRODUCTION**

A Project is said to be multiple-purpose one when it is intended for more than one of the following objects :

- | | |
|---------------|---------------------------|
| 1. Irrigation | 4. Flood control |
| 2. Powers | 5. Municipal water supply |
| 3. Navigation | 6. Defence purposes |

Thus the T.V.A. Dams are built to serve for Power, Navigation and Flood control. The U.S. Engineers' Low Dams across Mississippi are intended for Navigation and Power. The U.S. Bureau of Reclamation Dams in the Western States serve for Irrigation, Power and Flood control.

In India very few dams have been built so far and most of them are for single purpose, either Irrigation or Power. Thus in the Madras Province Periyar Dam built in 1894-98 is for Irrigation only while Pykara and Papanasam projects are for Power purpose only.

The Mettur Dam, at present the biggest in India is a major irrigation structure, though power of 10,000 kW (firm) is obtained as a bye-product. Some multi-purpose projects are now under contemplation in India and so the principles of allocation of costs for their various purposes has become necessary.

THEORIES OF ALLOCATION

Though the allocation of the total cost of the dam and appurtenant works is essentially based on sound judgement, nevertheless there are five theories which may be considered. Every one of these have some things to be said for and against it. The theories are summarised as follows :—

1. *Allocation may be made on the basis of estimated benefits which the dam would render to each of the various uses served.* The main difficulty comes in calculating the benefits for which special assumptions have to be made.

2. *Allocation on the basis of the comparative use of the joint facilities based on acre-feet.*—This method which appears feasible suffers from the fact that the power requirements are often cut down to regulate the reservoir from the point of floods and irrigation.

3. *Allocation on the basis of equal distribution.* This of course is the simplest but does not work scientifically. One way that this can be amended and made reasonable is by first calculating the cost of the intended parts for particular purposes; thus locks may be charged for Navigation only and Power House and Plant for Power only. Then the remaining items of the dam and appurtenant works can be considered as Joint Structures serving all purpose and the cost divided equally. There is one trouble, however, in this. The locks for example serve also as a part of the dam. Had it not been built, the space it occupies would have to be finished by long overflow dam forming part of the dam. Hence the whole cost of lock cannot be charged to Navigation. This kind of difference was made in the case of T.V.A. Dams for example in the Pickwick Landing. Thus of the total cost of 29.79 million dollars, the lock and channel improvement cost 5.81 million dollars. From this, however, was deducted 0.4 million dollars as the cost which will have to be incurred as a non-overflow dam in this portion. The direct charge for Navigation has been 5.41 million dollars. Similarly for the cost of Power House and Plant to the tune of 10.34 million dollars, a sum of 0.593 million dollars was deducted towards the cost of replacing the Power Intake Section as an ordinary non-overflow section. This theory was used in the first allocation for Wilson Dam (T.V.A.).

4. *Allocation based on alternate justifiable expenditure theory.*—This consists in dividing in proportion to the cost obtaining equal results by single purpose project. Thus in the cases of the Wilson, Wheeler and Norris Dams the actual cost was 94 million dollars. While the estimated cost of single purpose projects for the above sites would come to 160.7 million dollars made up as follows.

| | |
|--|-------------|
| Power 79.2 million dollars working a percentage of | 49.5 |
| Navigation 48.3 million dollars working a percentage of | 30.0 |
| Flood control 33.2 million dollars working a percentage of | 20.5 |
| <hr/> Total .. 160.7 | <hr/> 100.0 |

But a correction is made in the above calculations by deducting direct cost as in the original multi-purpose project from the estimated single purpose amounts.

| | Cost as single purpose project. | Direct cost. | Net | Percentage of allocation |
|------------------------|---------------------------------|--------------|-------|--------------------------|
| Power | 79.2 | 26.0 | 53.2 | 40 |
| Navigation | 48.3 | 4.4 | 43.9 | 35 |
| Flood controls | 33.2 | 2.6 | 30.6 | 25 |
| Total | 160.7 | 33.0 | 127.7 | 100 |

Thus the allocation for power, Navigation and Flood Control in T.V.A. works is 40, 35 and 25 per cent. respectively. This method is generally adopted by T.V.A.

5. *The Bye-Product Theory.*—The Bye-Product Theory holds that the Power should be charged only with direct power costs and as the none of the Joint Costs on the ground that the Joint Costs are incurred for general good and so should be paid by public revenue like other social services. This theory is too socialistic to be seriously considered in the present discussion.

APPLICATION OF THEORIES IN AMERICAN PRACTICE

The allocation made by the U.S. Bureau of Reclamation Engineers for the Missouri Projects, which are intended to develop 1.49 m.k.W., and irrigation of 4.76 m. as is given in the table below :—

| Object | Benefits | Percentage of total benefits | Annual costs | Amortization distributed | Net benefits | % | Actual Allocation | % |
|--------------------------|-----------|------------------------------|--------------|--------------------------|--------------|-------|-------------------|------|
| | M.dollars | | M. dollars | | M.dollars | | | |
| 1. Irrigation | 130 | 71.5 | 7.72+50 | 57.72 | 72.28 | 69.6 | 298 | 20.0 |
| 2. Power | 21.8 | 12.2 | 4.9+4.5 | 9.4 | 12.4 | 12.0 | 376 | 39.0 |
| 3. Flood control | 18.5 | 10.4 | 3.5 | 3.5 | 15.0 | 14.4 | 454 | 31.0 |
| 4. Navigation | 4.65 | 2.6 | 1.0 | 1.0 | 3.65 | 3.5 | 132 | 8.9 |
| 5. Municipal Water Works | 0.50 | 0.3 | Nil | Nil | 0.50 | 0.5 | 20 | 1.1 |
| Total | 175.45 | 100.0 | .. | 71.62 | 103.83 | 100.0 | 1480 | 100 |

The final allocation seems to be based not on benefits but on justifiable expenditure theory.

In case of T.V.A. it has been shown above that on the joint investments, the percentage allocation was 40, 35 and 25 for Power, Navigation and Flood control for Wilson, Wheeler and Norris Projects. The cost of the

Pickwick Landing Dam was also allocated in about the same proportion 30, 36 and 24 for Joint investments. These percentages when the total investments is considered, average to in these four dams 52.8, 29.7 and 17.5.

Considering the seven T.V.A. dams, the total estimated expenditure for the dams is 500 million dollars of which Power was assigned 310, Navigation 90 and Flood control 100 represent 62 per cent., 18 per cent. and 20 per cent. These percentages represent the allocation on the total investments. Considerable opposition was voiced by Mr. Mead and others in the valuation of Flood Control as 100 million dollars instead of a lower figure of 36 million dollars which was the figure suggested by them.

The total flood storage for T.V.A. is 10.67 million acre feet as against the total storage of 21.98 million acre feet in the whole river. This represents 48.5 per cent. and if the allocation of this as based on Second Theory, the flood control should have amounted to 339.5 million dollars out of 700 million dollars.

In the case of Grand Coulee Dam out of a total cost on the whole system of 437 million dollars including the canals, the allocation for Power and Navigation was 215.3 million dollars and Irrigation 221.7 million dollars. The cost of the Grand Coulee Dam itself is 200 million dollars. Thus the cost of the whole river dam was practically charged to the power. This example of Grand Coulee allocation does not follow any of the theories enumerated above and exhibits how each case has to be examined with regard to its allocation. What the Bureau did in the case of Grand Coulee seems perfectly justifiable. The dam proper really serves the purpose of Power and Navigation only for water has to be pumped to a further height before water is utilised for Irrigation.

Colorado Basin—In this basin, the total cost of all the projects is estimated as 2,185 million dollars. In order to irrigate 2.6 million acres of land and produce 3.5 m kW of power, out of this amount, only 25 million dollars coming to above 1.2 per cent. as allocated to flood control and the rest distributed between Irrigation and Power. The low percentage assigned to Flood Control seems to be due to the fact that the floods in Colorado are already controlled by Boulder and Parker Dams.

In the Bonvenlie Dam across Columbia, the U.S. engineers have estimated the total expenditure of 53 million dollars as the cost and allocated 57 per cent. to Power and 43 per cent. to Navigation.

Thus the allocation of costs seems to vary widely with each particular work.

Conclusion.—From the discussions, the following conclusions may be drawn :

1. Flood Control and Navigation must be fully valued and allowed for in any allocation of a multi-purpose Project as these form appreciable portions.
2. For Indian schemes where Irrigation, Power and Flood control seem to be the main factors, a general allocation of the Joint Investment can be 40, 30 and 30 per cent.

BIBLIOGRAPHY

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- (4) T.V.A.—A study in public administration by C. Herman Pritchett.
- (5) Section 9 of the Reclamation Project Act—1939.
- (6) The Colorado River—Comprehensive Report on the development of water resources—March 1946.
- (7) Putting the Missouri to work—Bureau of Reclamation publication.
- (8) Engineering economics and Public Works—A symposium—American Society of Civil Engineers—Proceedings. February 1938 and June 1938.
- (9) The Pickwick Landing Project. Tech. Report 3. T.V.A. (Page 332).

DISCUSSION BY THE BOARD

THE SECRETARY said that there were three questions at present being discussed by the Board :—

- (1) Indirect benefits of irrigation,
- (2) Allocation of cost in multi-purpose projects,
- (3) Amalgamation of water rate and land revenue for storage irrigation.

Nos. (1) and (3) had been discussed under the Administrative agenda Under (2) there were two papers for discussion, one by Mr. Om Parkash Bhasin (U. P.) and the other by Dr. K. L. Rao.

MR. T. J. MIRCHANDANI pointed out that there was a conclusion at the end of Dr. Rao's paper which did not arise out of the thesis at all. He wanted to ask him as to how he arrived at that conclusion.

MR. S. A. GADKARY remarked that he was inclined to think that there could be no such conclusion drawn and no such percentage could be fixed except in an individual specific case. A general basis would be absolutely unworkable. So far as river valley projects were concerned, in certain cases, irrigation might assume a very big proportion while in other irrigation might be a minor show. In that case, a higher percentage would have to go to Power. So every scheme would have to be discussed with respect to the particular advantages of the scheme and any percentage would be absolutely unworkable.

DEWAN BAHADUR N. GOVINDARAJA AYYANGAR remarked that he considered that there were probably four major purposes that appeared to him to be vital. These were flood control irrigation, power and navigation. He did not think that one need bestow undue importance on other purposes. In the present crisis, food was probably the most important thing that required emphasis. He considered that power was the twin brother of food because power helped to lift water and thereby increase agricultural production. Of course, flood control was important. Navigation could be important in India, only when it could contact the raw production centres with the industrial centres and that would come only when industries were fully developed. He therefore came to the conclusion that importance could only be given to food, power and flood control. Now so far as food was concerned, rice would take nearly 3 or 4 times the water that wheat required. Rice in South India required a number of wettings, and the requirements of water would be 50 in. to 54 in. per acre in addition to the rainfall. The difficulty in Madras was that they could not raise the water rates nor could they levy heavier inclusion charges or betterment fees. He therefore opined that there was no chance of their projects producing revenue and giving a large margin over the borrowing rate of interest. Acre for acre rice projects have to handle three times the water that wheat and other such crops require.

SHRI C. L. HANDA referred to administrative difficulties.

It was decided that the subject may remain under examination and for the time being each project should be considered on its own merits.

3F. Legal Aspects of Projects

PRELIMINARY NOTE

The following resolution was passed at the 1946 Board meeting :—

“ 1. Resolved that the Board welcomes the proposal to include in the Union Subjects “ Communications ” which term must necessarily include the waterways of the country.

The term ‘ waterways ’ comprises any stream or channel which is navigable, can be made navigable and the water running in and draining into that stream or channel.

“ 2. Resolved that the Board recommends that statutory provisions be made and necessary legislation enacted to provide for the following :

- (i) To set up, when necessary, in cases where more than one Province or state are concerned, catchment and or sub-catchment Boards to formulate proposals and, if required, to execute works, for the control, conservation and regulation of river supplies for the benefit of all parties concerned.
- (ii) To set up a statutory technical organisation which will co-ordinate and regulate the activities of the catchment and or sub-catchment boards ; this organisation to have powers to obtain and collect information relating to all waterways in India.
- (iii) To set up a statutory All India Arbitration Board to decide all issues concerning waterways that are referred to them for decision.
- (iv) To ensure that the Provinces and States shall be free to enact legislation in respect of generation and distribution of power and water within their respective territorial jurisdictions, and to develop the resources of waterways which are entirely within their territorial boundaries or have been allocated to them for such purpose.

“ 3. Resolved further that the Board recommends that the proposed Electricity Bill (1946) be modified so as to conform to the provisions stated in paragraph 2.”

This resolution was communicated to the Government of India, and subsequently a Popular Series Leaflet No. 4, Waterways of India—their problems and the administrative machinery required for obtaining maximum benefits—was issued in May 1947 and circulated to members of all the legislative bodies in India.

At the 1947 meeting of the Board it was resolved “ that the Board accepts the desirability for an early legislation on the lines proposed (to urge on the Government of India the importance and necessity of legislation to control and assist in the proper development and

conservation of the water resources of the country and the desirability of an early enactment of a comprehensive waterways, including ground water, irrigation and navigation Act), but would like to take further and vigorous action in this connection after the Constituent Assembly has adopted the recommendations of the Union Power Committee."

In the Draft Constitution of India prepared by the Constituent Assembly and published in March 1948, it was found that the provisions made in Article 239-242 which deal with "Interference with water supplies" fell short of the terms of the recommendations previously made by the Board. Accordingly the Secretary of the Board as directed by the Board addressed the Ministry of Works, Mines and Power pointing out the shortcomings together with suggestions for improvements and requested for bringing them to the notice of the Constituent Assembly.

In March this year the Ministry of Works, Mines and Power requested the Secretary to let them have the broad outlines of the Central Board of Irrigation's proposals in connection with the Waterways Bill. The following reply has been sent by the Secretary :—

"The proposed Waterways Bill is going to be a comprehensive and involved piece of legislation. The problem has been examined in some detail in the Central Board of Irrigation Popular Series Leaflet No. 4, entitled "Waterways of India".

"The preparation of the Bill involves considerable time and labour and unless a special officer is deputed for the purpose it is not possible for the Board to undertake to draft the Bill. It is understood, however, that the Central Waterpower, Irrigation and Navigation Commission has entrusted this work to one of its officers. There appears, therefore, no necessity of a duplication of this work in the Board's office but the Board would no doubt like to be consulted as soon as a tentative draft is ready.

"Without attempting to go into the details of the proposed legislation, it appears desirable, at this stage, to define the objectives of the proposed legislation. These should be :

- (a) To attain the optimum utilization of the natural resources of water from stream flow, from storage of flood waters, and from the sub-soil reservoir for purposes of irrigation and hydro-electric development, and to devise suitable administrative machinery for the purpose, in particular for the allocation of supplies from different resources to lands awaiting development in different States of the Union of India ; and
- (b) to lay down the law and suitable administrative and executive machinery for flood control measures, for navigation, for the prevention of pollution of natural waters, and for the development of fish life in natural and artificial water-courses.

Attention is invited to paragraphs 7—10 of the Leaflet No. 4, referred to above."

The Board also considered the possibility and advisability of a statutory provision that where perennial irrigation is provided by storage and that storage has been created by submerging certain areas, owners of land permanently benefited by the perennial irrigation should be required to give up some percentage of their land so as to provide an area out of which compensation, in the form of land, for those submerged, can be provided. After discussion the following resolution was passed by the Board:—

“(i) Resolved that the Board is of the considered opinion that in dealing with persons whose lands will be submerged under storage reservoirs or will go under canals and allied works, it is desirable to compensate them as far as possible by giving them land for land.

“(ii) that for resettlement of dispossessed land-holders, land should be obtained, in order, from the following sources—

(a) Government land, if any,

(b) A proportion of private lands, benefited by a project subject to the condition that portion left with an owner is not less than an economic holding:

“(iii) that acquisition of land for purposes of resettlement of dispossessed land-holders should be considered under the Land Acquisition Act, as acquisitioned for a public purpose;

“(iv) resolved further that in the interest of the large projects now under consideration, the Government of India be requested to ask Provinces and States concerned to undertake early legislation to implement the above recommendations.”

The above proposals are now under consideration with the Government of India.

THE YEAR'S WORKS DISCUSSION BY THE BOARD

The subject was discussed under the Administrative Agenda.

4F. Anti-Malarial Aspects of Projects

PRELIMINARY NOTE

This subject was introduced for the first time in 1946 in view of the fact that big irrigation projects were going to be taken up in India and the question of malarial incidence was of utmost importance in connection with them. The following resolution was passed by the Board at its 1947 meeting :—

“ Resolved that the Board is of the considered opinion that in all irrigation projects it should be the irrigation engineer's endeavour to have malaria officers associated with the project right from the investigation stage and to maintain them (Malaria Officers) throughout the construction period, in sufficient numbers. The Board is also of the opinion that as far as possible, there should be unitary control in the project area whereas the malaria officers should receive technical guidance from their own technical superiors; for all administration and executive functions, they should be under the engineer incharge of the project. Close association should be maintained between the project officers and the Malaria Institute of India. ”

In response to the resolution, the Bihar Government have intimated that the Irrigation Department is in agreement with the spirit of the resolution and they will give effect to it in their new big projects. The United Provinces Government have issued specific instructions in this respect. The Bombay Government have intimated that the following procedure is in vogue in the Public Works Department, Bombay for co-ordinating the activities of the Public Health Departments in irrigation projects :—

(1) In the case of minor irrigation projects the collectors should consult the local Public Health Officer (*i.e.* the District Health Officer if such officer is appointed in the district of the Assistant Director of Public Health) whether the proposed project is free from objection from the public health point of view. In case it is feared that malaria is likely to result, the advice of the Assistant Director of Public Health in-charge Malariology should be sought through the Director of Public Health.

(2) In case of irrigation projects contemplated by the Public Works Department, after a project is conceived and its broad outlines are determined, the Executive Engineer of the Division concerned should furnish the Assistant Director of Public Health in-charge Malariology with the following information :—

- (i) An index plan showing the head works—in the case of a reservoir this plan should show area submerged and contours of the highest and the lowest supply levels. It should also show towns and villages situated within a distance of five miles from the full supply level contour.

- (ii) A plan showing the alignment of the canals and the commanded area—the water courses need not be shown but the natural as well as artificial drainage channels, if proposed, should be shown. The plan should also show villages and towns within the commanded area.
- (iii) The types of crops intended to be raised on the canals and their approximate acreages.
- (iv) On receipt of the information mentioned above, the Assistant Director of Public Health should examine the project from the public health point of view and communicate his remarks and suggestions to the Executive Engineer giving at the same time, if possible, an estimate of the capital and recurring expenditure required to be carried out to comply with his suggestions so that this may be included in the main estimate of the project.

Replies from others are awaited.

Recent Literature

1. Hall, T.F., Penfound W.T. and Hess A.D. Water level relationships of plants in the Tennessee Valley with particular reference to Malaria Control—*Journal of the Tennessee Academy of Science*, Vol. 21, No. 1, January 1946.

THE YEAR'S WORK

DISCUSSION BY THE RESEARCH COMMITTEE

THE SECRETARY said that no contributions had been received under this subject, but that Dr. Puri of the Malaria Institute might like to say something.

DR. PURI referred to the Board's resolution passed on the subject and stressed the need for a very close liaison between the officers in-charge of projects and the Malaria Institute. He said that in a few cases the advice of the local staff of the Institute had been ignored by officers in-charge of works without reference to the Institute.

DISCUSSION BY THE BOARD

THE SECRETARY referred to the resolution passed by the Board last year and action taken by various administrations as intimated upto the Research Committee meeting. Subsequently Gwalior had intimated that resolution of the Board had been noted for future works. East Punjab had issued instruction on the subject for Nangal and Bhakra Dam Projects which had been published in the October 1948 issue of the Central Board of Irrigation Journal.

COLOEL JASWANT SINGH said that there had been no momentous change since he addressed the Board last year. He had recently seen the major anti-malarial Works in America particularly those of the T. V. A. It appeared to him as if they had solved their malaria problem finally. They had no malaria problem now but to obviate the malaria incidence they were still spending half a million dollars every year. It was important for the Board to ensure that no

malariogenic conditions were left after the projects were completed. He was happy to note a reference in the October Number of the Central Board of Irrigation Journal regarding the requirements of drainage in all the borrow-pits, and he had no doubt that those in-charge of the projects would bear this in mind. They had to ensure that mosquito breeding places were not left behind if they had to overcome the greatest hazards in this country—that is the loss of life and suffering from malaria. Referring to the observations made in the last para on page 320 of the October issue of the Central Board of Irrigation Journal, namely “ all the mosquito breeding places should be sprayed once a fortnight with 5 percent. D. D. T. in malariol, which is sprayed over the water surface to kill mosquito, s 80 ounces per acre and this application must be repeated more often if there is heavy rainfall soon after spraying ”. He suggested that D. D. T. should be applied to the dwelling of the people and not to open water surfaces. In that case D. D. T. would not only kill mosquitoes but give other collateral benefits such as killing flies and other insects, *etc.*

He suggested that wherever D. D. T. was used, it should be chiefly in its residual effect. Continuing he said that if D. D.,T. was sprayed on mosquito breeding places it might get washed away during frequent showers. On the other hand, if it was applied on surfaces (in dwellings where adult mosquitoes may rest) as an emulsion or in oil, its insecticidal effect would last for 6 weeks to 3 months under suitable conditions of humidity and temperature. Even if the effect lasted for 6 weeks he thought it would be more economical than pouring it oftener on the breeding places.

He said, he would be glad to show the Malaria Institute to any Member of the Board and discuss with him his individual problems either personally or by correspondence.

He then described some of the measures taken by the TVA for malaria control.

THE PRESIDENT then thanked Col. Jaswant Singh for his interesting talk.

Shri N. GOVINDARAJA AYYANGAR said that on the Tungabhadra Project they had practically eliminated malaria. He endorsed that D. D. T. left its effect for six weeks though he believed that whenever officers occupied their buildings or inspection bungalows the Health Officer sent in D. D. T. every fifth or sixth day in order to keep out all the flies and mosquitoes.

5F. Miscellaneous

PRELIMINARY NOTE

The following item was presented for discussion at the 1947 Research Committee Meeting :—

“ A method of coordination for the full utilization of water resources for irrigation in the United Provinces ” by J. W. Russell.

The discussion on this item has not taken place so far. The Board at its 1947 meeting passed the following resolution :—

“ Resolved that the Board again invites the attention of all administrations to the necessity of undertaking at an early date surveys of the potential water resources of all catchments for purposes of irrigation and hydro-electric development and in this connection commends the action taken by the Government of Bombay to appoint a technical committee and an officer on special duty for the purpose. The Board recommends further that to secure effective coordination of such activities in all Provinces and States the Director of Hydrology in Central Waterways, Irrigation and Navigation Commission, should be a member of local committee entrusted with this task. The Board also considers it desirable that the local representative of the Meteorological Department should also be a member of such committees.”

It was also considered desirable that the Board might recommend to likely committees to publish an Annual Water Year Book, and a sub-committee comprising the following officers was formed to decide upon the contents and form of that Water Year Book. :—

- (1) One of the Members of the Central Waterpower, Irrigation and Navigation Commission as convener,
- (2) Rao Bahadur Shri A. R. Venkatacharya,
- (3) Rai Bahadur Shri Kanwar Sain,
- (4) Dr. N. K. Bose,
- (5) Shri S. L. Malhotra,
- (6) Shri N. D. Gulhati, Secretary, Central Board of Irrigation,
- (7) Director of Hydrology, Central Waterpower, Irrigation and Navigation Commission as Secretary of the Sub-Committee.

A meeting of the Sub-Committee to draw up the outlines for the Year Book was held at Roorkee during the Informal Meeting of the Research Committee under the chairmanship of Mr. Mazumdar, Member, Irrigation, Central Waterpower, Irrigation and Navigation Commission.

The Government of Central Provinces and Berar have informed that the staff position of the Public Works Department there is so precarious that the Provincial Government can literally not spare the services of an officer of the seniority and competency required to undertake the work of hydrographic survey of the Province. They added that as the Central Waterpower, Irrigation and Navigation Commission were opening three divisions in that Province for the investigation of water supply resources, the Provincial Government felt that the Commission could easily combine this hydrographic survey as an integral part of their work of investigation into water supply resources. A request was accordingly made by the Government to the Chairman, Central Waterpower, Irrigation and Navigation Commission, which has been accepted.

The Government of Bombay said that the question of co-opting the local representatives of the Meteorological and Geological Departments was already under the consideration of their department of irrigation and those departments were being addressed to name their officers stationed in that Province who could be invited to attend the Technical Committee appointed in connection with the proposed Water Board for the Province of Bombay, and that the Director's consent is being obtained to include the Director of Hydrology in the Central Waterpower, Irrigation and Navigation Commission as a member of the Technical Committee in question. This has also been agreed to by the Chairman, Central Waterpower, Irrigation and Navigation Commission.

The Chief Engineer, East Punjab has written to say that all the items taken up by the Bombay Government for investigations are either already being done by that department or will soon be taken up. The publication of the Water Year Book too will soon be taken up by them as far as the East Punjab is concerned.

The Chief Engineer, Bihar intimates that proposal for establishing a Water Board in his Province were afoot and many surveys will be carried as soon as the Board is constituted.

Recent Literature

1. Straus, Michael W., Commissioner of Reclamation, United States of America.—Global Hydro-economics. A report on twentyone nations. International Commission on Large Dams, Third Congress, Stockholm, 1948.C4.

THE YEAR'S WORK

There was only one contribution during the year *viz.* :—

(1) " Short term aspects of the optimum use of river supplies for irrigation and hydro power " by Shri C. L. Handa, R.B., I.S.E., M.I.E. (India) and Shri Barkat Ram.

(1) SHORT TERM ASPECTS

OF THE

OPTIMUM USE OF RIVER SUPPLIES FOR IRRIGATION AND HYDRO POWER

by

Shri C. L. Handa, I.S.E. M.I.E.,

and

Shri Barkat Ram

INTRODUCTION

The dawn of independence in the Indian sub-continent has been accompanied by a great and immediate demand for the development of the maximum resources from rivers, with which nature has endowed this country in the most bountiful degree. Scarcely a week passes, when the description of the potentiality of some hydro-electric project coupled with irrigation and flood control benefits, does not feature prominently in the newspapers all over the country. This is a most welcome situation, because the talk of raising the low standards of the *common man*, is without meaning, unless there is an abundant production of food, and unless there is cheap hydro power available for small and large scale industries. The ideal of developing our river valley resources to their maximum potentiality, is all very well, but attention needs to be focussed more on the speedy achievement of even a fraction of that ideal, rather than have to wait for that ideal (howsoever perfect and pleasant the final picture may be) for an inordinately long time, for which the *common man* will have much less patience than those engineers, who are so deeply absorbed in their own paper plans—examining alternative after alternative—in order to get the maximum amount of irrigation and the maximum amount of hydro power out of every ounce of water and every foot of head. The primary value to India at this time, does not lie in the fact that she is the happy country, in which the maximum potential of power is lying stored on top of the 29,000 feet high Himalayas (of which even the U.S.A. feel jealous) but the fact that so far we have not even tapped 5 per cent. of the economically justifiable water power potential of the country. The comparative figures for per capita consumption

of electricity relatively to other countries are so ridiculously low that they can bear being quoted even in this learned gathering. These are—

| Name of country | | | | | | | Per Capita consumption of electricity (k.W. hours) |
|-----------------|----|----|----|----|----|----|---|
| India | .. | .. | .. | .. | .. | .. | 9.2 |
| England | .. | .. | .. | .. | .. | .. | 906 |
| U.S.A. | .. | .. | .. | .. | .. | .. | 1470 |
| Canada | .. | .. | .. | .. | .. | .. | 3510 |
| Switzerland | .. | .. | .. | .. | .. | .. | 1944 |
| Norway | .. | .. | .. | .. | .. | .. | 3090 |
| Sweden | .. | .. | .. | .. | .. | .. | 2000 |

This will show that a large gap has to be covered by India before she can assume her rightful place in the present scale of civilisation. How to cover this gap in such a way that the principal emphasis is on a co-ordinated, progressive and rapid development, is the objective with which this paper is being presented. Special reference has been made in particular to the Bhakra Nangal development project in the East Punjab, with which the authors can claim some familiarity extending over a period of four years first hand association.

OPTIMUM USE OF AVAILABLE RIVER SUPPLIES

A great number of engineering and economic studies have to be made for each river valley scheme in order to ascertain the water resources, economical storage, proper height of dam, capacity of irrigation canals, and the most economical generation for which the power stations should be equipped. Each multi-purpose project has its own particular features, which determine the above aspects quantitatively. There is, however, one factor common to all river projects and that is related to the practicability of splitting up the project into various stages, which make it possible that an advanced use may be made of each stage, as it gets ready. To illustrate this point, the following stages may be enumerated in the case of the Bhakra Nangal development :—

- (a) Surplus summer supplies of the river Sutlej can be utilised *via* the Nangal Canal, into the Bhakra Canals for providing four months irrigation facilities to the famine areas. This can be done in advance of the completion of the Bhakra Dam. The amount of these supplies can theoretically be equal to the full supply capacity of the Nangal Canal and Bhakra Canal system, but allowing for the gradual development in the beginning, one can safely take these supplies to be half their all supply capacity.

- (b) Winter supplies of the river Sutlej to be utilised for generation of hydro power through the power houses on the Nangal Canal. These power houses have a drop of about 1000 feet at each power house, and an average winter discharge of 3600 cusecs would be available. To start with one power house could be completed and equipped for generation, and the other power house could follow soon after.
- (c) The firm hydro power, would be based on (b) above, and secondary power, if required could be got out of (a).
- (d) A gradual increase could be made in (b) above, with such additional supplies as can be progressively got from the dam, not excluding the tail end of the period of construction.
- (e) Stage stepping up of generation capacity to be made according to the expected load growth.
- (f) The frame work of the project to be designed for maximum development of irrigation and hydro power, but only such portion to be filled in progressively, as are justified by actual need and rate of development. This implies that the fullest use of resources would be eventually possible but the time factor would receive primary consideration. Such portions of the project as can be completed with available resources, plus a minimum of imported resources would be completed so that they can be brought into the service of the people. Meanwhile work would proceed continuously and progressively to accomplish the totality of the various provisions in the project which will be kept suitably flexible, so as to permit the interlinking of the various stages with as little wasteful modification, of previous works as possible.

Happily for the Bhakra Nangal development, the above stages of the work are susceptible of broad demarcation. The areas to be developed are thirsting for water. Inhabitants for these areas are available in plenty, out of the vast population that has been dislocated from the West Punjab. Four months irrigation, in advance of the perennial supply that will follow a few years later, will be most welcome for raising fodder, *jawar*, *bajra* and possibly providing (in certain favourable years) an advance irrigation to be made use of for wheat sowing. The introduction of summer irrigation within a period of about three years will hold out the most attractive promise to the people, who will enthusiastically co-operate in the construction of the Bhakra Nangal Canals. Regarding hydro power, the energising of the first power station, will bring in a firm power of about 25,000 kW. This will very much suit the creation and development of the electrical market. Shortly afterwards, much more power would be made available. The planning of cottage and large industries could proceed on the basis of adequate power on the completion of the Bhakra Dam. Meanwhile the construction of factories could be planned by industrialists, helped by the Government, on the basis of their maximum eventual needs, but on the assured prospect of their immediate but fractional needs, being met within about three years' time. The idea of stage development, accompanied by the certainty of rapid completion of the earlier stages would appeal to the public at large, much more than the more distant prospect of a bigger achievement. At

this psychological moment in the evolution of the country it is not the ideal perfection or the overall colossal magnitude of any productive engineering undertaking, but the speed and assured promise of earlier realisation, that will evoke an enthusiastic response from the people.

ECONOMIC JUSTIFICATION OF RIVER VALLEY DEVELOPMENT PROJECTS IN THE FINAL STAGE

It goes without saying that the financial soundness of River Valley Projects must be a matter of utmost concern with the Governments who sponsor these projects for the simple reason that these undertakings involve very huge sums of money, and it would be a very great strain on the finances of a Province, if the net revenues from the project were not to cover the interest, depreciation and operation charges within a reasonable period, which is customarily taken as ten years after the completion of the project. In view of the fact that the introduction of irrigation must obviously very much enhance the productive capacity of un-irrigated land, and the fact that the facilities due to availability of electric power, make life so much more pleasant and worth living, it would be perfectly justifiable to assume, that the completion of the project would be accompanied by a material rise in the price of agricultural land and urban properties. Those who benefit, cannot therefore, with any justification, grudge the payment of a betterment tax commensurate with the advantage which Government bring to their very doorstep. In the case of projects in the State of Mysore, the rate of contribution per acre has ranged from Rs. 100 to Rs. 150 spread over a period of 10 or 12 years. This contribution from the people would be a co-operative step which can set off an appreciable bit of the capital expenditure and recurring charges.

The rates to be charged for the supply of irrigation facilities should be related to the yield from crops and the increased cost of such yield. With wheat selling at Rs. 20/- per maund, there is no justification in fixing the water-rate at rupees four per acre, which rate was reasonable when the rate of wheat was rupees five per maund. The rate now need not be four times—as the present high food prices, let us hope, are transitory—and it is unlikely that today's cost of living may subsist without upheaval in the country. Similarly the bias in favour of a three pie or four pie rate per unit of electric power, delivered at load centres must be appreciably influenced by the high cost of materials, labour and electrical equipment. With present day abnormal costs, we should be happy if our hydro projects can supply power at five pies or six pies per unit, delivered at load centres. It is well to remember that the present day cost of thermal power inclusive of transmission and distribution charges is of the order of 12 to 15 pies per unit. And then our coal and oil resources are by no means adequate, and there is an overriding need for conservation.

The above background is necessary for determining the financial yardstick, which will measure the economic justification of a river-valley project. In general it may be stated that any project holding out a promise of transforming huge un-irrigated areas into irrigation colonies, and of supplying electric power where none exists heretofore, will be productive if the direct and indirect

benefits are taken into account. Taking only the direct benefits into view such projects will have their chances of productivity improved, provided Governmental policy is suitably orientated so as to create a favourable field and psychology for rapid development. This implies a lot of educative publicity, so that the people may have an intelligent picture of the development and they should be able to share with the Government, the sense of expectation, exaltation and also sacrifices which every one must make to expedite the accomplishment.

A number of studies have to be made to determine the over-all cost of a multiple-purpose project. But such studies are liable to get out of date very soon under the continually fluctuating rates of materials and labour—due to the unusual political and economic conditions of these post-war and post-partition days. Still engineers cannot afford to relax in their watch of public expenditures, and the effort has to be all the greater when we have to pay more and more for less and less value.

RELATIVE COSTS OF PRINCIPAL FEATURES OF IRRIGATION-CUM-POWER PROJECTS

The details in respect of costs on various features will necessarily vary for each specific project. All the same, when the main items are expressed as a percentage of the total cost of the undertaking, the results have an important general value. With this in view, we give below the approximate costs of the Bhakra Nangal Development, in respect of the main units of the project, expressed as a percentage of total cost. Even if the absolute figures of cost are different from those assumed in our study, due to changes in rates or modifications of certain assumptions, the over-all ratios are less liable to such difference.

Relative costs of various units of the Bhakra Nangal Project expressed as a percentage of the total cost.

I—Bhakra Dam (500 feet high)

(a) Civil Works

| | | |
|--|-----|-------------------------------------|
| 1. Dam and Foundations | 2.8 | Per cent. of total cost of project. |
| 2. Diversion Works | 2.2 | .. |
| 3. Irrigation Outlets.. .. . | 0.6 | .. |
| 4. Spillways | 1.1 | .. |
| 5. Buildings | 2.2 | .. |
| 6. Railways and Communications | 1.5 | .. |
| 7. Special Tools and Plant | 2.2 | .. |
| 8. Nangal Barrage | 2.0 | .. |
| 9. Establishment | 3.4 | .. |
| Total .. | 25 | .. |

II—Nangal and Bhakra Canal Systems

| | | | | | | |
|------------------------------------|----|----|----|----|-------|-------------------------------------|
| 1. Earthwork Canals | .. | .. | .. | .. | 8.6 | per cent. of total cost of project. |
| 2. Earthwork distributaries | .. | .. | .. | .. | 4.3 | .. |
| 3. Lining Nangal and Bhakra Canals | .. | .. | .. | .. | 10.8 | .. |
| 4. Cross Drainage Works | .. | .. | .. | .. | 3.2 | .. |
| 5. Buildings | .. | .. | .. | .. | 1.1 | .. |
| 6. Special Tools and Plant | .. | .. | .. | .. | 1.0 | .. |
| 7. Establishment | .. | .. | .. | .. | 1.0 | .. |
| | | | | | | |
| | | | | | Total | 30 |

III—Electrical

| | | | | | | |
|---|----|----|----|----|-------|----|
| 1. Generating Plant Bhakra and Nangal | .. | .. | .. | .. | 16.3 | .. |
| 2. Power Houses (Civil Works) | .. | .. | .. | .. | 7.1 | .. |
| 3. Transmission and Distribution for Bhakra Nangal Grid | | | | | 21.6 | .. |
| | | | | | Total | 45 |

Grand Total .. 100 per cent.

The above figures are given by way of illustration, as their relative magnitude can provide a good guide in assessing the various items of work as to the scope that they provide for co-ordinating the construction programme under the present day limitations of shortage of essential materials like cement, steel and coal. It will also be obvious as to how far we have unavoidably to depend on foreign help and how far we can proceed off our own bat without having to depend on dollars or imported know-how.

Further studies have also been made to calculate the financial returns from these projects. But the quantitative results of these studies are entirely dependent on certain fundamental assumptions. It is considered more important to state the nature of these assumptions, than to quote the result of a particular set of studies.

THE FUNDAMENTAL FACTORS AFFECTING THE RETURN AND THE ECONOMIC JUSTIFICATION ARE :

1. Capital Outlay by years taking into account the best co-ordination for the various stages
2. Earliest possible accomplishment of the various stages so that they can bring fractional benefits into the service of the people and also earn revenue
3. Rate of growth of irrigation—both flow and from tubewells
4. Rate of growth of electrical load and the gradual creation of a market for the maximum generating capacity. The generating capacity would of course be stepped up gradually by putting in additional units when the load conditions so demand.

It can safely be stated that provided the policy of stage development enunciated in the earlier part of this paper, is followed, and the people get to use the fractional irrigation and power facilities within a reasonable time limit, which does not frustrate their short term hopes, then the development would receive an assured momentum as it goes on from stage to stage, and would eventually be financially remunerative. Assuming that the policy of industrialization succeeds, and the generating capacity is absorbed in a period of twenty five years after completion, the gross revenue from irrigation as compared with sale of power is estimated to vary as 1 : 3 in the 10th year after completion of projects. The ratio on full development of electric load upto generating capacity, as between irrigation and power income is estimated as 1 : 4. The development of irrigation is expected to take only half the time as compared with the full development of electric load. In the above computation, the rate of power has been taken as 5½ pies per unit and the gross revenue per acre irrigated at rupees six per annum.

HOW THE ENGINEER CAN HELP EARLY DEVELOPMENT

The onus of the technical leadership of river valley projects all over the country lies on the engineers. They have to be realists and they have to make the best use of available resources in order to complete such stages of the big undertakings as will provide to the people a practical proof that bigger benefits are on the way. The problems will vary from project to project and also with the occasion. The achievement of the objective, particularly in its short range aspect, demands, that investigations, research and collaboration should proceed unceasingly in order to expedite the programmes. The field is as vast as we engineers, like to make it. A few instances, elementary yet important, are mentioned :—

1. *Materials*

- (a) For temporary structures needed for the duration of the project, *e.g.* temporary buildings *etc.*—we would not at all hesitate to use sun dried bricks, timber, thatch roofs and other locally available materials, according to local conditions and usage.
- (b) Use of indigenous limes (*kankar* lime *etc.*) for buildings, canal linings *etc.* should be investigated and encouraged.

2. *Planning and Designs*

- (a) *Subsidiary Works.*—These should keep in view the fact that maximum use is made of available materials. Also that elaboration and perfection are laudable objects no doubt, but when they are got at the price of too much delay or too much setting back of the principal objective (making a dam or any other integral part of the undertaking), then we are paying too much. Every thing has to be subordinated to the early bringing in of results *e.g.* so much more food produced, so much more cottage and big industries started.
- (b) *Main Structures* *e.g.*, *The Dam or the Barrages* *etc.*—Here no risk can be taken. Every bag of cement and every ton of steel saved for this purpose, is economy in the right direction.

WHAT GOVERNMENT CAN DO

The Government have to recognize that construction of multi-purpose projects—involving high concrete dams, or lined canals of ten thousand cusecs or over capacity, are very large jobs. They can only be accomplished within the desirable time limits, if the engineers in-charge can have the full freedom of initiative, within agreed financial limits. The day to-day decisions of technical and administrative matters concerning the projects, should best be completely delegated to the men on the spot, who alone are in the best position to comprehend and overcome the forces of nature against which they have to contend in order to build structures which have to become monuments of the age. Too much red-tape, damps the spirit and initiative of workers in the field, whose enthusiasm has to be kept buoyed up by the delegation of confidence and powers which are absolutely necessary for the efficient and economical execution of complicated jobs.

Besides this, the Government can lend immense help to the organizations in-charge of the construction by establishing public relation agencies, who can interpret fractional data and progress to the public, so that there may be an overall effort for the achievement of the objective—which is so broad based that it effects government and the people alike.

NEED FOR FURTHER RESEARCH AND CO-ORDINATION

The subject matter of this paper is not a new finding, nor does it come out of a laboratory like that of hydraulics or soil mechanics. It is all the same of immediate importance and can bear repetition and emphasis. An urgent message confronts the engineers and research workers who are engaged in the planning and construction of multipurpose projects. The country looks forward to its engineering and research forces more than at any time before, for the quickest building up of its strength by development of river resources. The short term angle has such special psychological and economic significance at this critical time that if we falter in this, we may fail completely. Let us therefore, not rest content, only with the existence of tremendous long range potentialities. We have to put our heads together for evolving a technique of quick accomplishment in the face of difficulties, of which we engineers have to be more conscious, than the layman, who is watching us with suspense and expectation.

DISCUSSION BY THE RESEARCH COMMITTEE

Introducing the paper, SHRI HANDA said that he had tried to indicate in it the urgent necessity of achieving quick results from the multi-purpose projects under construction in the country, and had suggested how it could be done by fractional development. He said that the country looked forward to her engineers and research officers more than at any other time in the past, for the quickest building up of her strength by development of river resources. The short term angle had such special psychological and economic significance at this

critical time that one should not rest content, only with the existence of tremendous long range potentialities. Engineers should put their heads together for evolving a technique of quick accomplishment, in the face of difficulties, of which they must be more conscious than the layman who was watching with suspense and expectation.

The difficulties in obtaining materials were very very great and these would last for a period of three to five years. Having been a witness to some of the works in the Punjab, SHRI HANDA felt that resources in machinery, in personnel and in materials were now quantitatively fairly considerably more than when the Punjab built Trimmu or Kalabagh. The need of the moment was, however, that work should be sectionalized and divided in portions as illustrated in the paper. In arid districts, there was a definite need for a four a five months summer irrigation. Similarly, the pre-storage water supply could be used in power houses. He instanced the Ross Dam which was built in three successive stages and hydro generation was started after the first stage. It was most important, he said that the first stage materialised within a specified time and as quickly as possible. A certain amount of modification of major designs may be necessary. The cost that would be incurred for such modification would be small. The idea of the stage development, accompanied by the certainty of rapid completion of the earlier stages would appeal to the public at large, much more than the more distant prospect of a bigger achievement. The introduction of summer irrigation within a period of about three years would hold out a most attractive promise to the people, who would enthusiastically cooperate in the construction of the works. Regarding hydro-power, the early energising of one power station, would very much suit the creation and development of the electrical market.

Concluding, SHRI HANDA stressed that it was vital that when engineers put up a programme to government, and take on themselves a lot of responsibility they should have adequate powers of decision. No body was really capable of discharging his responsibilities unless he had corresponding powers, corresponding capacity and corresponding delegation to discharge this responsibility.

DR. RAO then illustrated with sketches how the Ross Dam was built in three stages and how at the first stage it was productive. He also stressed the need that execution of projects should be speeded. He suggested that foreign contractors should be called in for the construction of dams.

DR. J. K. MALHOTRA said that there was a definite sense of frustration in the minds of the people of the East Punjab. They wanted more tangible results to be obtained, and also wanted to know how early and how soon they would be able to get electricity and water from the Bhakra and Nangal projects. The public frustration was primarily due to faulty publicity. People's hopes had been raised by this sort of publicity and these hopes had not materialised so far. Although the reasons behind the delay were too well known, the public was not in a mood to appreciate them. It would be much better if they were told the maximum period for the completion of these projects so that they would know where they stood.

RAI BAHADUR KANWAR SAIN said that the subject of the paper was very important. He would sum up the paper in one sentence; "Plan on a long range basis but construct on short term basis". Construction should be taken in hand only when the materials were available. In the country there were limited resources of materials and labour. Every project under construction would be subject to such restrictions which must be imported by the availability of labour and material. Each project was busy in pushing up its own projects, but essential materials of construction were not available for all items. Their sources were more or less common. Therefore, if the authorities on the top could decide what projects should be completed in the next five years with the available materials, engineers could then concentrate on these projects. If all projects were taken up together, it would not be possible to complete any of them. The speaker urged that limited resources should not be spread out on too many projects. This would only imply postponing and delaying the completion of even those projects which could be taken up at one time.

Speaking about Nangal and Bhakra Projects, RAI BAHADUR KANWAR SAIN said that originally when the Nangal Project was taken up by the Punjab Government, the greatest factor which went towards inducing the Punjab Government to sanction it, was, that water and power could be given some time in the middle of 1949. The position today, so far as one could see was that the Nangal Project could not give water and power even for and other three years or more. It was this sort of thing which really took away the confidence which the layman had in engineers. The speaker appealed to the authorities to give engineers full administrative control on the projects.

R.B. H.L. VADEHRA supported the previous speaker and said that only those projects should be undertaken which can be completed during a reasonable time. He also referred to the experience on the Western Yamuna Canal where people were happy with supplies for about three to four months.

RAI BAHADUR BIJAWAT supported the previous speaker and said that while planning should be on a long term basis, when it came to construction, engineers should promise only what could be achieved. He suggested that all resources should be pooled and distributed in such a way that provinces or areas that badly need food production should be given such resources distributed over a certain number of years. He suggested that a High Power Planning Committee be constituted which would look into the needs of the provinces and dispose of the resources at their disposal. There should be a priority list prepared by this High Power Planning Committee. Unless this was done, each scheme was being considered as an individual scheme and an over-all picture of India, was not taken into consideration.

MR. IYER (Central Electricity Commission) agreed that it was necessary to concentrate attention on such projects that could be achieved early. He said that the question of priority was a difficult task, and committees seldom produced results. He said that it was essential to distribute all technical manpower on construction with whatever material was available.

MR. MATHRANI said that programmes should be limited. He agreed that committees after committees would be waste of time. No outsider could work wonders. They must tackle their problems themselves. He cited the instance of the Damodar Valley Project, where foreign experts were not comprehending the things properly:

He opined that foreign contractors would not suit the conditions in India.

MR. R. R. HANDA said that their difficulty was that they were short of engineers all over India. They also wanted to complete quite a number of projects which gave electricity as well as extra food. If they depended only on their own engineers they might take very many more years to complete these works than if they imported engineering firms from abroad. Earlier results would result in earlier development of the country and hence earlier industrial development and rise of standard of living and prosperity etc. From economical point of view also this would be cheaper because Government of India had to spend money abroad for importing food. The earlier our Grow More Food projects were completed this use of our sterling balances abroad would be either stopped or reduced. That money could be used in other very essential works. His opinion was that on occasion like this it was not unpatriotic to employ some engineering firms from abroad in order to complete our works on the clear understandings that these firms would work only as contractors and would have no political concessions.

MR. M. L. SOOD felt that engineers were prone to under-estimate expenditure and paint unduly rosy picture of the benefits. He recommended that expenditure should not be under-estimated and revenue expected overrated.

MR. C. L. HANDA in reply said that he would confine himself to only one phase of the discussion viz the employment of foreign contractors. This matter needed very careful consideration because it was unwise to expect that all difficulties would be solved by merely employing foreign contractors. One could only learn walking by walking. Similarly difficulties in the country would only be solved if Indians tackled the job themselves. He gave an instance of certain Chinese engineers, who were visiting the U.S.A. dams at the same time as the speaker was there. This party of about six Chinese engineers was going round the works on an inspection tour. They appeared rather casual and made no efforts to study the works in detail. When asked about it, they said another party of younger engineers would come from China for that sort of thing. Then another party of 20 engineers came and they were to stay at the Bureau of Reclamation for 2 years. When they were asked, they said that they would hardly be able to get an insight into the main things during this period. Their real learning would start when they got back to their country and tackled things for themselves. Another Chinese engineer was at the T.V.A. He had been there for two years already and he intended to stay for five years more. He was making a thorough job of it and he was writing home. So, it should be borne in mind that no amount of superficial acquaintance with the job would solve the problems. One had to depend on his own initiative and had to solve his problems for himself and first hand. Hence only the minimum amount of dependence on foreign assistance should be made.

THE PRESIDENT in summing up the discussions said that the issues raised were of fundamental importance. Dealing with the question of foreign contractors, he said that while in certain specialised jobs and exceptional conditions, their employment would be permissible, the proposal of wholesale dependence on them for anything big and difficult would be suicidal. India could not afford to live on the brains and enterprise of others. They themselves had enough brains and spirit of enterprise. All that was needed was the opportunity for the exercise of these faculties for maximum creation and production effort. In the past such opportunity was generally denied to them but in the few cases when opportunities did come to them, they had discovered to their surprise and satisfaction that what outsiders had done, they could do and in a better way. Combined with their knowledge and experience they brought to bear on their task their patriotic fervour to achieve results for the nation. He quoted the example of Trimmu Barrage of the Haveli Project which was exclusively Indian manned and was completed in record time of 18 months and at a saving of over a *crore* of rupees out of the estimate of $2\frac{1}{2}$ *crores* of rupees.

THE PRESIDENT warned both engineers and administrators against undue faith in the capacity of, and continued dependence on, foreign contractors.

THE PRESIDENT warned that those who would indiscriminately call in foreign contractors, would be doing harm to the present and future generations.

Further he agreed with Dr. Malhotra that faulty publicity gave false hopes to the public.

THE PRESIDENT expressed in favour of the idea of fractional stage development.

THE PRESIDENT warned that those who would call foreign contractors to works, would be doing a harm to the present generation and to the next. He felt very strongly about it and having something to do with the policy in the Central Government, he would like to warn one and all in the Provincial Governments to be careful as to how they expressed themselves before their Chief Engineers and Ministers.

Further he agreed with Dr. Malhotra that faulty publicity gave false hopes to the public. The public would get dissatisfied if the projects did not get completed within the required time.

Regarding the fractional stage development, he said that the development was yet in preliminary stages.

DISCUSSION BY THE BOARD

THE SECRETARY said that a paper by Shri C. L. Handa was discussed at the Research Committee meeting. This paper evoked considerable interest and the consensus of opinion was that planning should be on a long term basis but to achieve immediate results construction should be on fractional development basis.

The recommendations of the Research Committee was accepted.

Section G—General

1G. River Pollution

PRELIMINARY NOTE

This subject was introduced on the agenda for the first time in 1947. There was no contribution or discussion on it.

Recent Literature

1. The Interstate Commission on the Potomac river basin, its policy and programme—Interstate Commission on the Potomac River Basin, Washington, D. C. 1947.

2. Hogo, C., Petle, A. E. J. and Collett, W. F. Prevention of water pollution by oil from engineering works—Engineering, Vol. 163, Nos. 4247-48, June 20 and 27, 1947.

THE YEAR'S WORK

There was only one contribution under this subject.

(1) Efficiency of the sedimentation tank at Bantala.

(1) EFFICIENCY OF THE SEDIMENTATION TANK AT BANTALA (1)

The sewage and storm water of Calcutta used to be thrown into the river Bidyadhari before it deteriorated. During 1937-38 a channel was constructed by the Calcutta Corporation to carry the sewage and the storm water to a distant tidal river Kulligong. It was apprehended that this raw sewage if dropped into the water of Kulligong might deteriorate that river. It was arranged that the sewage water be pumped into high level channel and passed through sedimentation tanks constructed specially for that purpose at Bantala before passing the water to the channel leading to the Kulligong. Discusses the efficiency of the sedimentation tank at Bantala.

The working of the sedimentation tank can be followed from Figure 1G.1 which is not to scale. The path of the water entering and leaving the tank through channels are shown by arrows. There are two tanks marked P and Q in the index map on either side of the channel leading into the sedimentation tanks. As the water enters, it encounters the first system of sieves on the side of a bridge which retains large sized floating and suspended matter. Two vertical doors on either side of the channel allow the water to be carried through two underground channels to the centres of the two tanks P and Q respectively. In each of the tanks the water moves to the surface at the centre and then

(1) River Research Institute, West Bengal, Annual Report, 1947, pages 167—171.

spreads out in all directions, flowing gently through two systems of sieves successively and then finally overflowing across a round wall. The suspended matter is dropped in spaces between the two sieve arrangements and between the sieve and the wall. This is collected by scrapers with a small amount of water which keeps the sediment fluid and is finally removed by pumping through the pipes to the lagoons. There are altogether four lagoons each about 500 feet \times 500 feet to arrest the suspended matter by long grasses grown in them and to absorb the small amount of water associated with the sediment.

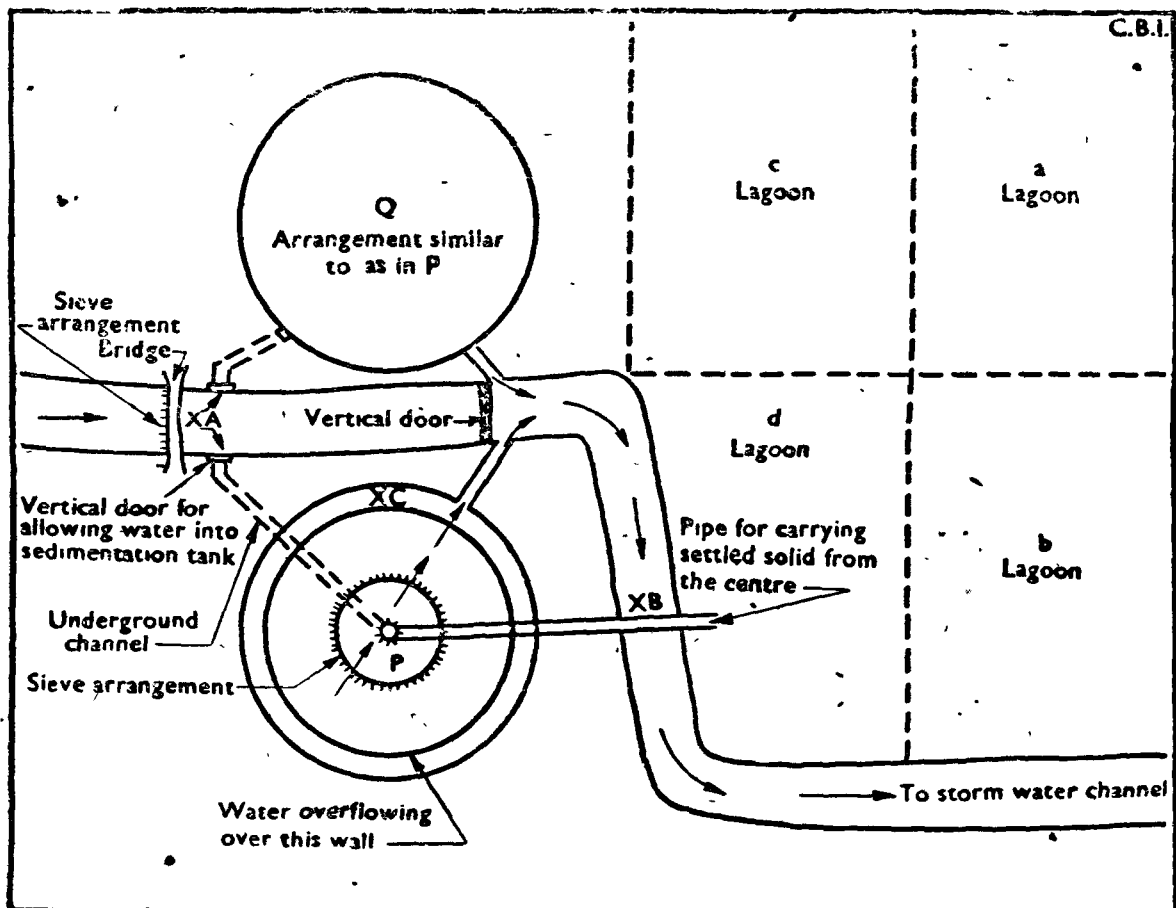


Figure 1G. 1 : Showing arrangement of sedimentation tank at Bantata.

In order to test the efficiency of the sedimentation tank the tests enumerated below were carried out on the samples collected. The samples were all collected at 0.6 depth from the channel leading into the sedimentation tank as well as from the channel, leading out from the sedimentation tank, to get comparable results. Samples were also collected from the sedimentation tank itself. A bottle sampler was used which could be dipped to any desired depth and be opened and closed from above by pulling or releasing a strings. The inlet had a depth of about 10 feet and the samples at that place were collected from a depth of six feet (the point marked A in the index map Figure 1G1). Inside the sedimentation tank only the overflowing desilted water was

Collected (point C). The depth of water in the outlet channel was about 2.5 feet and the samples were collected from a depth of 1.5 feet (point B). From each of those three points one litre of water sample was collected daily in the morning. They were then brought to the laboratory for analysis on the same date. The analysis was carried out on the following line :—

- (1) One hundred cc. of the sample previously shaken thoroughly for some time was allowed to evaporate on a weighed dry basin in an air-oven and the resulting increase in weight noted. That gave the weight of the suspended matter and soluble salt present in one hundred cc.
- (2) The sample was filtered and as before 100 cc. of the filtrate was evaporated on a weighed dry basin. The increase in weight gave the amount of salt and soluble matter together with particles not retained by Whatman filter paper No. 42, present in 100 cc.
- (3) The difference of values obtained from (1) and (2) gave the amount of suspended solid in 100 cc. of the original sample..
- (4) The product in the basin in experiment (1) was ignited to give loss on ignition, a measure of organic matter and bicarbonate present.
- (5) The *pH* was determined by Lovibond comparator.
- (6) The filtrate from experiment (2) was titrated with $N/50 H_2SO_4$ using phenolphthalin and methyl orange as indicators to detect and measure the presence of hydroxide, bicarbonate and carbonate.

The values are given in the Table 1G.I.

From a perusal of the results obtained it would be seen that the *pH* value showed that the nature of the water was alkaline. With very few exceptions the samples did not give colouration with phenolphthalin but they coloured methyl orange requiring some amount of $N/50$ acid to neutralise, thereby indicating absence of hydroxide and carbonate. The alkalinity was thus mainly due to presence of bicarbonate.

The effect after passing through the sedimentation tank on the total solid content, soluble salt content and the organic matter (loss on ignition) was statistically examined. The difference in each of those characteristics between the three kinds of samples was tested by means of "Student's 't' where

$$t = \frac{\text{difference between the means of the two samples}}{\text{standard error of the difference}}$$

Most of these differences with regard to the abovementioned characteristic were found to be not significant on the 5 per cent. level. What is meant by this is that the chance of getting the value of 't' higher than the observed value is greater than five per cent. Again when that difference is said to be significant on the five per cent. level it is meant that the observed value of 't' (which is a sort of measure of the difference) is large enough and the chance of exceeding that in a random sample is very small (less than 5 per cent.) so that, that difference could not be explained away as sampling fluctuation.

TABLE 1 G-I

| Date 1947 | Point of collection —A— Entrance B—Exit C—Tank | Total solid and soluble salt in 100 c.c. | Soluble salt and any fine particle not retain- ed by W. filter pa- per No. 42 in 100 c.c. | Total suspend- ed solid in 100 c.c. | Loss on ignition in 100 c.c. | pH | Carbo- nate parts per million | Bi-car- bonate parts per million |
|--------------|---|--|--|---|---------------------------------------|-----|---|--|
| January— | | | | | | | | |
| 10 | A | 0.0543 | 0.0208 | 0.0335 | 0.0077 | 8.4 | 0 | 390.4 |
| | B | 0.0499 | 0.0196 | 0.0303 | 0.0110 | 8.4 | 0 | 390.4 |
| | C | 0.0470 | 0.0190 | 0.0280 | 0.0070 | 8.4 | 0 | 390.4 |
| 11 | A | 0.0416 | 0.0262 | 0.0154 | 0.0111 | 8.0 | 0 | 390.4 |
| | B | 0.0354 | 0.0288 | 0.0066 | 0.0120 | 8.2 | 9 | 383.08 |
| | C | 0.0448 | 0.0290 | 0.0158 | 0.0094 | 8.2 | 0 | 385.54 |
| 12 | A | 0.0499 | 0.0196 | 0.0304 | 0.0083 | 8.4 | 0 | 387.96 |
| | B | 0.0480 | 0.0202 | 0.0278 | 0.0152 | 8.4 | 0 | 390.4 |
| | C | 0.0472 | 0.0202 | 0.0270 | 0.0080 | 8.4 | 0 | 387.96 |
| 13 | A | 0.0509 | .. | .. | 0.0079 | 8.4 | 0 | 390.4 |
| | B | 0.0536 | 0.0172 | 0.0364 | 0.0054 | 8.4 | 0 | 385.54 |
| | C | 0.0512 | 0.0231 | 0.0281 | 0.0052 | 8.4 | 0 | 387.96 |
| 14 | A | 0.0540 | 0.0238 | 0.0302 | 0.0184 | 8.4 | 0 | 392.84 |
| | B | 0.0558 | 0.0201 | 0.0357 | 0.0092 | 8.4 | 0 | 390.4 |
| | C | 0.0440 | 0.0242 | 0.0198 | 0.0110 | 8.4 | 0 | 400.16 |
| 15 | A | 0.0476 | 0.0199 | 0.0285 | 0.0040 | 8.4 | 0 | 385.54 |
| | B | 0.0500 | 0.0202 | 0.0298 | 0.0060 | 8.4 | 0 | 385.54 |
| | C | 0.0397 | 0.0215 | 0.0182 | 0.0019 | 8.4 | 0 | 383.08 |
| 16 | A | 0.0501 | 0.0238 | 0.0263 | 0.0071 | 8.4 | 0 | 383.08 |
| | B | 0.0512 | 0.0190 | 0.0322 | 0.0034 | 8.4 | 6 | 370.85 |
| | C | 0.0500 | 0.0228 | 0.0278 | 0.0126 | 8.4 | 10 | 353.80 |
| 17 | A | 0.0530 | 0.0279 | 0.0251 | 0.0084 | 7.5 | 0 | 390.4 |
| | B | 0.0382 | 0.0316 | 0.0066 | 0.0066 | 8.0 | 0 | 390.4 |
| | C | 0.0572 | 0.0318 | 0.0254 | 0.0148 | 7.5 | 0 | 392.84 |

TABLE 1G-I—contd.

| Date 1947 | Point of collection A—en- trance B—exist C—Tank | Total solid and soluble salt in 100 c.c. | Soluble and any fine particle not re- tained by W. filter pa- per No. 42 in 100 c.c. | Total suspended solid in 100 c.c. | Loss on ignition in 100 c.c. | pH | Carbo- nate parts per million | Bi-car- bonate parts per million |
|--------------|--|---|--|--|---------------------------------------|-----|---|--|
| January— | | | | | | | | |
| 18 | A .. | 0.0510 | 0.0214 | 0.0296 | 0.0170 | 8.4 | 0 | 387.96 |
| | B .. | 0.0504 | 0.0192 | 0.0312 | 0.0114 | 8.2 | 0 | 395.28 |
| | C .. | 0.0532 | 0.0220 | 0.0312 | 0.0130 | 8.4 | 0 | 392.84 |
| 19 | A .. | 0.0538 | 0.0220 | 0.0318 | 0.0075 | 8.4 | 4 | 380.64 |
| | B .. | 0.0513 | 0.0194 | 0.0319 | 0.0073 | 8.4 | 4 | 383.08 |
| | C .. | 0.0520 | 0.0204 | 0.0316 | 0.0030 | 8.4 | 6 | 375.76 |
| 20 | A .. | 0.0773 | 0.0238 | 0.0535 | 0.0160 | 7.8 | 0 | 439.2 |
| | B .. | 0.0608 | 0.0244 | 0.0434 | 0.0154 | 8.2 | 0 | 444.08 |
| | C .. | 0.0662 | 0.0250 | 0.0412 | 0.0164 | 8.4 | 0 | 448.96 |
| 21 | A .. | 0.0626 | 0.0237 | 0.0389 | 0.0206 | 8.3 | 0 | 444.08 |
| | B .. | 0.0599 | 0.0216 | 0.0383 | 0.0176 | 8.1 | 0 | 446.52 |
| | C .. | 0.0588 | 0.0246 | 0.0342 | 0.0160 | 8.2 | 0 | 439.2 |
| 23 | A .. | 0.0608 | 0.0238 | 0.0370 | 0.0154 | 8.4 | 0 | 436.76 |
| | B .. | 0.0566 | 0.0222 | 0.0344 | 0.0094 | 8.0 | 0 | 427.00 |
| | C .. | 0.0629 | 0.0231 | 0.0398 | 0.0153 | 7.9 | 0 | 436.76 |
| 24 | A .. | 0.0536 | 0.0241 | 0.0295 | 0.0090 | 8.4 | 0 | 439.20 |
| | B .. | 0.0576 | 0.0228 | 0.0348 | 0.0090 | 8.4 | 0 | 436.76 |
| | C .. | 0.0598 | 0.0234 | 0.0364 | 0.0118 | 7.8 | 0 | 456.2 |
| 25 | A .. | 0.0536 | 0.0190 | 0.0346 | 0.0250 | 7.6 | 0 | 446.52 |
| | B .. | 0.0538 | 0.0208 | 0.0330 | 0.0192 | 7.8 | 0 | 446.52 |
| | C .. | 0.0496 | 0.0155 | 0.0341 | 0.0068 | 7.4 | 0 | 448.96 |
| 30 | A .. | 0.0498 | 0.0139 | 0.0359 | 0.0066 | 8.4 | 0 | 448.96 |
| | B .. | 0.0500 | 0.0166 | 0.0334 | 0.0098 | 8.3 | 0 | 436.76 |
| | C .. | 0.0438 | 0.0140 | 0.0298 | 0.0042 | 8.3 | 0 | 446.52 |

TABLE 1 G.1—*contd.*

| Date 1947 | Point of collec- tion— A—En- trance B—Exit C—Tank | Total solid and soluble Salt in 100 c.c. | Soluble salt and any fine particle not re- tained by W. filter paper No. 42 in 100 c.c. | Total suspend- ed solid in 100 c.c. | Loss on ignition in 100 c.c. | pH | Carbo- nate parts per million | Bi-car- bonate parts per million |
|----------------|---|--|--|--|---------------------------------------|-----|---|--|
| January— 31 | A .. | 0.0536 | 0.0180 | 0.0356 | 0.0076 | 7.8 | 0 | 436.76 |
| | B .. | 0.0636 | 0.0211 | 0.0425 | 0.0110 | 8.2 | 0 | 439.20 |
| | C .. | 0.0468 | 0.0221 | 0.0247 | 0.0088 | 7.8 | 0 | 431.88 |
| February— 1 | A .. | 0.0656 | 0.0093 | 0.0553 | 0.0144 | 8.2 | 0 | 436.76 |
| | B .. | 0.0608 | 0.0082 | 0.0526 | 0.0214 | 8.1 | 0 | 429.44 |
| | C .. | 0.0532 | 0.0064 | 0.0465 | 0.0096 | 8.1 | 0 | 431.88 |
| 8 | A .. | 0.0646 | 0.0031 | 0.0615 | 0.0201 | 8.3 | 0 | 439.20 |
| | B .. | 0.0630 | 0.0011 | 0.0619 | 0.0282 | 8.1 | 0 | 436.76 |
| | C .. | 0.0714 | 0.0003 | 0.0713 | 0.0212 | 8.3 | 0 | 446.52 |
| 9 | A .. | 0.0644 | 0.0237 | 0.0407 | 0.0234 | 8.0 | 0 | 431.88 |
| | B .. | 0.0670 | 0.0226 | 0.0444 | 0.0156 | 8.0 | 0 | 346.76 |
| | C .. | 0.0604 | 0.0212 | 0.0392 | 0.0160 | 8.2 | 0 | 444.08 |
| 10 | A .. | 0.0687 | 0.0231 | 0.0446 | 0.0102 | 8.0 | 0 | 402.6 |
| | B .. | 0.0658 | 0.0222 | 0.0436 | 0.0064 | 8.1 | 0 | 405.04 |
| | C .. | 0.0623 | 0.0238 | 0.0385 | 0.0101 | 7.9 | 0 | 412.36 |
| 11 | A .. | 0.0718 | 0.0202 | 0.0526 | 0.0166 | 7.8 | 0 | 405.04 |
| | B .. | 0.0710 | 0.0206 | 0.0514 | 0.0254 | 7.8 | 0 | 392.84 |
| | C .. | 0.0650 | 0.0270 | 0.0380 | 0.0286 | 7.8 | 0 | 405.04 |
| 12 | A .. | 0.0594 | 0.0242 | 0.0352 | 0.0200 | 7.8 | 0 | 393.28 |
| | B .. | 0.0672 | 0.0224 | 0.0448 | 0.0242 | 7.9 | 0 | 292.80 |
| | C .. | 0.0632 | 0.0214 | 0.0418 | 0.0226 | 7.9 | 0 | 297.68 |

The total number of pairs formed with the same characteristic of two samples were 22 or 23 so that the number of degrees of freedom for 't' is 21 or 22. For that value, the levels of significance of 't' are 2.08 (on the five per cent. level) and 2.82 or 2.83 (on one per cent. level). This means that the chance of exceeding the value 2.08 for 't' in a sample is 5 per cent. while the chance of exceeding the value 2.83 is only one per cent. The values of Student's 't' are given in Table 1GII.

TABLE 1G.II
Values of Student's 't'

| Difference between samples | Total solid content | Total soluble salt content | Total solids together with the soluble content | Organic matter |
|----------------------------|---------------------|----------------------------|--|----------------|
| A-B .. | 0.53 | 0.91 | 1.09 | 1.21 |
| A-C .. | 2.12 | -0.34 | 4.69 | 1.96 |
| B-C .. | 1.43 | -1.47 | 0.61 | 0.99 |

In Table 1G.II, A denotes sample taken from the inlet to the sedimentation tank, B denotes the sample from the exit channel, and C the sample taken from within the sedimentation tank. When the difference between the samples is expressed as (A-B) it is meant that in the numerator in the expression for 't' the mean of sample B had been subtracted from the mean of sample A and so on. It is found from the above that except in the case of soluble salt content the value of 't' is positive, that is to say, the mean value of either the solid contents, or the solid plus soluble contents, or the organic matter, is on an average greatest in sample A (taken from the inlet) and least in sample C (taken from within the sedimentation tank). Thus each of those three characteristics is somewhat lowered as the water came within the tank but is again increased though not to the original value as the water passed on to the exit channel.

These differences between the samples from the three places is however mostly not significant on the five per cent. level, so that the difference observed might also have arisen from sampling fluctuation. Only the difference in the total solid contents between the sample A (taken from the entrance) and C (taken from within the tank) is significant just on the five per cent. level, while the difference in the total solids plus soluble contents between the two samples was significant on a higher level (1 per cent. level).

Thus the analysis shows that a significant amount of the solid contents dropped down as the water entered the sedimentation tank but as the water came out *via* the exit channel some amount of solid particles are again taken up in the suspended state, so that the decrease in the solid content of the water after passing through the sedimentation channel is not significant.

DISCUSSION BY THE RESEARCH COMMITTEE

DR. BOSE said that he had nothing to add by way of introduction. The report was noted.

DISCUSSION BY THE BOARD

THE SECRETARY said that only one item was contributed at the Research committee meeting. There was no discussion.

2G. Spray Irrigation

PRELIMINARY NOTE

There was no contribution or discussion on the subject at the 1947 Research Committee Meeting.

Recent Literature

(1) Christiansen, J. E. Lawn sprinkler systems—The College of Agriculture University of California, Berkeley Circular 134, March 1947.

(2) Lyon A. V. and Pennefather R. R. Furrow irrigation of community settlements—Reprint from the Journal of Council for Scientific and Industrial Research, Vol. 19, No. 1 February 1946.

THE YEAR'S WORK

There was no Contribution or discussion at the Research Committee Meeting.

DISCUSSION BY THE BOARD

(For discussion by the Board see page 537)

3G. Definition of Terms in Common Use

PRELIMINARY NOTE

The Board at its 1946 Annual Meeting decided to reprint publication No. 5 'Glossary of Technical and Vernacular Terms in connection with Irrigation in India, together with standard Notation'. The work on this publication is in progress in the Board's office.

Recent Literature

(1) A glossary of technical terms for use in Indian Forestry—Indian Forests Records Vol. 2, No. 1, 1946.

THE YEAR'S WORK

There was no Contribution or discussion at the Research Committee Meeting

DISCUSSION BY THE BOARD

(For discussion by the Board see page 537)

4G. Standard Notation

PRELIMINARY NOTE

There was no contribution or discussion on this subject at the 1947 Research Committee Meeting.

THE YEAR'S WORK

There was no Contribution or discussion at the Research Committee Meeting.

DISCUSSION BY THE BOARD

(For discussion by the Board see page 537).

5G. Nomograms

PRELIMINARY NOTE

At the 1946 meeting of the Research Committee a series of nomograms were presented by the Indian Waterways, Experiment Station, (now Central Water-power, Irrigation and Navigation Research Station) Poona, giving relations of different hydraulic elements in various formulae.

At that meeting it was felt that it would be desirable to collect all nomograms prepared in different provinces and issue them as Board publications. It was decided this question would be examined later.

Four nomograms have further been received from the Irrigation Research Institute, Punjab.

There was no contribution or discussion on the subject at the 1947 meeting of the Research Committee.

Recent Literature

(1) Smith, A. T. nomograph for design of various concrete mines—Concrete, Vol. 55, No. 3, March 1947.

THE YEAR'S WORK

DISCUSSION BY THE RESEARCH COMMITTEE

There was no contribution and no discussion under these four subjects. It was decided to continue to keep the items on the agenda.

DISCUSSION BY THE BOARD

THE SECRETARY said that there was no contribution and no discussion under these subject heads at the Research Committee meeting.

MR. J. C. HARDIKAR said that he did not think spray irrigation was practised anywhere in India. As such it did not seem worthwhile to keep the subject on the agenda.

THE SECRETARY replied that spray irrigation was important only for irrigation in high value crops—garden crops like tomatoes, banana and the like, for which it could be economical. In America and Australia large areas under banana crop got this type of irrigation. They could also develop this system in their country, particularly on tube well areas where it would be easy to create the additional head required.

THE PRESIDENT said that although the equipment for this type of irrigation was costly it could be as cheap as other systems as there was no wastage. This would be particularly useful for high value crops and on slopes.

MR. J. P. NAEGAMVALA said that another point in its favour was that in its practice drainage works were not needed which meant considerable savings.

6G. Use of Diagrams in the Analysis of Statistical Data

by

G. M. Panchang

The chapter on diagrams in R. A. Fisher's classical work the "Statistical Methods for Research Workers" opens with the words:

"The Preliminary examination of most data is facilitated by the use of diagrams. Diagrams prove nothing, but bring outstanding features readily to the eye."

It is to bring these "outstanding features readily to the eye" that most engineers and scientists have long been availing of the diagrammatic method in the interpretation of their data. Attention is intended to be called in this note to particular aspect of it, namely the plotting of data on logarithmic paper, which in essence, is a simplified methods of plotting the logarithms of the observed data without actually evaluating them.

The method owes its origin in the difficulty experienced by non-mathematicians for readily ascertaining the mathematical form an expression would take for describing any observed distribution of points whenever it differed from the linear. Restricting the number of parameters to not more than two, the expression chosen has been

$$y = c x^k \quad (6G.1)$$

where k the nearest index number of the single power function best descriptive of the lie of the points is determined from the observed data. Taking logarithms of both sides the expression takes the shape

$$\log y = \log c + k \log x \quad (6G.2)$$

so that despite the non-linear distribution of the original points represented by (6G.1) the points for their logarithms will all lie on a straight line given by (6G.2). It is this peculiar feature of equation (6G. 1) that led many early investigators to resort to this form more frequently than any other.

The alternative method open to the student would be to fit in more constants for a polynomial expression, starting with a quadratic in the first instance. Ultimately this would result in the method of successive approximation which by its very conception would involve long-drawn calculations and make it laborious. The engineer has his shot therefore by attempting to estimate his relation only approximately with the help of two parameters in his equation (6G.1). He simply plots the observed data on logarithmic paper or alternatively the logarithms of the observed data on plain paper, when the slope of the least square average line passing through the points gives the index of the power relation.

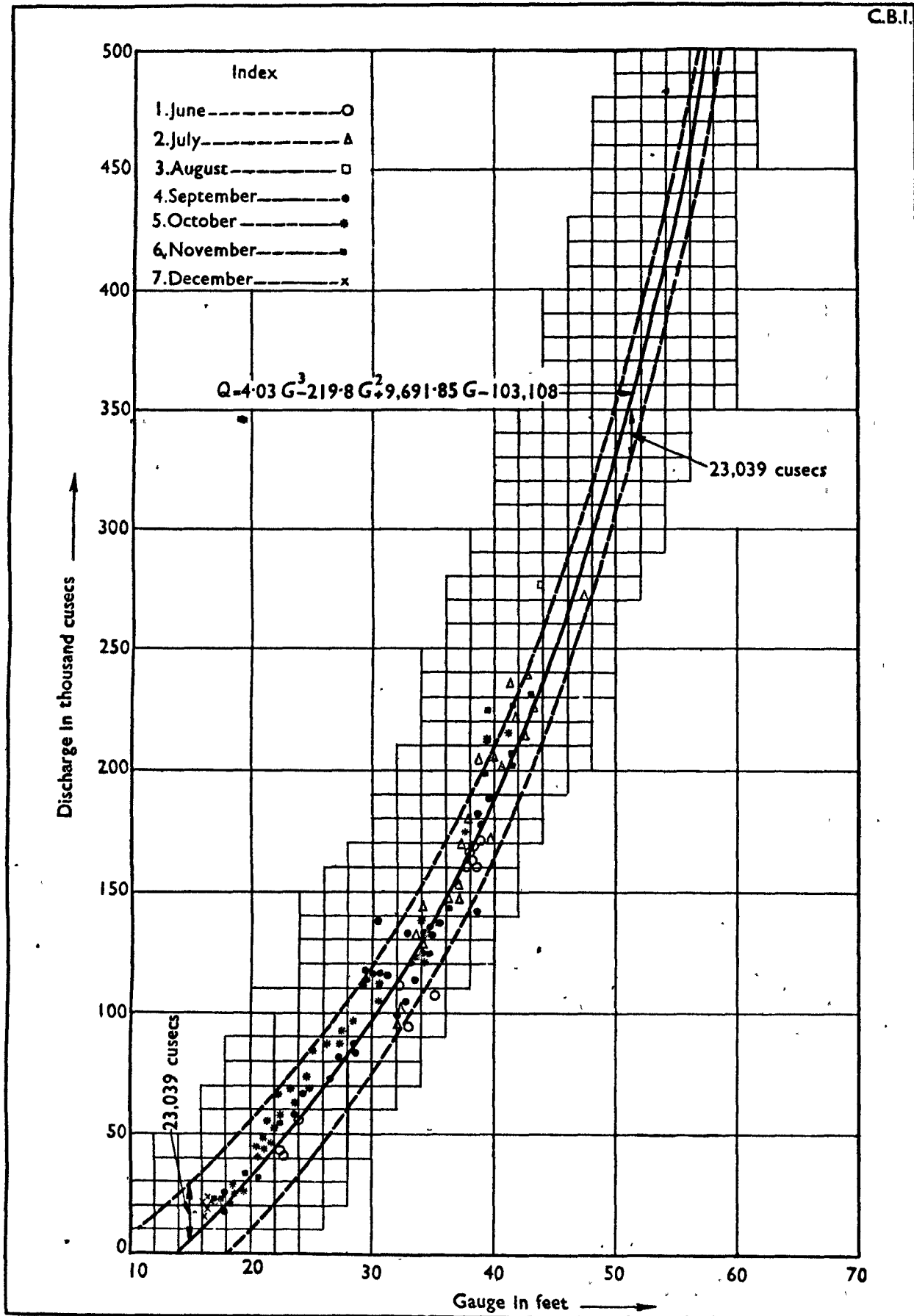


Figure 6G.1:- Showing 90 percent confidence belt along a cubic degree mean curve through the daily gauge & discharge points for River Saptkosi at Sona Khumbi Khola gauge site (June- December 1947)

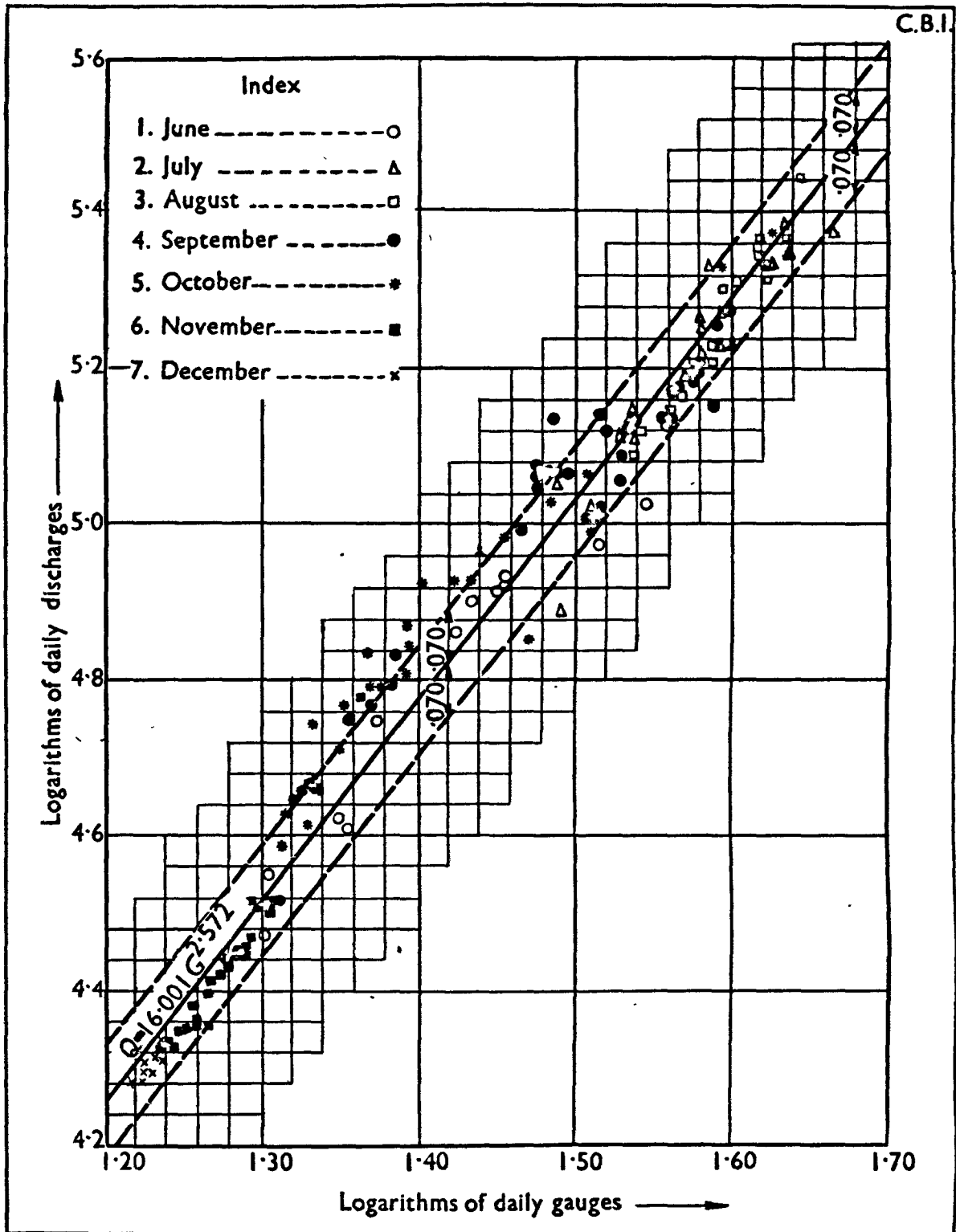


Figure 6G.2:- Showing 90 percent.confidence belt along a mean line through the logarithms of daily gauges and discharges of River Saptkosi at Sona Khumbi Khola gauge (June- December 1947)

While the essential soundness of this approach must be appreciated at least so far as the relation between x and y remains univariate, and monotonic, it is necessary to remember certain inherent limitations of the method also. The geometric proportion rate of increase of the numbers for an arithmetic proportion rate of the logarithms is too well known to need repetition. But the pattern of the relative distribution of the logarithmic numbers while being diminished in magnitude will not be far different from that of the original numbers.

Any general flattening of the curve will be only apparent and not real. This is well illustrated by a plotting of 168 days, data for discharges and gauges on the River Sapt Kosi at Sona Khumbi Khola Gauge site (for the months June to December 1947) in Figures 6G.1 and 6G.2. It is obvious from Figure 6G.1 that the trend of the points for the actual data is non-linear which the logarithmic transformation in Figure 6G.2 brings to linearity to an appreciable extent. Yet a few peculiar tendencies apparent in Figure 6G.1 continue to make their presence apparent in Figure 6G.2 also though in a smaller measure. In fact, according to the statistical methods of fitting a straight line to a given set of data the fit in Figure 6G.2 can by no means be called satisfactory*. It is just as bad, if no worse than the fit of a straight line to the distribution in Figure 6G.1. Considerable improvements, however, have been achieved in the goodness of fit in Figure 6G.1 by fitting a cubic parabola which shows the lie of the points in a truer sense. Perhaps Figure 6G.2 also can be similarly treated for an improved fit, but it is feared the resulting expression in logarithms will be more cumbersome than helpful in actual practice. Thus the net gain the logarithmic transformation of the data has achieved is more apparent than real.

Yet another handicap which the method is subject to and has been mentioned in passing above is the inequality of scale values in all reaches of the domain of the points. The distance between two points or from an observed point to the mean line does not indicate the relative magnitude between the two values, but only that between their two logarithms which values, strictly speaking, are not associated with any useful significance in practice. On the other hand the method helps essentially to deceive the eye and thus leave a false impression of pleasing the mind. The correct method of diagrammatic

*The 90 per cent. confidence belt along the best linear fit to the data, encloses no more than 81 per cent. of the plotted points. Also, see appendix for analyses of variance results.

representation of data even when the lie of the points is really logarithmic is not to plot the logarithm values for being joined by a straight line, but to plot the actual values and draw the appropriate *power* curve through them. The latter method provides the student with a ready means of comparing the relative differences *etc.*, in the scatter of the points obtaining. But how is this scatter or to put it more correctly, the probable domain of such scatter ascertained for any given set of data. Statistical methods come to our rescue once again.

It is common practice in most bivariate correlation studies to mark out certain regions in the domain of the points as confidence belts of difference degrees of confidence. Thus, for example, a confidence belt of 91 per cent. degree of confidence of any pre-assigned shape is defined as the narrowest belt of the described shape which will envelope 90 per cent. points inside and only 10 per cent. outside. Two belts satisfying this definition are shown respectively in Figures 6G.1 and 6G.2. It is easy to see the belts appear neat and enclosing compact areas. But in view of the observations being expressed in terms of their logarithm values in Figure 6G.2 it was thought rather desirable to see the confidence belt transformed to its natural scale. The enveloping lines of the confidence belt in Figure 6G.2 have, therefore, been reproduced in natural scale in Figure 6G.3 along with the mean line. Just a cursory glance at this new picture will suffice to erase the complacent effect which had previously been produced on the mind by Figure 6G.2. The two boundary lines which had been running parallel in Figure 6G.2 are seen in Figure 6G.3 to open out in two never-diverging directions. Thus if the results obtained by the logarithmic method of plotting when transformed to their natural scale cannot be any better than what is shown by Figure 6G.3, it can by no stretch of imagination be called a happy method at all. The present opportunity is taken therefore to warn the unwary student of the dangers that may emanate by following an inappropriate method of analysis. The warning seems to be all the more well needed especially during these days of extreme specialisation when the analysis of large masses of data can be safely entrusted to the specialist statistician and not dispensed with in a haphazard manner, by the novice or a non-technician. The note will be closed appropriately enough by quoting the great servant again,

“It should always be remembered that the choice of the appropriate methods of statistical treatment is quite independent of the choice of the methods of diagrammatic representation.”

as R. A. Fisher has concluded this chapter on Diagrams.

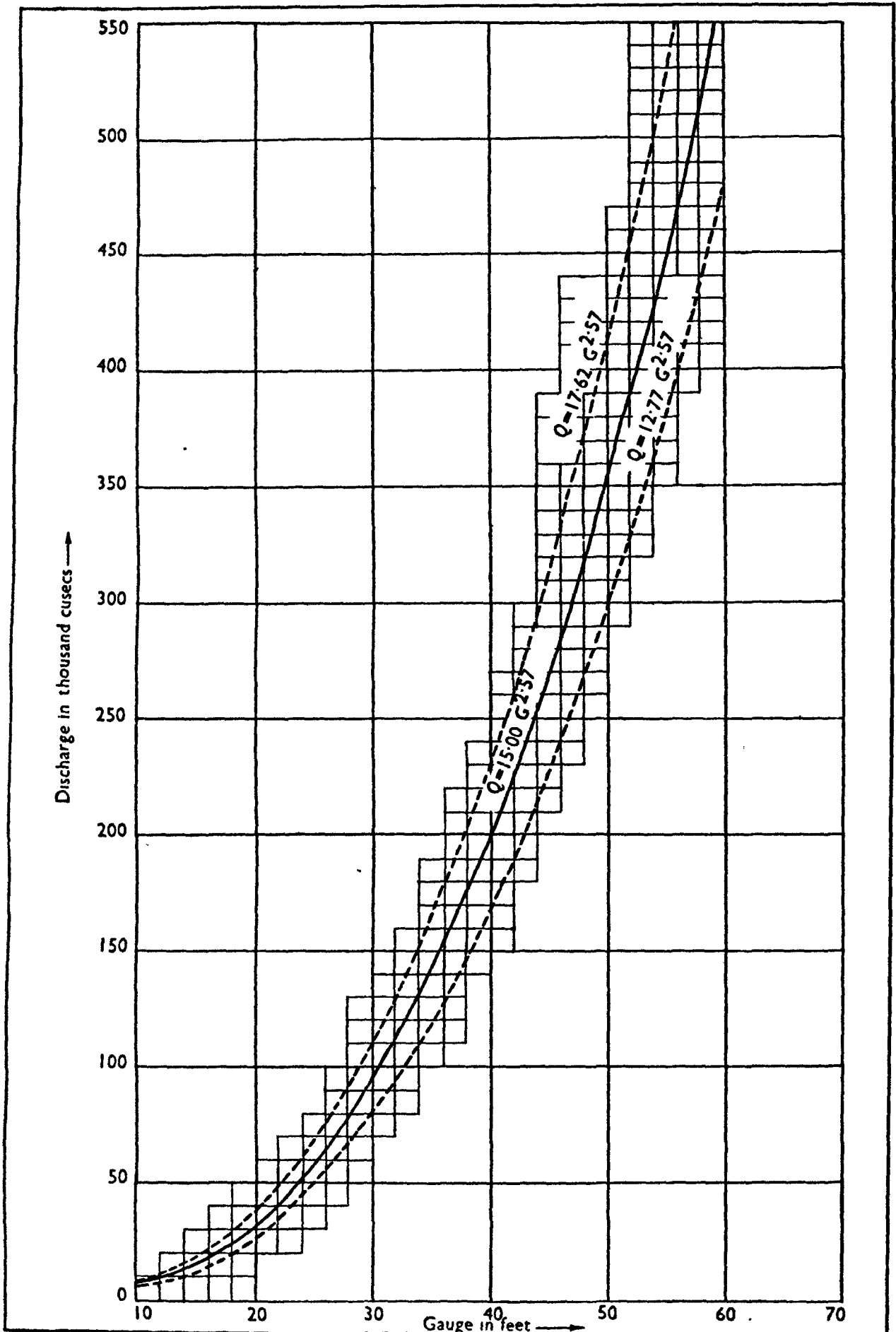


Figure 6G.3:- Showing natural scale transformation of the confidence belt shown on logarithmic scale in figure 6G.2

APPENDIX

TABLES FOR ANALYSES OF VARIANCE

(i) For fitting a linear equation to actual gauge and discharge readings.

| Source of Variance | Degrees of Freedom | Sum of Squares | Mean Square | Significant at |
|---------------------------------|------------------------------|----------------|-------------|---------------------|
| Due to regression | 1 | 1,932.8157 | .. | 0.1 per cent. level |
| Deviation from regression | 15 | 61.6905 | 4.1127 | 0.1 per cent. level |
| Between arrays with | 16 | 1,994.5062 | 124.6566 | |
| Within arrays | 151 | 74.0652 | 0.4905 | |
| Total | 167 | 2,068.5714 | | |
| Standard Deviation | $s = 0.7004 = 14,007$ cusecs | | | |

(ii) For fitting a cubic equation to the same.

| Source of Variance | Degrees of Freedom | Sum of Squares | Mean Square | Significant at |
|---------------------------------|------------------------------|----------------|-------------|---------------------------------|
| Due to regression | 3 | 1,973.5163 | 657.8387 | 0.1 per cent. level |
| Deviation from regression | 13 | 20.9900 | 1.6146 | Just beyond 0.1 per cent. level |
| Between arrays | 16 | 1,994.5062 | 124.7566 | |
| Within arrays | 151 | 74.0652 | 0.4905 | |
| Total | 167 | 2,068.5714 | | |
| Standard Deviation | $s = 0.7004 = 14,007$ cusecs | | | |

(iii) For fitting a linear equation to the logarithms of the gauge and discharge readings.

| Source of Variance | Degrees of Freedom | Sum of Squares | Mean Squares | Significant at |
|---------------------------------|--------------------|----------------|--------------|---------------------|
| Due to regression | 1 | 8,423.3108 | .. | 0.1 per cent. level |
| Deviation from regression | 23 | 113.8116 | 4.9483 | 0.1 per cent. level |
| Between arrays | 24 | 8,537.1224 | 335.7134 | |
| Within arrays | 143 | 103.3538 | 0.7228 | |
| Total | 167 | 8,640.4762 | .. | |

DISCUSSION BY THE RESEARCH COMMITTEE

MR. PANCHANG introduced his paper on the subject and said that there were two occasions when an observed set of data was plotted on logarithmic paper,

(1) When the range of data was too wide to make its graphical representation convenient on an average size paper, and

(2) When the mathematical law governing the distribution of points was not obvious

logarithmic plotting was taken recourse to in order to flatten any non-linear trends.

While the method might be good in itself, just for the sake of plotting, it frequently led to a pitfall when the method was extended for the purpose of deducing an approximate expression of the mathematical law binding the variables.

The present note demonstrated one such instance and concluded with a suggestion that the task of fitting appropriate mathematical expressions might be delegated to persons best qualified for such work especially during these days of extreme specialisation.

DR. BOS said that the use of diagrams in analysing statistical data was sometimes very useful. Of course, it was necessary to know the history of the data.

DISCUSSION BY THE BOARD

There was no discussion. It was decided to keep the subject on the agenda.

7G. Standardization of Steel Sheet Piling

PRELIMINARY NOTE

This subject was introduced on the agenda in 1947. For detailed preliminary note on the subject attention is invited to last year's agenda for the meeting.

The Research Committee at its last meeting had a lengthy discussion on the subject when Mr. Sen of the Tata's was also present. It was agreed that the universal pile 5 inches by 15 inches should be retained, but that the Tata's might consider two points, firstly, whether these could be given a slight bend on a mass scale without damaging its structural aspects and without adding to the cost considerably and secondly, whether Z-Section was possible, also to consider how far it could be extracted and how easily damaged portions could be set right. Further that some tests should be undertaken by extracting some piles that had been in ground under structures for the last 20 years to see to what extent they have suffered from corrosion.

The Board at its last meeting confirmed decision of the Research Committee and welcomed the suggestion that Tata's were going to or could manufacture inter-locking type of piles as well.

THE YEAR'S WORK

DISCUSSION BY THE RESEARCH COMMITTEE

There was no contribution and no discussion under this head.

DISCUSSION BY THE BOARD.

there was no discussion

8G. Soil Conservation

PRELIMINARY NOTE

Prior to the last Board meeting in December 1947 discussion on problem connected with soil conservation were included under the title 'Soil denudation as an adverse factor to river supplies and agriculture'. With the regrouping of the subjects last year it was decided that the subject of 'Soil Conservation' be treated separately and under it should be included discussion of methods and practice of soil conservation.

Soil erosion is a curse for the nation. It is being tackled as problem No. 1 in many countries but has not received due notice of the authorities in India. Some work has been done in the East Punjab in this connection but what is wanted is to evolve and to pursue a well co-ordinated policy of land utilisation. In pursuance of the policy, the Central Board of Irrigation has made a number of recommendations in the past urging the Central and Provincial Governments to carry out measures to control erosion and have suggested to the Government of India to set up a Central Land Utilisation Board but so far no final action has been taken by the Government of India in this connection

The Board at its last meeting passed the following resolution :

"Whereas soil conservation work is being undertaken in different parts of the country and includes

- (1) Control of grazing and scraping of grass in, and afforestation of waste lands,
 - (2) Terracing of un-irrigated fields
 - (3) Reclamation of badly gullied lands
 - (4) Torrent training and canalisation of smaller streams
 - (5) Fixation of shifting sands; and
 - (6) Application of soil moving machinery to all these problems,
- and whereas it is the considered opinion of the Board that work should be correlated with the activities of other departments work, the Central, as well as Provincial and State Governments be requested to create at an early date suitable co-ordinating bodies for this purpose."

A press communique from the Government of the United Provinces shows that the United Provinces Government have set up a Board known as Land Management Board consisting of the following members :

- (1) Hon'ble Minister Revenue—Chairman.
- (2) The Chief Conservator of Forests, United Provinces, (ex-officio).

- (3) The Conservator of Forests, Land Management Circle.
- (4) The Conservator of Forests, Working Plans and Research Circle.
- (5) The Chief Engineer, Irrigation Branch.
- (6) The Director of Agriculture.
- (7) The Director, Animal Husbandry Department.
- (8) The Development Commissioner, United Provinces.
- (9) The President, Court of Wards.
- (10) The Gaon Panchayat Organization Officer (if and when appointed).
- (11) The Officer In-charge, Animal Nutrition Section, Imperial Veterinary Institute.
- (12) The Agricultural Chemist, Kanpur.
- (13) The Professor of Geology, Benares Hindu University.
- (14) Five other members from the public.

The Revenue Secretary will act as Secretary to the Board.

The functions of the Board will be :—

- (a) To adopt measures to check further erosion and to reclaim ravines and other areas already badly eroded with particular reference to the ravines of the Yamuna and Chambal rivers ;
- (b) To create village fuel plantations to release cow-dung for its proper use as manure and to provide small timber for agricultural implements and cottage industries ;
- (c) To adopt measures to increase fodder supplies and grazing facilities ;
- (d) Collection of statistics dealing with all aspects of the fodder and grazing problems, including investigations into the nutrient value of leaf fodder and grasses ;
- (e) Co-ordination of research and experiments between Government Departments and fodder and grazing problems and examination of research projects and initiation of new experiments on such problems ;
- (f) Investigation of the best economic land use of all waste-lands including *bhurs, kholas, etc.*, particularly the ravines of the Yamuna and the Chambal.

- (g) To utilize the state lands such as spare railway land, canal banks road side avenues, nazul *etc.*, to the best possible and
- (h) To create the executive organisation necessary to give effect to above measures ;
- (i) To apply practically on a large scale the experimental results.

The Chief Engineers, East Punjab have intimated that they have already proposed that they would like to have their representative on the proposed Land Management Department for the Province as suggested at the Second Senior Officers Conference, held at Dehra Dun in November, 1946.

The Chief Engineer, Travancore, states that soil erosion is no where so clearly seen and its evil results so markedly perceived as in Travancore. In pursuance of the resolutions of the Board on the subject he has requested the Government to instruct the authorities of the Agricultural and Land Revenue Departments to take steps to educate the people of the evil facing the state and insist on terrace cultivation as a first step.

It has been intimated by the Agricultural and Rural Development Department, Bombay, that after careful consideration, Government of Bombay have come to the conclusion that an inclusion of an officer of the Soil Conservation Section on the Water Board* proposed to be constituted in the Province will meet the need of the co-ordinating body as proposed by the Central Board of Irrigation.

No paper was contributed on the subject last year.

THE YEAR'S WORK

The following items were discussed at the 1948 Meeting of the Research Committee :—

- (1) Runoff and erosion experiment in trays.
- (2) Analysis of rainfall at the runoff experiment sites.
- (3) Runoff and soil erosion experiments with the help of artificial showers.

* Central Board of Irrigation Journal, January 1948, page 4.

(1) RUNOFF AND SOIL EROSION EXPERIMENT IN TRAYS**ABSTRACT**

Studies of the relation between rainfall, runoff and experiments in trays were also continued during the year at the three sites, *viz.*, Ramgarh and Sudamdih on the Damodar, and Barakar (Giridih) on the Barakar. The experiments were as before made on four trays—two on 20° slope and two on 50° slope. On each degree of slope, there was one tray with vegetation cover and another with bare soil. The duplicate arrangement at Barakar-Giridih was discontinued this year and there was one tray with each of the four specifications at all the sites.

RAINFALL

Rainfall at each of the sites was measured by rain gauges set up at the sites. The daily rainfall data at the three sites for the year 1947 were recorded.

The total number of rainy days at Barakar-Giridih during the year was 88 of which rainfall exceeded one inch in depth on 12 days. The maximum rainfall occurred on July 31, 1947, the magnitude being 2.56 inches. This also synchronised with the highest floods in the Barakar river during the year which occurred on 1st August 1947.

At Ramgarh there were 86 rainy days during the year of which 11 days recorded rainfall of more than one inch in magnitude. The heaviest precipitation for the year was 3.42 inches on September 2, 1947, this being the storm producing the highest floods in the Damodar. Rainfall on two other days exceeded two inches in depth, these being 2.31 inches on June 8, 1947 and 2.53 inches on October 12, 1947.

At Sudamdih precipitation occurred on 76 days and was more than one inch in magnitude on 13 days. The maximum rainfall was 2.45 inches on July 5, 1947, although on September 2, 1947 (corresponding to the highest floods in the Damodar) there occurred a precipitation of nearly the same magnitude, *viz.*, 2.32 inches. The maximum average daily intensity of rainfall recorded at the three sites are given in Table 8G. I.

TABLE 8G. I

| Site | Date 1947 | Rainfall in inches | Intensity of rainfall in inch per hour |
|-----------------------|-------------------|-----------------------|---|
| Barakar-Giridih | June 21 | 9.92 | 1.84 |
| Ramgarh | September 1 | 0.75 | 2.35 |
| Sudamdih | August 24 | 1.54 | 2.49 |

The storm from the September 1 to 4, 1947 registered a total rainfall of 6.78 inches at Ramgarh and 4.23 inches at Sudamdih. This storm produced the highest floods in the Damodar. At Barakar-Giridih the storm corresponding to the highest floods in the Barakar recorded a precipitation of 4.43 inches in the three days from July 29 to 31, 1947.

(1) River Research Institute, West Bengal, Annual Report, 1947 pages 171—182.

RUNOFF EROSION

The amount of rainfall, runoff and erosion were recorded month by month at the three sites separately. Curves for monthly rainfall, runoff percentage and erosion per unit rainfall are given in Figure 8G.I.

At Barakar-Giridih the total rainfall in the year was 47.01 inches while the average depth of runoff from the trays was 9.74 inches giving a runoff percentage of 20.7 on the average. The runoff percentage was highest (26.5) in the month of September. In October and July also the runoff percentage was higher than the average for the year (23.4 and 22.0) respectively while in August it was 20.6. In other months of the year the percentage was much lower than the average value. The average depth of erosion per unit rainfall for the whole year was 23.1×10^{-6} . This was higher than the average for 1946. The rate of erosion per unit rainfall was highest in June.

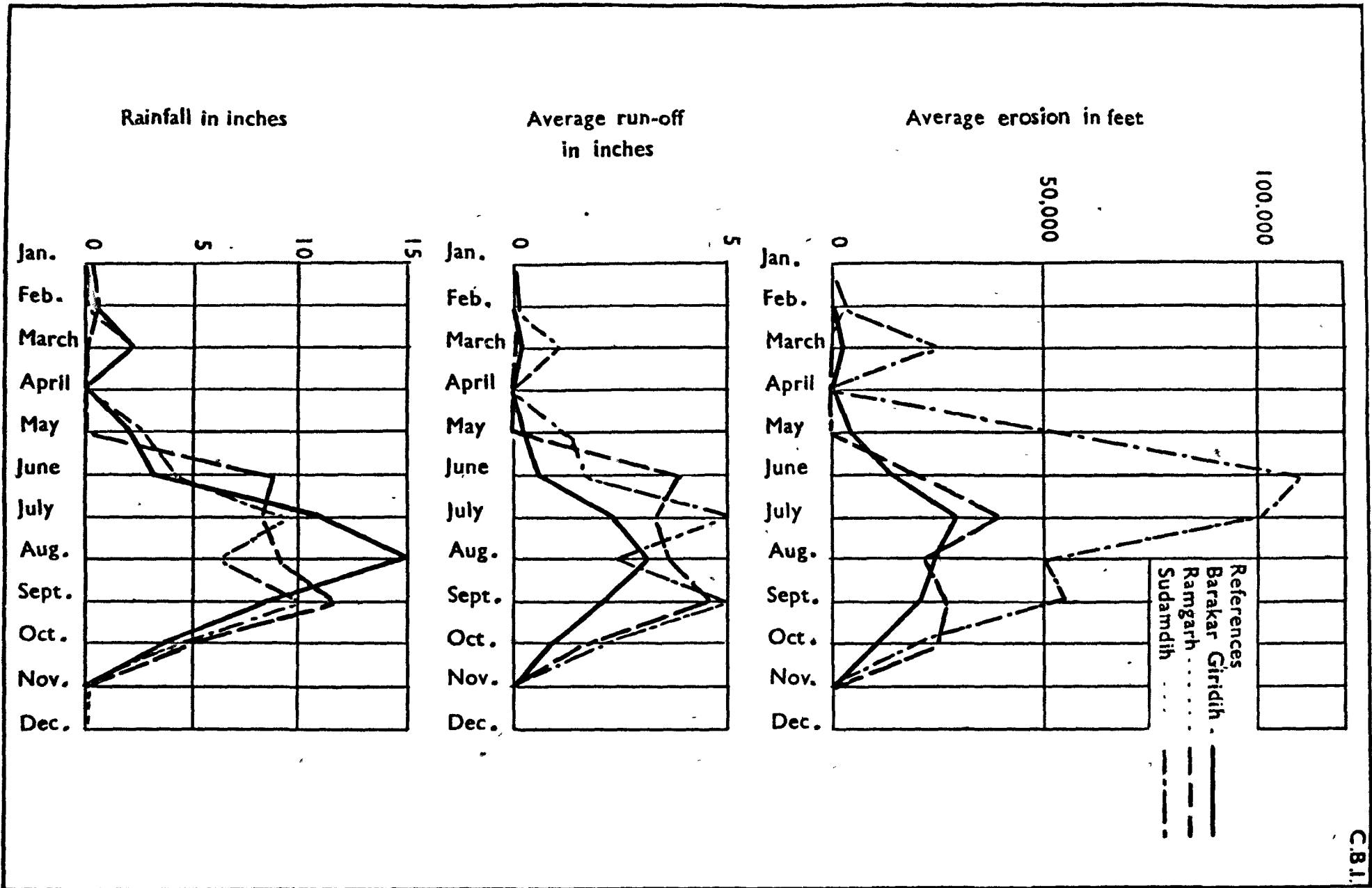
At Ramgarh the total rainfall for the year was 43.69 inches with an average runoff of 17.80 inches depth so that the runoff percentage is 40.7 on an average. The average percentage of runoff was highest (44.3) in June about 40 or 41 in July, August and September and less in other months. The average depth of erosion for the year was 31.50×10^{-6} feet per unit rainfall, as against 27.5×10^{-6} feet in the previous year.

At Sudamdih the total rainfall recorded during the year was 39.25 inches and the average depth of runoff was 19.48 inches so that the percentage of runoff was 47.1 on the average as against 68 per cent. in the previous year, while the average erosion per unit rainfall for the whole year was 105.0×10^{-6} feet which was higher than the corresponding figure (76.9×10^{-6} feet) in the previous year.

It is thus found that both runoff and erosion are the highest at Sudamdih but the runoff percentage at this site for the year was not as high as in the previous year. The runoff percentages for the different months as also for the whole year showed a decline at Barakar-Giridih and Sudamdih, while it was of the same order as in the previous year at Ramgarh.

As observed in the previous year the erosion at Sudamdih was nearly 5 times than that at Barakar-Giridih while more than three times than that at Ramgarh which conforms to the belief that the coal field areas (of which the soil at Sudamdih is representative) erode heavily.

Figure 8G.1 :- Graph showing rainfall run-off and erosion



The runoff and erosion in different trays for each of the site was analysed statistically. The analysis was done for showers of not very low magnitude and intensity (magnitude higher than 0.5 inches and intensity higher than 0.3 inches). There were 18 such showers at Ramgarh, 22 at Sudamdih and 15 at Barakar-Giridih.

The analysis was two-fold : (1) In the first place the order of difference between the trays of different specifications was tested by the Student's *t*-test. These tests were carried on for pairs of trays of same slope but differing in the vegetation, and also for trays of same type of soil but of different slopes. (2) The significance of the difference between the different trays and also between showers was tested by the analysis of variance and the *Z* test. Both runoff percentages and erosion per unit rainfall were subjected to the above tests.

The results of the above analysis may be stated as follows.

(a) *Runoff Percentage*

In the case of runoff percentage the difference between the trays was very highly significant, and the difference between the different showers was also highly significant, at each of the three sites. The difference between bare soil and trays of the same slope but with vegetation cover was also very highly significant at all the three sites. The difference due to slope variation was significant, but not of such a high order as that due to vegetation cover, at Ramgarh and Sudamdih, while at Baraka-Giridih it was not significant at all.

(b) *Erosion per unit Rainfall*

In the case of erosion also the difference from tray to tray is highly significant as also the difference from shower to shower, though in a lesser degree. The difference in the erosion for vegetation cover is highly significant at all the three sites, while the difference due to slope variation has not been found to be significant in any of the sites except in the case of trays on bare soil at Barakar-Giridih.

CONCLUSION

Thus it is found that the vegetation plays a more important part than variation in slope (at least the variation that has been introduced) both for runoff and erosion.

(2) ANALYSIS OF RAINFALL AT THE RUN OFF EXPERIMENT SITES (2)

Rainfall, Runoff and Soil Erosion experiments were carried out on the same lines in the Damodar Valley as in the previous years at the three sites, Ramgarh, Barakar-Giridih and Sudamdih.

One Symon's Rain gauge was set up at Chas Road with effect from the month of October 1947.

At Barakar-Giridih two new features were added in the programme. They are (i) Rainfall and Soil Erosion experiments by artificial showers and (ii) Weather Observations.

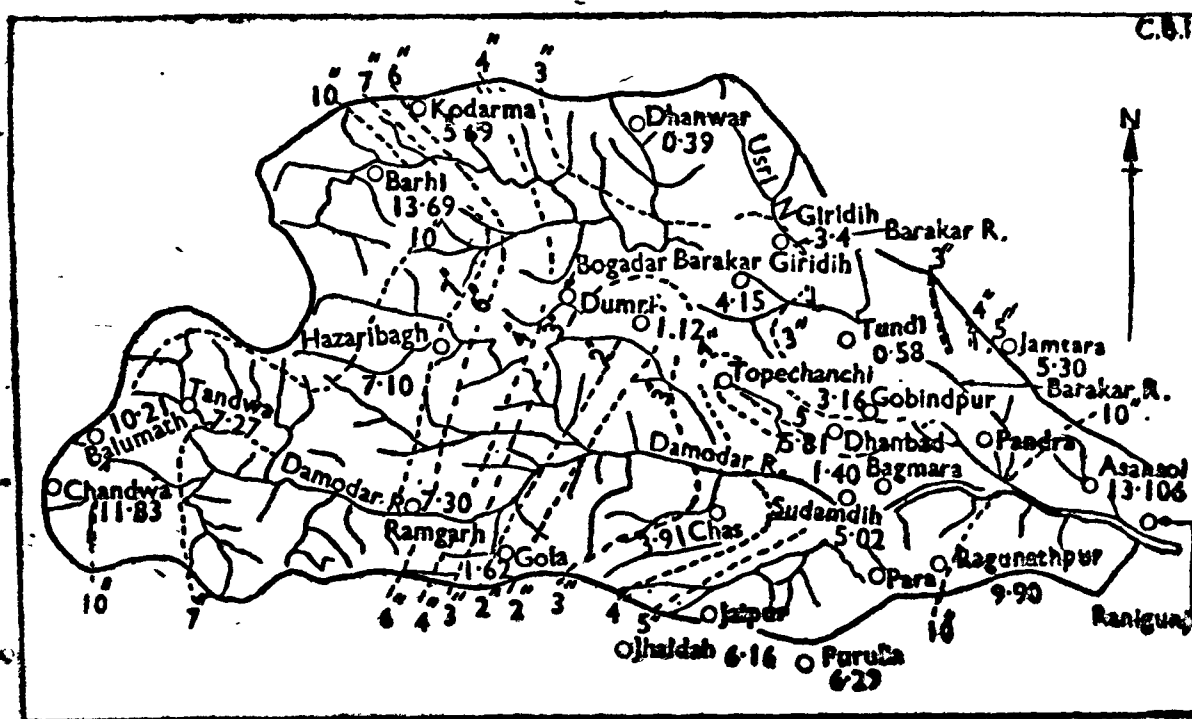


Figure 8G.2 : Storm map of the Damodar Valley showing rainy contour of the upper catchment from September 14, 1946 to September 18, 1946.

The three years' rainfalls during storm periods at the observation sites during the years 1944, 1945, 1946 and 1947 have been computed. The period August 24 to 31, 1944 recorded a rainfall of more than six inches and the period September 14 to 18, 1946 recorded an average rainfall of 5.99 inches. The latter storm was of cyclonic type and rain contour map of the upper catchment of the Damodar Valley has been prepared (Figure 8G. 2) showing the distribution of rainfall of the period between September 14 to 18, 1946. There were three depressions and the biggest depression was at Barhi. At Barhi it was a cloud burst type of rainfall and the Barakar river was inflated and behaved violently. The surging mass of water uprooted big trees and clashed with the Barakar bridge which ultimately gave way.

(*) River Research Institute, West Bengal, Annual Report, pages 184-189.

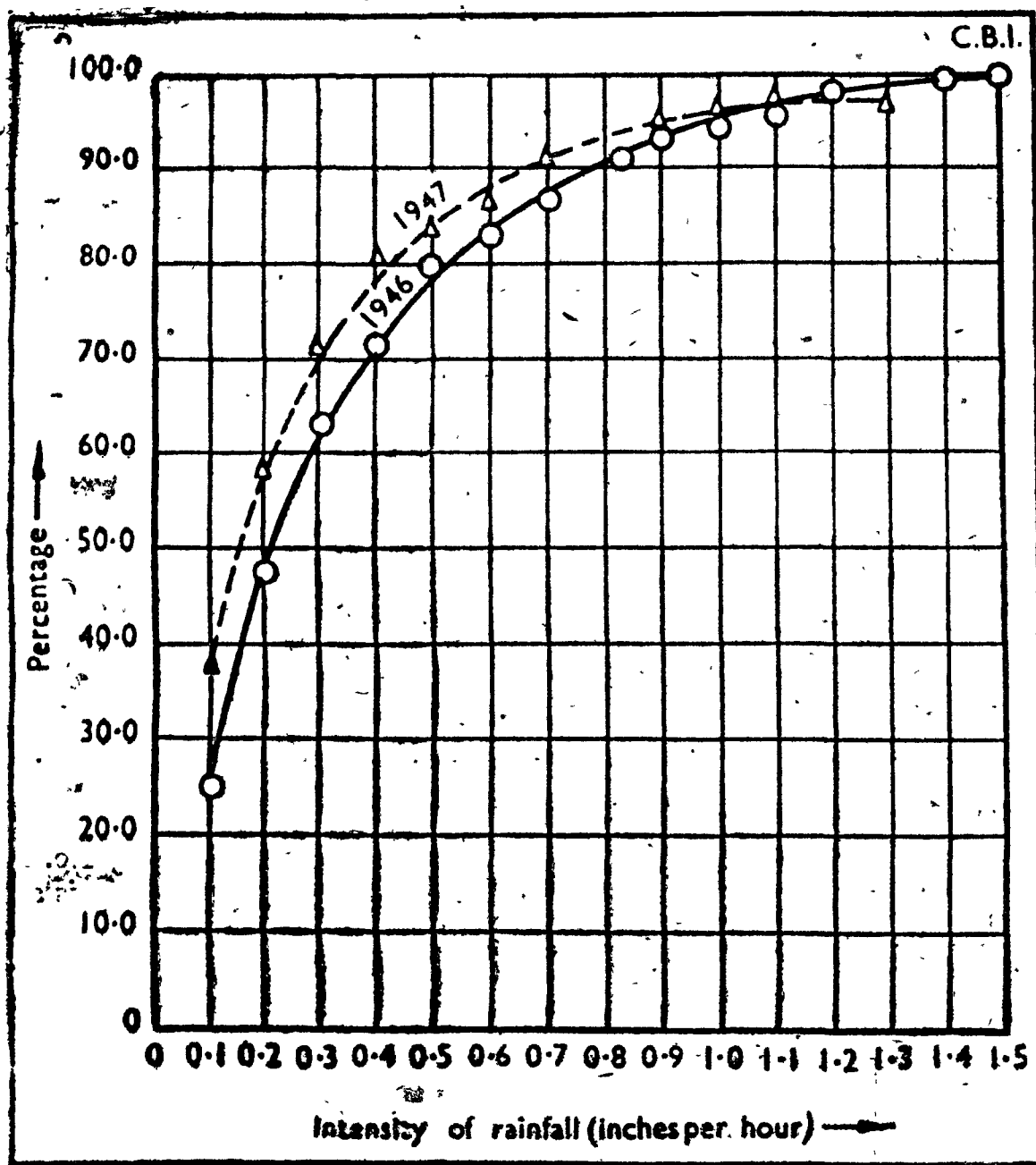


Figure 8G. 3 : Showing cumulative percentage curves of rainfall intensities at Barakar Giridih.

To study the frequency of intensities and magnitude of daily rainfall, summation percentage curves of intensities of all the showers at Barakar-Giridih (Figure 8G. 3) and summation percentage frequency curves of daily rainfall magnitudes for 1947 at Barakar-Giridih, Sudamdih and Ramgarh (Figure 8G. 4) have been constituted. From the cumulative percentage frequency curves of Barakar-Giridih for the year 1946 and 1947 (Figure 8G. 3) ranging from intensities 0.05 inch per hour to 1.5 inches per hour, it is seen that more than 95 per cent. of the showers have intensities less than 1.0 inch per hour.

For the three sites Barakar-Giridih and Ramgarh rainfalls of one day duration have been considered ranging from 0.05 inches to 2.55 inches. Rainfalls below 0.5 inches have no direct bearing upon the Runoff Rainfall intensity above 2.5 inches seldom occurs. Also a comparative graph of summation percentage frequency curves of Barakar-Giridih for the year 1945, 1946 and 1947 have been constituted (Figure 8G. 5). From both the cumulative percentage frequency curves of intensities and summation percentage curves of daily rainfall magnitudes it is evident that daily rainfalls of low magnitudes and showers of low intensities have been frequent during these three years 1945, 1946 and 1947 in th Damodar Valley.

(3) RUNOFF AND SOIL EROSION EXPERIMENTS WITH THE HELP OF ARTIFICIAL SHOWERS (*)

ABSTRACT

To study the phenomenon of runoff and soil erosion in experiments with the help of natural rainfall it is very difficult to control the intensity, duration and the quantity of shower ; consequently, the relationship between runoff and the soil erosion cannot be determined accurately.

Experiments were, therefore, set up at Barakar-Giridih to study the phenomenon of surface runoff and soil erosion with the help of artificial showers.

Two plots having the same type of vegetation cover have been laid out on a slope of 5° 5', both having equal area of 25 square feet. The tray No. 1 is rectangular in shape while the tray No. 2 is circular in shape. Rain is artificially poured over the trays from graduated drums through showers. Runoff is also received in graduated drums, Figures 8G.6, 8G.7 and 8G.8.

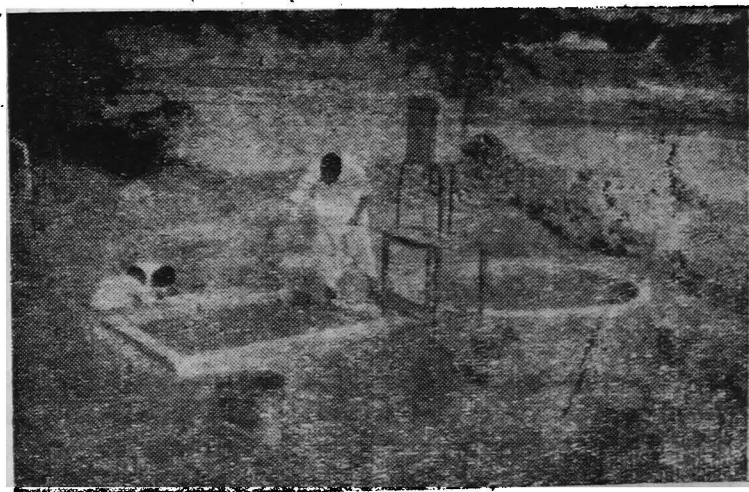


Figure 8G.6

(*) River Research Institute, West Bengal, Annual Report, 1947, pages 100-101.

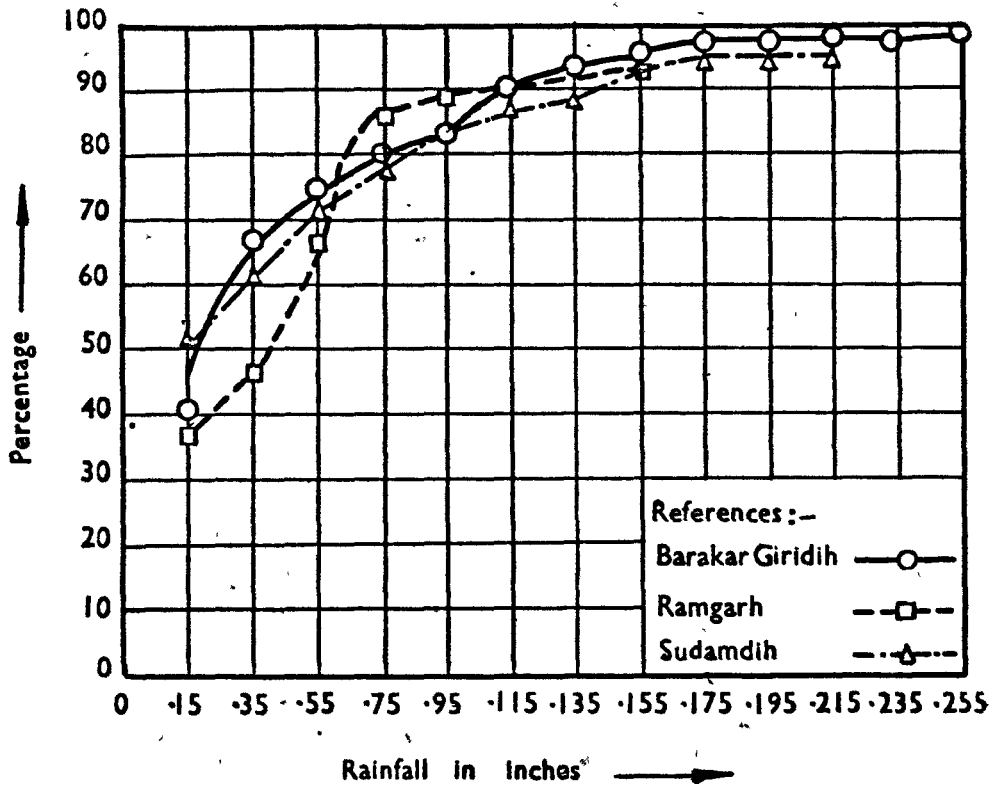


Figure 8G.4:- Showing summation percentage curves of daily rainfall for the year 1947

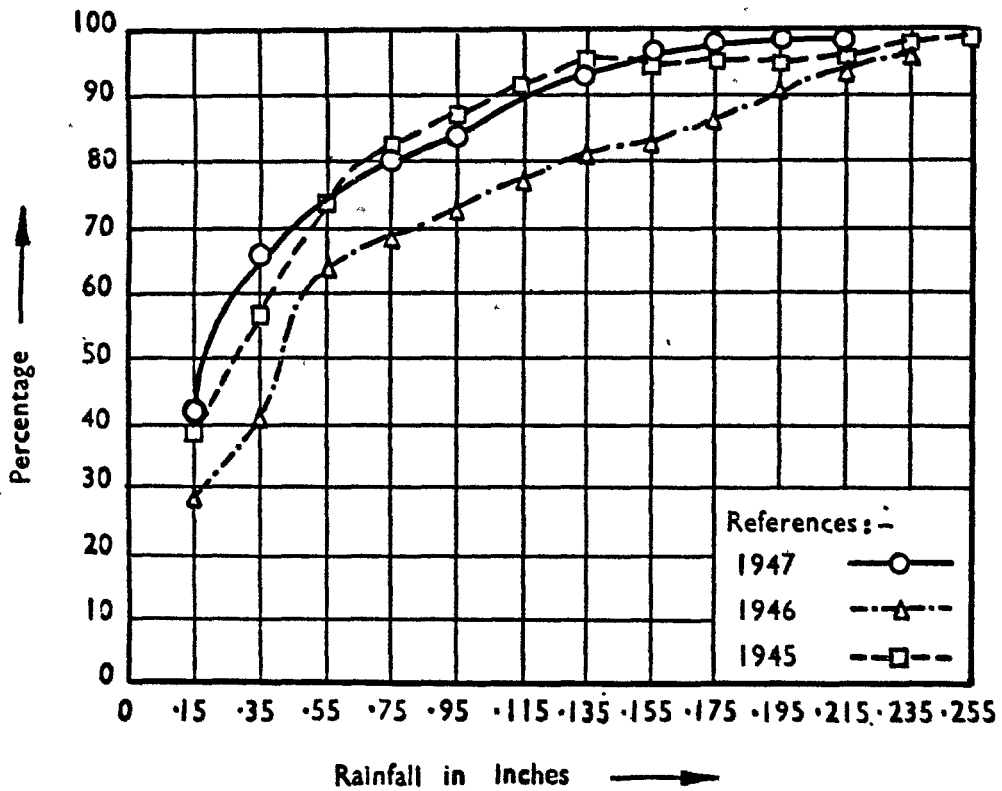


Figure 8G.5:- Showing summation percentage curves of daily rainfall at Barakar Giridih

At fixed time intervals rainfall are runoff and measured from the manometer attached with the drums and the maximum discharge in c.c. is calculated. The readings are taken till the runoff ceases.

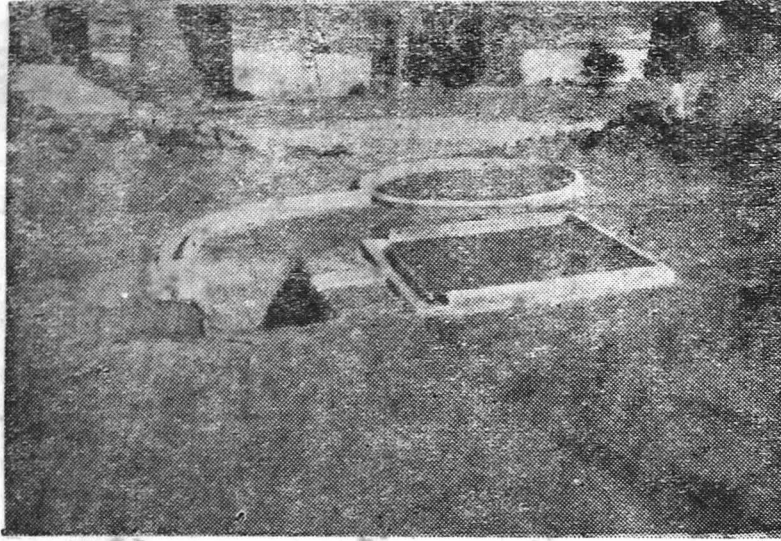


Figure 8G.7

If we constitute the runoff graph, we find that the runoff begins some time after rain begins to be poured in. The rate of runoff gradually rises and attains a maximum value at some intermediate time and again decreases until ultimately it ceases altogether. This is exactly what happens when a storm passes over a watershed. The resultant hydrograph follows nature very closely, Figure 8G.9.

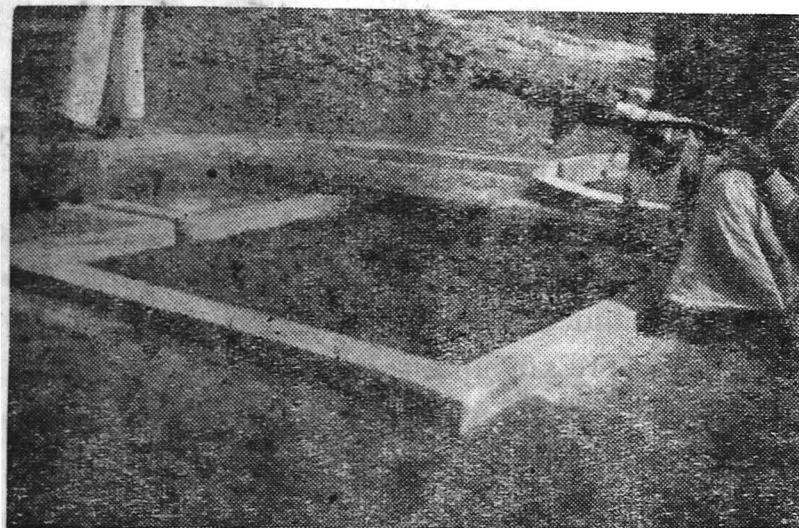


Figure 8G.8

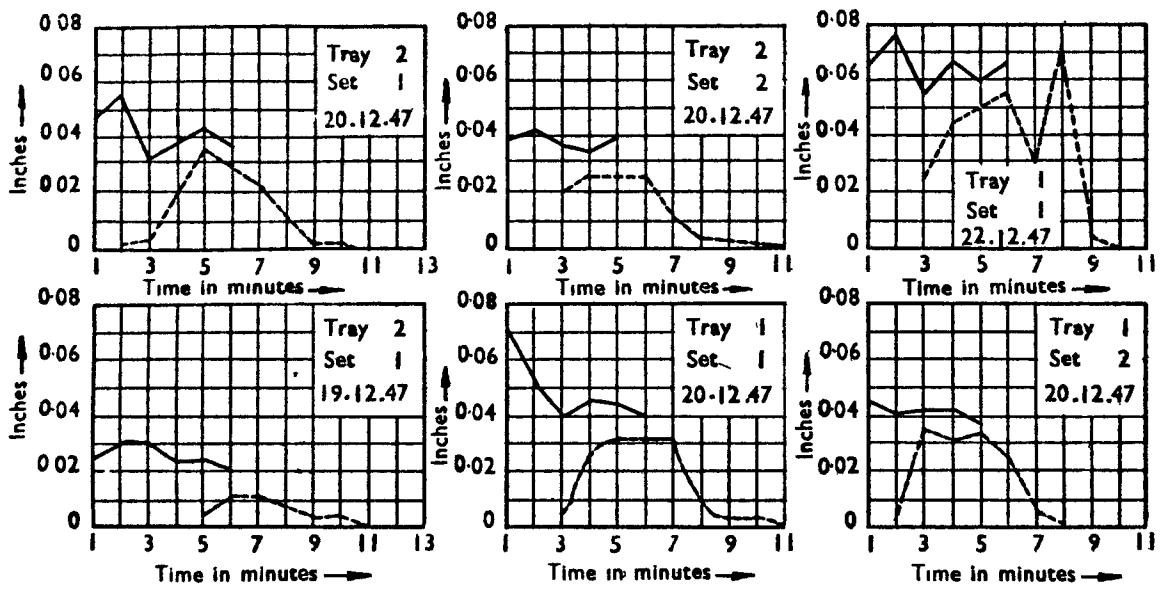
A specimen shower with rainfall runoff and calculation of intensity, etc., is shown in Table 8G.II.

TABLE 8G.II

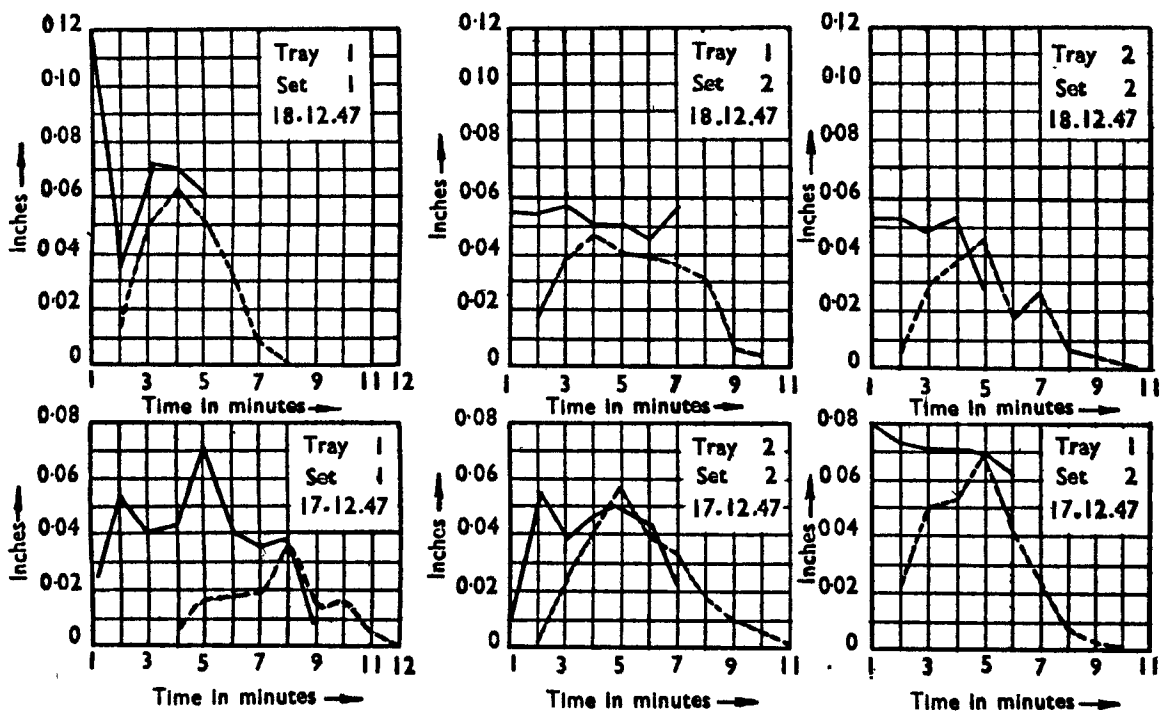
| Time in minutes, and seconds | Depth in rainfall in inches (from manometer) | Depth of runoff in inches (from manometer) |
|------------------------------|---|---|
| 0-0 | 0.00 | 0.00 |
| 1-0 | 0.052 | 0.00 |
| 2-0 | 0.098 | 0.00 |
| 3-0 | 0.146 | 0.002 |
| 4-0 | 0.186 | 0.013 |
| 5-0 | 0.226 | 0.034 |
| 6-0 | 2.262 | 0.056 |
| 7-0 | 0.298 | 0.078 |
| 8-0 | 0.332 | 0.102 |
| 9-0 | 0.366 | 0.122 |
| 10-0 | 0.396 | 0.140 |
| 10-10 | 0.40 | 0.146 |
| 10-11 | 0.40 | 0.148 |
| 10-12 | 0.40 | 0.148 |
| 10-13 | 0.40 | |
| 10-14 | 0.40 | |

We see, therefore, that for a period of 10 minutes 10 seconds a rain of 0.4 inch fell over the tray producing a runoff of 0.148 inches. In the eighth minute, it gave a maximum quantity of runoff amounting to 0.024 inch. Since one inch of runoff here amounts to 59,000 c.c. the maximum discharge in c.c. have been compiled as 22.6 c. c. per second. The intensity for the shower is 2.4 inches.

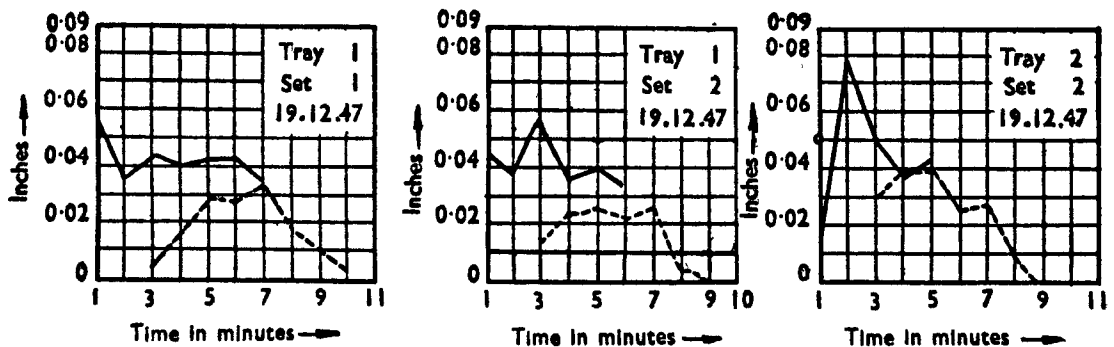
Data from different showers have been analysed to see if there exists any relationship between the intensity of rainfall and the maximum discharge.



(1)



(2)



(3)

References :-
 Rainfall in Inches —————
 Runoff in Inches - - - - -

Figure 8G.9 [1,2,3]:- Showing comparative rainfall and runoff graphs of artificial showers

The values of correlation co-efficients between these factors have been calculated separately for the two trays and their insignificance tested by the *t*-test

$$\text{where } t = \frac{r}{\sqrt{1-r^2}} \sqrt{n-2}$$

The results are given in Table 8G.III.

TABLE 8G.III

| Trays. | Value of correlation co-efficient. <i>r</i> | Degrees of freedom (<i>n</i> -2). | Observed value of “ <i>t</i> ” | Theoretical values of “ <i>t</i> ” | | Remarks. |
|----------------|--|---------------------------------------|-----------------------------------|---------------------------------------|-------------|----------------------------------|
| | | | | 1 per cent. | 5 per cent. | |
| Rectangular .. | 0.87 | 11 | 5.851 | 3.106 | 2.201 | Highly significant. |
| Circular .. | 0.67 | 11 | 2.621 | 3.106 | 2.201 | Significant on 5 per cent. level |

The value of *r* is highly significant for the rectangular tray and for the circular tray it is found to be significant on the 5 per cent. level. Further investigation will be carried out on this matter when adequate data will be available.

The investigation so far tends to show that each tray will give a separate equation owing to the variance in shape. To find out the maximum discharge more accurately it is suggested to take the manometer readings more frequently.

For each shower, the two trays gave different runoff volumes and erosion masses. To find out if it is due to the shape of the catchment that the runoff volumes vary, the significance of the difference in the percentages of runoff from the circular and the rectangular trays has been tested by Student's “*t*”-test. The value of “*t*” calculated from the runoff volume

$$\text{for 17 showers is } \int \frac{x\sqrt{n}}{Sx} = \frac{5.9 \times \sqrt{17}}{12.4} = 1.96$$

For (*n* - 1 = 16) degrees of freedom, the 5 per cent. level of significance of “*t*” is 2.16, that is, the chance of exceeding the value 2.16 in a random sample is 5 per cent. The observed value of “*t*” here is lower than this level. Therefore the chance of getting a higher value of “*t*” (or the mean diameter) in a random simultaneous sampling of the two trays is greater than 5 per cent. The difference is, therefore, not significant on the 5 per cent. level.

The difference between the erosion from the two trays has been similarly tested by Student's "t". The erosion figures have been converted to grams per inch of rainfall. By applying the t-test to the 17 pairs of erosion figures for the two trays for the same 17 showers, we get the value of "t" as

$$t = \frac{x\sqrt{n}}{5x} = \frac{4.77 \times \sqrt{17}}{7.42} = 2.65,$$

while the 5 per cent. level of significance of "t" is 2.12. Therefore the chance of getting a higher value of the mean difference in erosion than that observed here in a random simultaneous sampling of the two trays is less than 5 per cent., so that the observed value of the difference is large enough and is significant on the 5 per cent. level.

Therefore due to the shape of the catchment (other factors remaining constant) the runoff volumes do not behave differently but the erosion masses differ significantly.

Further investigations are being done with artificial showers and runoff and erosion resulting therefrom.

DISCUSSION BY THE RESEARCH COMMITTEE

- Mr. G. SINHA introduced item (1).

Mr. S. K. BANERJEE introduced items (2) and (3). As regards item (3) he said that formerly the rainfall runoff erosion observations were being carried on in small trays depending on natural showers, but several difficulties were encountered :—

(1) The first and foremost difficulty being that as it is not possible to control the intensity of shower in natural rainfall it is extremely difficult to isolate the runoff and erosion caused by separate intensities of showers. (2) The second drawback was that it was very difficult to carry on the observation when therein continued for a pretty long time. (3) The next drawback was that these observations could be carried on during the rainy season only, that is, only four months in a year.

To get over these difficulties an attempt was made to see if it is possible to carry on these observations by means of artificial showers, as in that case it would be possible to carry on the observation all throughout the year.

Accordingly two small plots of the same area and same slope were selected and rainfall runoff erosion observation was started by means of artificial showers. By this process the intensity and duration of rainfall could be varied according to desire and requirement and as such the runoff and erosion caused by separate intensities could be isolated. These experiments are being continued.

DISCUSSION BY THE BOARD

There was no discussion. It was decided to retain the subject on the agenda.

9G. The Selection of Subjects for Discussion at the Following Meeting

PRELIMINARY NOTE . .

In 1947 the subjects under discussion were rearranged into seven sections according to which we have taken up the discussion at this meeting of the Research Committee.

DISCUSSION BY THE RESEARCH COMMITTEE

The suggestion of Rai Bahadur M. C. Bijawat to change the names and sub-head (i) Yield under A—Hydrology, 7, Sub-terranean Waters to Sources and Yield was accepted.

DISCUSSION BY THE BOARD

DR. J. K. MALHOTRA suggested that certain subjects under the head G—General needed to be shifted to some other headings. 'Spray Irrigation' should go under 'Water requirements of crops', 'River Pollution' under 'Quality of Waters', and 'Soil Conservation' partly under 'Hydraulic Works', and partly under 'Soil Science'.

MR. J. C. HARDIKAR pointed out that 'River Pollution' was altogether a different subject from 'Quality of Waters' and as such should remain a separate subject as at present.

THE SECRETARY said that the Research Committee had accepted that sub-head (i) Yield under A—Hydrology, Sub-terranean Waters, be renamed "(1) Sources and Yield".

Another addition was sub-head (vi) Buildings research under E—Soil Science, 1. Soil Mechanics.

Under Section D—Water Power Works, subject 7—Miscellaneous was introduced to include the papers that were not covered by other subject heads.

The proposals of the Research Committee were approved and it was decided that other changes be left over for the Research Committee meeting.

10G. Co-ordination of Research Work for the Ensuing Year

PRELIMINARY NOTE

Last year ten Research Organisations took part in the proceedings of the Research Committee, viz:—

- (1) The Central Waterways, Irrigation and Navigation Research Station, Poona.
- (2) The Punjab Irrigation Research Institute, Lahore.
- (3) The Irrigation Research Division, Sind.
- (4) The United Provinces Irrigation Research Station.
- (5) The River Research Institute, Bengal.
- (6) The Irrigation Research Station, Madras.
- (7) The Poona Irrigation and Research Division, Poona.
- (8) The Hyderabad Engineering Research Laboratories.
- (9) The Hydraulic Research Station, Krishnarajasagar, Mysore, and
- (10) The Irrigation Research Laboratories, Ceylon.

Reports were received from all the above mentioned organisations except from Hyderabad and Ceylon and items from these reports were discussed under various subject heads.

As the reports received from some of the Research Stations were incomplete it was recommended by the Research Committee that the Research Organisation should be requested to supply complete reports giving details of all the works carried out in their respective organisations during the year. The Board at its last meeting accepted the recommendations of the Research Committee.

The Chief Engineers of the Provinces and States in Pakistan have ceased to be the members of the Board from April 1, 1948. Under the rules they can apply again for membership through diplomatic channels but none has done so far. As such the question of co-ordination of research work from (a) Irrigation Research Institute, Lahore (b) Irrigation Research Division, Sind does not arise.

The East Punjab Government have started another Irrigation Research Institute at Amritsar with their Hydraulic Research Station at Malikpur near Pathankot.

There will, therefore, be nine research organisations who will participate in the deliberations of the Eighteenth Research Committee Meeting. Complete reports from all the nine research stations have been received. Items from these reports have been listed for discussion under the various subject heads.

It is gratifying to note that Assam is planning to start an Irrigation Research and Soil Laboratory. It is further very heartening to note the increasing amount of research work being turned out by different research organisations. The number of items discussed by the Research Committee in 1944 was 41, in 1945—54, in 1946—179, in 1947—153 and this year we have 185 items for discussion.

THE YEAR'S WORK
DISCUSSION BY THE RESEARCH COMMITTEE

THE SECRETARY asked for suggestion regarding subjects which should be discussed at the next meeting.

DR. RAO said that in view of the large number of subjects, it would be better if all subjects were first discussed between research officers and then if any subject was of much importance that should be brought up to in the general meeting of the Research Committee.

DR. BOSE said that he had already suggested a similar arrangement to the Secretary. Research Officers should sit together and discuss the details of their work between themselves. He felt it was absolutely necessary that a day may be fixed for the Research Officers to meet by themselves.

THE SECRETARY said that he intended to raise discussion on this subject under "item 9—Co-ordination of Research Work for the ensuing year" but since the point had been raised, the two subject heads might be grouped for discussion. It was necessary in this connection, he said, to remember that this was primarily a Research Officers' meeting. Of course, other engineers were invited so that research officers and engineers should get to know the point view of each other. He welcomed the suggestion that some time be given to research officers to discuss matters by themselves. This was particularly necessary for the junior research officers who might feel shy of resolving their doubts in a full meeting. This necessity had also been felt earlier and from the previous year one afternoon was reserved for Research Officers meeting. This year the meeting of the National Committee of the International Conference on Soil Mechanics and Foundation Engineering had to be fitted in that period. From next year, he proposed, to set apart a complete day for the Research Officers' meeting. He suggested Wednesday or Thursday, for the purpose.

THE CHAIRMAN said that it was a very good suggestion and should be accepted.

It was decided to allot in future Thursday (4th day) for the Research Officers Meeting.

DISCUSSION BY THE BOARD

THE SECRETARY said that it was suggested at the last Research Committee meeting that each Research Station should send two copies of its annual report to all other Research Stations, instead of one copy as was being done under existing practice.

The proposal was approved.

11G. Any other Business

HISTORICAL ACCOUNT OF IRRIGATION RESEARCH DONE IN INDIA

PRELIMINARY NOTE

In 1945 the Board accepted the following resolution passed by the Research Committee.

“With a view to the compilation of an Historical Account of the research in connection with irrigation and waterways carried out in India, the Committee recommends that each organisation should supply the Secretary with a brief description of research which has been undertaken in its Province or State, stating the names of the officers responsible for each particular item of research not later than the 1st June 1946, for discussion at the 1946 meeting of the Research Committee. The Secretary, Central Board of Irrigation should then prepare a draft for approval by the Board at its 1946 meeting.

The contributions should be sent to the Secretary through Board members in order to ensure that adequate reference is made to research work done prior to the formation of Research Organisation, and by officers not directly connected with the latter.”

The Board further resolved, “that contributions should be compiled under subjects mentioning the various officers who had dealt with the particular subject”.

In this connection contributions for the draft publication have been received from Bombay, the Central Waterways, Irrigation and Navigation Research Station, Poona, United Provinces, Hyderabad and Bengal. Ceylon has nothing to contribute. Sind sent in a note but after scrutiny it was returned for further amplification. East Punjab has promised to send in a contribution. Replies from Madras and Mysore are still awaited.

THE YEAR'S WORK

DISCUSSION BY THE RESEARCH COMMITTEE

THE SECRETARY said that he desired to draw the attention of the Research Committee to the necessity of translating technical terms into the National language. It would probably be necessary to set up a special agency for the purposes. He did not propose that they should come to an immediate decision on the subject, but he wanted them to give this important matter their best consideration and let him have their suggestions. Perhaps by the time of the Annual Board Meeting, they should take a decision in the matter and set up a proper organisation for the work.

MR. GOVINDA RAO said that in Madras there were already two committees working on this subject. The Secretary might get in touch with them.

RAI BAHADUR BIJAWAT suggested that the words to be selected should be simple and expressive.

DR. MALHOTRA said that the test should be, how expressive and short a word is and that it might be useful to retain such words even if they did not strictly belong to the national language.

THE CHAIRMAN said that serious efforts in this direction would have to be made and he desired that suggestions be forwarded to the Secretary so that a decision be possible at the Board Meeting.

The meeting came to a close with a hearty vote of thanks to the Chair.

DISCUSSION BY THE BOARD

THE SECRETARY referred to page 318 of the technical agenda and said that contributions on the subject (Historical account of Irrigation Research done in India) were still awaited from East Punjab and Mysore.

Discussion was then taken up on the item "Translation of Technical Terms into the National Language".

THE SECRETARY said that a letter was addressed to all Board Members and Research Officers in India inviting suggestions on the subject so that a decision might be possible at the meeting. The following is a summary of the replies received :

(1) *Central Electricity Commission*.—Intimates that the Chairman is generally in favour of adopting, for technical terms, the expression already in use and would rather like switching on for all to International Terms.

(2) *River Research Institute, West Bengal*.—States that it is not clear what National language is meant. Intimates further that translation of some of the technical terms into Bengali has already been undertaken by the Bangiya Sahitya Parishad and Bangiya Biggyan Parishad in Calcutta.

(3) *Chief Engineer, Mysore*.—Informs that no organisation for such work exists in Mysore State.

(4) *Electrical Commissioner, Government of Bombay*.—Suggests that professors in Indian Engineering Colleges be given honoraria to work up the necessary vocabulary in Hindi, a course adopted by the Osmania University (Hyderabad-Deccan) and that further Education Department should depute some selected individuals to write the text books in Hindi. It is, however, added that international words like volts, amps, current *etc.* should stay as they are, in the National language.

(5) *Chief Engineer, Irrigation—Hyderabad*.—Intimates that individual efforts for translating engineering terms in Hyderabad did not prove successful and the Government, as a result, established a Translation Bureau which has been doing large amount of works during the last 25 years. The terms coined or translated by the Bureau are in Urdu. Further suggests that for details the Director of Translation Bureau may be addressed.

(6) *Director, Translation Bureau, Osmania University, Hyderabad*.—On a request, the Director has supplied a copy of Numerical Index to Technical Terms compiled and coined so far, a copy of each of Mathematical and Astronomical Terms, a list of publication in Engineering and allied subjects of the Translation Bureau. These will be put up for perusal at the meeting.

(7) *Executive Engineer, Irrigation Research Division, United Provinces*.—Suggests that the Hon'ble Minister for Communications, United Provinces and the Vice-Chancellor, Banaras University may be referred on the subject.

(8) *Executive Engineer, Poona Irrigation and Research Division*.—Suggests to contact Dr. Raghuvira who has published a dictionary of technical terms and further informs that (1) Secretary, International Academy of Indian Culture, Poona Branch, (2) Maharashtra Sthapatya Sabha, Poona, (3) Dr. D. D. Karve, Principal, Fergusson College, Poona and (4) Rao Bahadur N. S. Joshi, Poona have promised to help in preparing technical terms.

(9) *Director, Irrigation Research, East Punjab*.—Suggests the following points for the consideration of the Board :

(i) Chalking out a programme according to which the technical irrigation terms might be rendered into the National Language and taking necessary steps to this end. Points out that start should be made rather than fixing a target date for the completion of the work.

(ii) Forming of a policy for the source of technical vocabularies in the National Language *viz.*, whether Sanskrit or the technical terms as are being used to stay as they are in the National language.

(iii) Translation of allied sciences like mathematics, physics *etc.* as they are essential in connection with the translation of irrigation terms.

(iv) Persons to be entrusted with the translation work *viz.*, whether linguists and philologists alone or in association with the engineers and also whether C.B.I. would take up the job itself or leave it to individual or provincial enterprise.

(v) Writing of National Language terms in Roman also for a limited period so that provinces who do not use it may become familiar with the new terms.

(vi) Translation of text books and other publications into National Language.

(vii) Volunteers services of Dr. J. K. Malhotra and of self, if required.

(10) *Chief Engineer, P.W.D., Assam.*—Suggests to contact (1) Dr. Raghuvira, (2) Vigyan Parishad, Allahabad, (3) Dr. Vasudev Sharma, Agarwala Archaeological Department, Delhi and (4) Hindi Sahitya Samelan, Allahabad on the subjects.

(11) *Chief Engineer, Travancore.*—Intimates that no attempt has been made in the state to translate technical terms into the National Language.

(12) *Chief Electrical Engineer, Mysore.*—Holds that English should be retained so that higher studies in Engineering and science can be taught and understood in this international language, thus enabling Indian engineers to contribute their mite to the knowledge of the world.

(13) *Chief Engineer, West Bengal.*—Informs that in West Bengal, a committee composed of eminent scholars of the province has been appointed for translation of English technical terms in administrative use into Bengali and it is hoped that gradually all the English technical terms will be translated into Bengali by that committee. Suggests that a similar committee may be formed for the job and that the Engineering or Technical Departments should confine their activities in compiling as many technical terms as possible and in getting them translated by the said committee.

(14) *Chief Engineer, Irrigation Works, East Punjab.*—Informs that the Director of Public Instructions, East Punjab may be contacted on the subject. He has also passed on a copy of C.B.I. letter to the Chief Engineer Buildings and Roads, East Punjab for suggesting suitable words and phrases in Hindi for the English words and phrases contained in Chapter I of the Manual of Irrigation Practice.

(15) *Secretary to Government, P.W.D., Bombay* informs that (1) the Maharashtra Sahitya Parishad, Poona and (2) The Maharashtra Sathapatya Mahasabha, Poona who have done some work on the subject may be addressed.

(16) *Director, Hydraulic Research Station, Krishnarajasagar* suggests that most of the technical terms now in use may be incorporated as such so that it will be easy for all to understand or all terms may be translated into Sanskrit and incorporated into all local languages.

(17) *Vigyan Parishad, Allahabad* informs that glossary of scientific terms printed by it is out of stock and further intimates that Hindi Parishad, Allahabad, Shri Sukh Sampat Rai Bahadur, Ajmer and Dr. Raghuvira may be addressed on the subject.

(18) *Director, Engineering Research Laboratories, Hyderabad* suggests that the Director, Translation Bureau, Osmania University may be consulted in this connection.

(19) *Banaras Hindu University* informs that this type of work has been done by the Nagari Pracharini Sabha, Banaras and the Hindi Sahitya Samelan, Allahabad and not by this University.

(20) *Chief Engineer, Electricity Branch, East Punjab* suggests that a special committee should be set up for the job after collecting all available literature on the subject and also draws attention to the work done by the Osmania University.

(21) *Chief Engineer, Central Provinces and Berar* intimates that Dr. Raghuvira has done a good deal of valuable work on the subject and may be consulted.

(22) *Chief Engineer (Special) Irrigation, Madras* informs that the Government of Madras have appointed a committee to prepare Encyclopedia for local provincial terms and they may be helpful in translation work and further suggests that the Government of Madras may be approached on the subject.

(23) *Chief Engineer, Bikaner* has forwarded a number of irrigation forms that are being used containing exact translation of Urdu form.

(24) *Chief Engineer, Irrigation Branch, United Provinces* informs that the translation work is being done by the United Provinces and Central Provinces Governments, Hindi Sahitya Samelan and the Nagri Pracharni Sabha.

(25) *Hindi Sahitya Samelan, Allahabad* intimates that they are just starting with the work but are ready to lend all help to the C.B.I. for the Irrigation Section.

(26) *Executive Engineer, Irrigation Research Station, Madras* has no suggestion to make except that English words should be retained to the extent possible in view of their international application.

(27) *Dictionary Publishing House, Ajmer* intimate that they have published five volumes of 20th Century English Dictionary of scientific and technical terms which may be of some use to the C.B.I. Also forwards some literature about the details of the dictionary.

(28) *President Maharashtra Sathapatya Mahasabha, Poona*, has recommended that the matter be referred to Prof. S. V. Apte who is M.A. in Physics, a scholar in Sanskrit and a retired Professor of the College of Engineering, Poona, who is already busy in the framing of scientific words. Forwarded a list of technical terms in Hindi.

(29) *Chief Engineer, Orissa*.—It is not advisable for the Central Board of Irrigation to take up this work just now. A beginning will have to be made in the Engineering Institutions for preparing text books on Engineering subjects in the National Language. Hence the future engineers who study through those text books as well as those in foreign languages will be in a better position to translate the technical terms.

(30) *The Secretary, Maharashtra Sathapatya Mahasabha, Poona*.—Referred to the list of words supplied by the President of the Mahasabha. This vocabulary should serve as guidance at the discussions at the meeting of the Central Board of Irrigation :

(2) “ The actual framing of words is not left to any individual writer of essays published by the Mahasabha, but framed by our expert Prof. Sakharam Vinayak Apte, who is both a scientist being M.Sc. (Physics) and a Sanskrit Scholar and a student of Etymology. ”

(3) “ The Association gave deep thought to this type of work and after many discussions and mature considerations came to the conclusion that it is neither desirable nor practicable to proceed with the work of framing scientific words by itself. Such an act will fail in its objective, unless accompanied by actual writings (papers) in local languages. These too must be done side-by-side essays written in national language and scientific words for that essay framed and introduced simultaneously in the essays and discussed ”.

(31) *Honorary Secretary, Paribhasha Mandal, Maharashtra Sahitya Parishad, Poona*.—“ The terminology Committee of this Parishad has compiled and published in a book form a large number of terms dealing with the basic sciences like Physics, Chemistry, Mathematics, Botany, Geology etc. The publication is, however, now out of point, and a second edition is under preparation. In this edition, a number of scientific branches which could not be taken up in the first edition are being included. The Committee will, however, be glad to supply your Board in advance the necessary equivalents which could be used in National language, if you could kindly supply me a list of English terms for which equivalents are sought ”.

(32) *Director of Public Instructions, East Punjab*.—No work regarding translation of technical terms in the National Language has so far been done by this department.

(33) *Secretary to Government of Orissa, Public Works Department, Electricity Branch.*—The Central Advisory Board of Education, in pursuance of a recommendation of the Scientific Terminology Committee, appointed a board of reference to deal with all questions regarding the grouping of Indian Languages according to their natural affinities and issues arising in connection with the adoption of Scientific as well as Technical terms in those languages. On the suggestion of the Board, five Regional Committees to deal with different languages were set up and Bengali, Assami, and Oriya constituted the Eastern Group. The Board also approached the Provincial Government regarding setting up of a regional committee for the above languages forming the eastern group. Government accepted the suggestions on the setting up of a Regional Committee for the languages Bengali, Assamese and Oriya forming the Eastern Group.

The authorities of the Utkal University, who were consulted in the matter have intimated that so far no translation of technical terms has been made by them. However they have appointed a Paribhasa Committee who will consider among other matters the question of translating from foreign languages and coining suitable words in Oriya for various purposes.

(34) *Chief Engineer, Irrigation Department, Bihar.*—Forwarded a copy of a memo from the Translation Department, Government of Bihar containing informations and suggestions on the subject.

The Board might be interested to know that a Hindi version of the Central Board of Irrigation Leaflet No. 3.—New Projects for Irrigation and Power in India—1948 had been prepared by Dr. Raghuwira, Member Constituent Assembly and was now ready for the press. The Secretary had also started to prepare a card catalogue of all Hindi words relating to Mathematics, Physics and Engineering.

A general discussion then ensued in which many members took part. No decisions were taken but the general concensus of opinion was :—

- (i) All technical engineering terms should be translated into Hindi and the engineers and philologists should co-operate in this work. For the next many years the Hindi terms and the English terms should be used side by side. It was felt that at this stage English terms should not be discarded.
- (ii) All technical terms translated into Hindi should be adopted in all other Indian languages so that throughout India the same technical terms would appear in all languages with minor modifications, if any.
- (iii) Articles in Hindi should be encouraged in the Central Board of Irrigation Journal.

It was agreed that the work taken in hand on the translation of technical terms should continue and as more experience was gained it would be possible to take final decisions.

THE SECRETARY then requested Dr. J. K. Malhotra to read a few pages from the Hindi version of Leaflet No. 3 to give Members an idea of the work done.

DR. J. K. MALHOTRA read out some extracts.

MR. S. A. GADKARY proposed a vote of thanks to the President and said that the members of the Board, and of its Executive Committee appreciated highly his guidance for the last three years and the services rendered by Mr. Khosla to the Board. He hoped that his guidance would be forthcoming in future also in the same manner as when he was in the Presidential chair. So on behalf of everyone he wished to record their appreciation of his work and service to the Board.

MR. P. B. ADVANI endorsed all that had been said by Mr. Gadkary.

THE PRESIDENT thanked all the members and said that it had been a rare privilege for him to be associated with this Board for such a long time. He assured them of his help in the years to come.

APPENDICES

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APPENDIX I

Damodar Catchment*

PRELIMINARY SURVEY TO STUDY WATER LOSSES BY TRANSPIRATION AND EVAPORATION

by

R. K. Misra,

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The Damodar Catchment consists of the "basin" and "plain" areas (Figure 1). The former lies in Bihar and the latter in West Bengal. It is the basin area of the catchment which is primarily important from the view point of development, and it is this area that is referred to as the Damodar Catchment. Places of main activity with regard to the collection of actual data are shown in Figure 2.

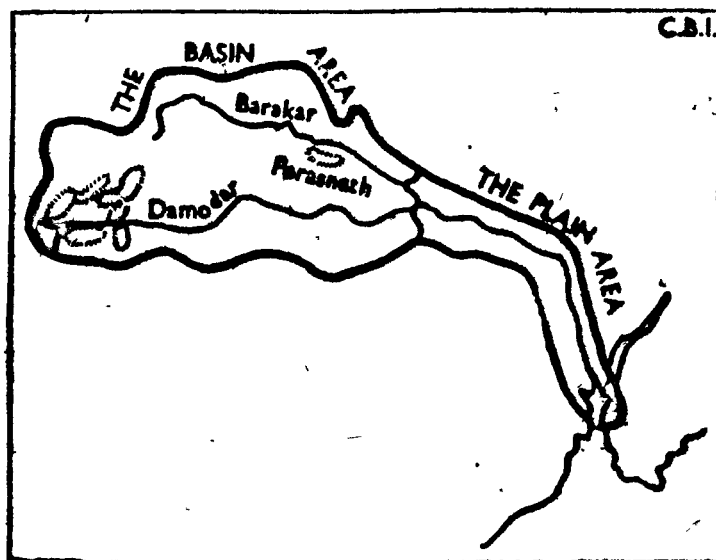


Figure 1 : *The Damodar Catchment.*

*A revised form of the report that was presented to the Sub-committee on Water balance investigations the Damodar Valley on April 15, 1948.

The Damodar Catchment comprises mainly the Hazaribagh and Manbhum districts. It also includes parts of Palamau, Ranchi and the Santal Parganas. The approximate area of each of the above districts enveloped by the catchment is given in Table 1.

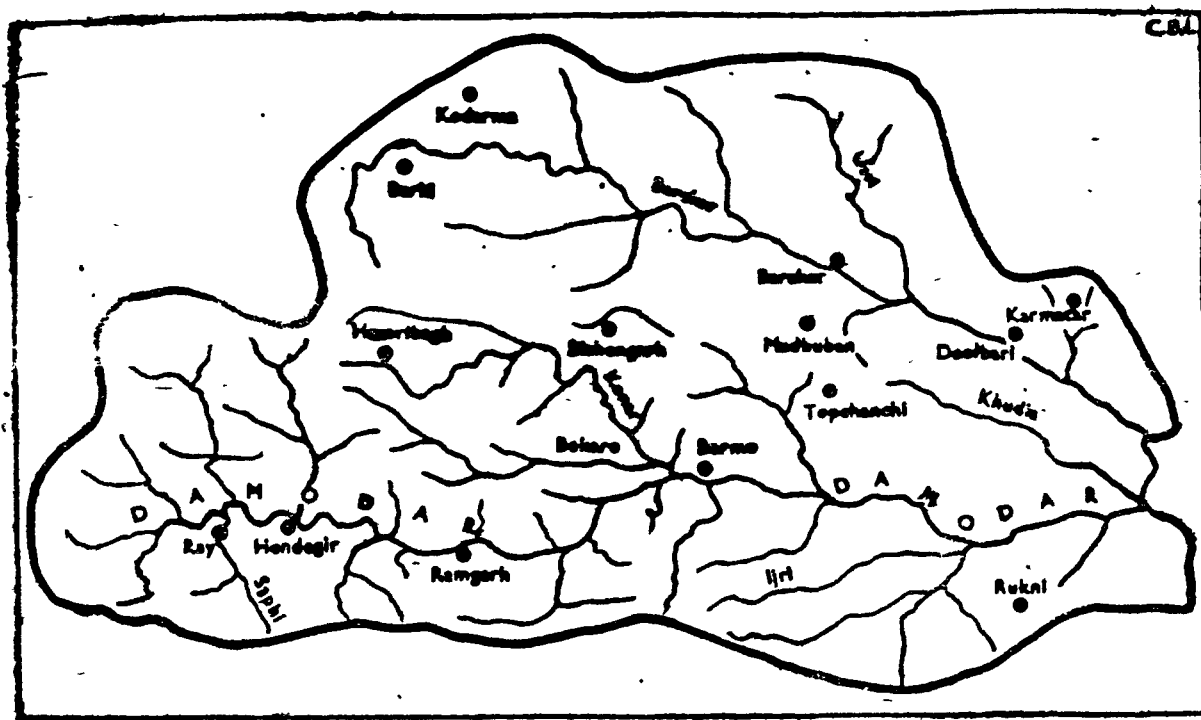


Figure 2: Index map of Damodar Catchment indicating the places visited and in particular where detailed observations were made.

TABLE J

Approximate area of the five districts of Bihar falling within the Damodar Catchment.

| District | Area in square miles |
|----------------|----------------------|
| Hazaribagh | 4,600 |
| Manbhum | 1,690 |
| Palamau | 290 |
| Ranch | 390 |
| Santal Pargana | 230 |
| Tota | 7,200 |

The catchment is a region of plateaux and mountainous spurs. The highest peak in the catchment is that of Parasnath—4430 feet in height—belonging to the Tundi hills which are situated

near the boundary of the Hazaribagh and Manbhum districts. The elevations of the various places of the catchment visited in connection with the present work are given in Table II. Names within brackets indicate the actual places where the altimeter was read.

TABLE II

Approximate height of certain places of the Damodar Catchment in feet above sea level.

| Places | Height in feet |
|------------------------------|----------------|
| Barhi (Kolunga) | 1 300 |
| Barakar Giridih (Dhetlagarh) | 700 |
| Karmatar | 700 |
| Deolbari (Kasiatar) | 500 |
| Topchanchi (Deya Buspahar) | 800 |
| Madhuban (Khaperberha) | 1 000 |
| Gumia (Hazari) | 700 |
| Phusro (Naklmauja) | 800 |
| Bishengarh | 1,600 |
| Hazaribagh (Morangi) | 2,200 |
| Ray | 1,300 |
| Hendegir | 1,800 |
| Rukn | 400 |

The chief plateaux of the area are those of Ranchi and Hazaribagh. Their height varies from about 1,000 feet to 2,000 feet.

RIVERS OF THE CATCHMENT

The Damodar Catchment actually consists of the two basins of the Damodar and Barakar rivers. The Tundi hills serve as the main water parting between these two basins.

Many small streams of the Chota Nagpur plateau combine to form the Damodar river in Palamau district about 25 miles away from the south western boundary of Hazaribagh. This river then runs a course of about 90 miles through south Hazaribagh and then traverses about 250 miles through the Manbhum, Bankura, Burdwan and Hooghly districts before joining the Hooghly below Calcutta.

The biggest tributary of the Damodar is the river Barakar. Chief amongst other are Garhi or Tandwa, Haharo, Naikari, Marmarha, Bhera, Konar, Bokharo, Khanjo and Jamunia.

Barakar originates in the northern plateau of Hazaribagh. First it flows towards the north. From about Barhi it changes its course to east by south, passes through north of the Parasnath range and then crosses the Hazaribagh boundary 32 miles before joining the Damodar near Kulti. Its main tributaries are Leruja, Gokhana, Akta, Kisko, Bareto, Arga, Usri and Barakhatha.

The rivers of this area are fed only by rainwater. Floods of brief duration follow the rainfall. When this water has been discharged into the sea very little remains in the river beds. The summer more or less dries off all the rivers.

Wells are numerous in this area but very little water remains in these after the winter season.

ROCK

The rock of the catchment is Archaean gneiss (Benal gneiss). There are isolated areas of Gondwana rocks along and, at some places, even within the Damodar bed as well as in the Barakar valley around Giridih. Micaceous shales are abundant north of Barakar River especially in the Barhi-Kodarma sector.

The Archaean rocks is either itself exposed or bears its debris on the top throughout the catchment. The decomposition product is a loamy soil with many shades of red colour.

DISTRIBUTION OF TREES AND PLANTS

FORESTS

The forests of this area belong, according to H.G. Champion's classification, to the (i) Dry and (ii) Moist Peninsular *Sal* type. The prominent species of these forests are woody, and deciduous in habit. The leaf-fall in case of these species occurs during March and April. The *sal*, itself has a very brief period of leaf-fall, say about a month starting by the end of February. Champion while writing about the moist deciduous forests, which are found in this area mainly along the rivers and on high hill says that in such cases the *sal* has a semi-evergreen habit with only a very brief deciduous period of 5 to 15 days. Fresh leaves are slowly set forth after the period of leaf-fall so that by the end of May or beginning of June the new leaves acquire the normal size. While the new leaves are still being set forth, the flowering followed by fruiting sets in.

The forests of this area have been and are still mostly under private ownership. The process of "reservation" has yet to begin on a mass scale.

AGRICULTURE

The shape, size and location of the agricultural lands are influenced by the general undulating nature of the tract. Level stretches of land are infrequent. Terraced fields with high *bunds* is the general rule.

The crops being mainly rainfed are raised during the monsoon and post-monsoon period. The land lies mostly fallow during the rest of the year.

"*Jhuming*" is a characteristic feature of agriculture in certain parts of this area involving shifting cultivation, the destruction of the forest cover and the consequent exposure of the soil to erosion.

GENERAL IMPRESSIONS REGARDING THE VEGETATIVE COVER

Any person who passes through the Damodar Catchment cannot fail to note the unplanned deforestation and eroded wastelands. Erosion appears to be widespread at least 80 per cent. of the land being affected by it. Gullies of the worst type are frequently, to be met with in the forest areas (Figure 3). Gullying and scouring are common in the agricultural surroundings as well as on the waste lands (Figures 4 and 5). Stream erosion is frequently met with on the banks of *nalas* and rivers. The most severely affected areas are the northern tracts of the Hazaribagh district between Barhi and Giridih the Santal Parganas near Karmatar and the southern tracts of the Manbhum district.

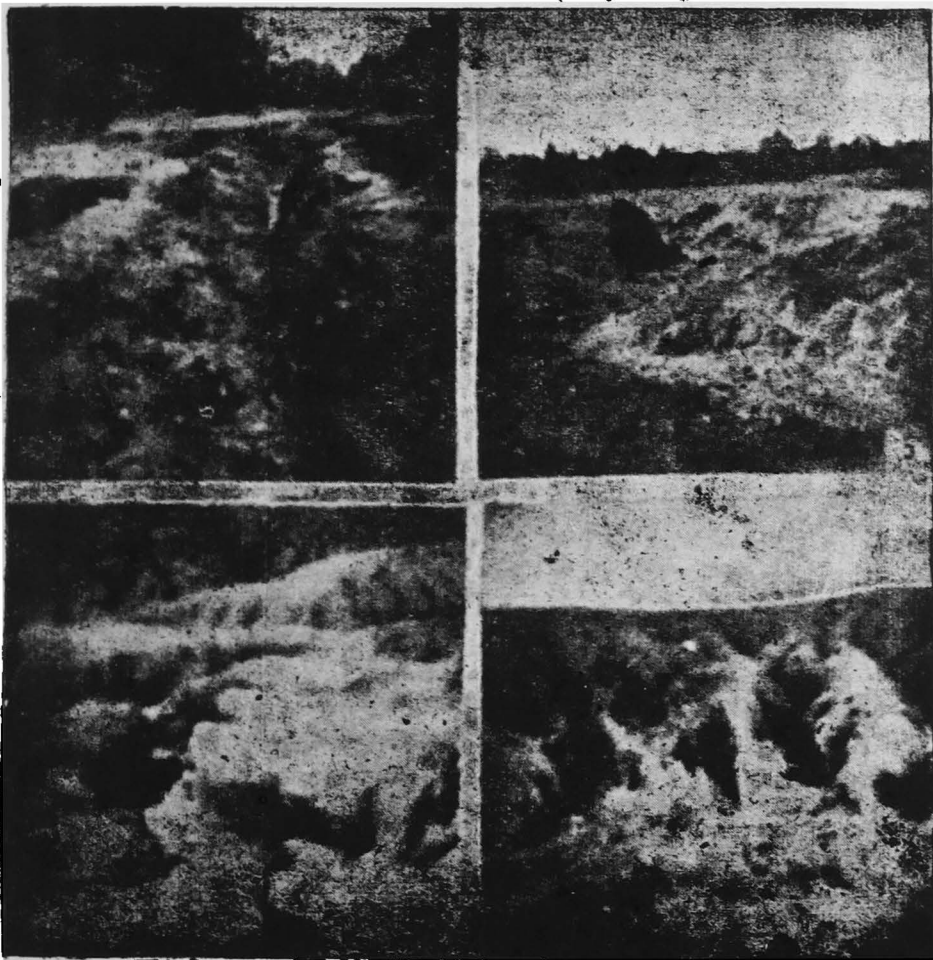


Figure 3: *View of a huge gully within a forest. Such gullies are quite common in the forest areas as well as on the waste lands.*

Figures 4 and 5: *Gullying and scouring of the waste lands.*

Figure 6: *A magnified view of small fissures and finger gullies on one side of the bund of a paddy field.*

Rapid deforestation and the erosion which follows it are in evidence every where (Figure 7). Surface excavation for minerals has also led to erosion in the mining tracts. Agricultural practices including *Jhuming* have aggravated local erosion.



Figure 7: Picture depicting the way in which the exploitation of forests by man has been going on ceaselessly. The stumps are the only remains of the huge trees. The sapling forest in the background may be noted in contrast to larger trees of the fore-ground. The exploited area has been ploughed and it is here that the erosion would start its picy.

DISTRIBUTION OF VEGETATION

The areas of the catchment under various categories which will be given here are based on the means of the three years' figures of the Season and Crop Report of the Agricultural Department of Bihar, the years being 1943-44, 44-45 and 45-46.

Area under forests, cultivation, etc.—Table III contains the areas of the catchment under forest and cultivation. It also shows the area which is lying waste, culturable or otherwise, and which is not available for cultivation. It will be seen that the forests cover about 33 per cent. of the total area and nearly an equal percentage is under cultivation.

TABLE III

Distribution of the area of the catchment

| Area under | Area in square miles |
|-------------------------------|----------------------|
| Forests | 2,380 |
| Not available for cultivation | 860 |
| Waste lands | 860 |
| Fallow | 940 |
| Under cultivation | 2,160 |
| Total | 7,000 |

Area under crops—The crops grown in the catchment are indicated below.

- | | |
|---|--------------------------------------|
| 1. Winter rice. | 15. Rape and Mustard. |
| 2. Autumn rice. | 16. Groundnut. |
| 3. Summer rice. | 17. Coconut. |
| 4. Wheat. | 18. Castor. |
| 5. Barley. | 19. Condiments and spices. |
| 6. Jowar. | 20. Sugarcane. |
| 7. Bajra. | 21. Cotton. |
| 8. Marua. | 22. Jute. |
| 9. Maize. | 23. Indigo. |
| 10. Gram. | 24. Tea. |
| 11. Arhar. | 25. Tobacco. |
| 12. Other food grains including pulses. | 26. Fodder crops. |
| 13. Linseed. | 27. Fruits. |
| 14. Til. | 28. Potatoes. |
| | 29. Vegetables including root crops. |

Area under the principal crops is given in Table IV. Rice is the main crop covering about 55 per cent. of the total area under cultivation.

TABLE IV

Area of the catchment covered by the principal crops.

| Area Under | Area in square miles |
|------------------------------|----------------------|
| Winter rice | 800 |
| Autumn rice | 550 |
| Maize | 150 |
| Rape and Mustard | 60 |
| Gram | 50 |
| Til | 30 |
| Barley | 30 |
| Linseed | 20 |
| Wheat | 10 |
| Sugarcane | 10 |
| Other crops | 150 |
| Total area under cultivation | 2,160 |

VEGETATION

The vegetation of the catchment, excluding the crops, may be grouped as (i) forest vegetation and (ii) that other than forests. The vegetation on waste lands, along roadsides and in the form of groves is included in the latter. An attempt was made to estimate the total number of plants in the catchment and their sizes during the tour under review. The following may be noted in this connection :—

- (1) Observations were taken at eleven places scattered over the whole area of the Damodar Valley.
- (2) The area observed at each place was 100 feet by 100 feet. Thus the total area of the catchment sampled was 110,000 square feet.
- (3) The observations consisted of: (i) number of plants, (ii) over-all height of representative plants in feet, and (iii) breast-height diameter of the main stem in inches.
- (4) Plants with a breast-height diameter of over two inches have been referred to as trees and those below two inches as saplings.

The forest vegetation.—The number of trees and saplings of some twenty-two species of plants common in the forests of this area is given in Table V. It represents the total sampled area of the forests. The first five species in the table represent 72 per cent. of the total number of plants of the sampled area. *Sal* alone represents 46 per cent. This species is most predominant and the forests of this area are indeed called after its name. The other four, *viz.*, *Kend*, *Piuar*, *Asan* and *Bhelwa* represent 11, eight, four and three per cent. respectively. All these are utilized mainly for timber; *Sal* yields the best out of these. Natives eat *Kend* and *Bhelwa* fruits also. The stone of *Bhelwa* fruits yields oil for the natives. *Manua* fruits are used for various purposes including distillation. The flowers of *Dudhki* shrub are campanulate and collect honey-dew in their funnels in the morning which is liked by the natives. *Indrajauz* shrub bears seeds which have a tuft of very soft light brown hairs double the size of the seed. This shrub can beneficially be exploited for its beautiful fibre. The fruits of *Harra* and *Bahera* are used as spices and they have medicinal value as well.

Table V bears out one more feature very prominently. A large part of the forest tract is populated by saplings. This itself is a clear indication of the rapid deforestation which has been going on for decades.

Table VI gives the number of plants and certain measurements on the first five species of Table V place-wise. Other species have been grouped together and their number and measurements are also given in Table VI.

TABLE V

The number of common plant species met within an aggregate area of 11,10,000 square feet sampled from the forests of the catchment.

| Local name of the species | Botanical name | Number of trees | Number of saplings | Total |
|---------------------------|---------------------------------------|-----------------|--------------------|--------------|
| 1. Sal | <i>Shorea robusta</i> | 390 | 1,480 | 1,870 |
| 2. Kend | <i>Diospyros melanoxylon</i> | 37 | 403 | 440 |
| 3. Piyar | <i>Buchanania latifolia</i> | 40 | 299 | 339 |
| 4. Asan | <i>Terminalia tomentosa</i> | 25 | 151 | 176 |
| 5. Ehelwa | <i>Semecarpus anacardioides</i> | 27 | 102 | 129 |
| 6. Kanela .. .. | .. .. | 1 | 94 | 95 |
| 7. Dhaura | <i>Anogeissus latifolia</i> | 11 | 72 | 83 |
| 8. Mahua | <i>Bassia latifolia</i> | 29 | 43 | 72 |
| 9. Dudhki .. .. | .. .. | 0 | 68 | 68 |
| 10. Indrajawa .. .. | .. .. | 0 | 68 | 68 |
| 11. Kanode | <i>Carissa spinarum</i> | 4 | 58 | 62 |
| 12. Jamun | <i>Eugenia jambolana</i> | 1 | 49 | 50 |
| 13. Aonla | <i>Emblica officinalis</i> | 0 | 44 | 44 |
| 14. Harra | <i>Terminalia chebula</i> | 4 | 37 | 41 |
| 15. Sidha | <i>Lagerstroemia parvifolia</i> | 4 | 19 | 23 |
| 16. Paisar | <i>Pterocarpus marsupium</i> | 3 | 7 | 10 |
| 17. Kusum | <i>Schleichera trijuga</i> | 8 | 0 | 8 |
| 18. Dhak | <i>Butea frondosa</i> | 7 | 1 | 8 |
| 19. Babera | <i>Terminalia belerica</i> | 0 | 7 | 7 |
| 20. Karam | <i>Adina cordifolia</i> | 4 | 0 | 4 |
| 21. Ga'gal | <i>Cochlopermum gossypium</i> | 3 | 1 | 4 |
| 22. Gamhar | <i>Gmelina arborea</i> | 1 | 1 | 2 |
| 23. Miscellaneous .. .. | .. .. | 31 | 404 | 435 |
| Total .. .. | .. .. | 690 | 3,400 | 4,038 |

TABLE VI

Principal species of plants met within an area of 10,000, square feet sampled at each of the following places and their mean height in feet and diameter in inches.

| Places | Sal | | | | | | Kend | | | | | |
|-----------------|--------|--------|-----------|----------|--------|-----------|---------------|--------|-----------|----------|--------|-----------|
| | Trees | | | Saplings | | | Trees | | | Saplings | | |
| | No. | Height | Dia-meter | No. | Height | Dia-meter | No. | Height | Dia-meter | No. | Height | Dia-meter |
| Barhi | 32 | 19 | 3.7 | 59 | 6 | 1.2 | 0 | .. | .. | 83 | 6 | 1.7 |
| Barakar-Giridih | 40 | 22 | 4.2 | 74 | 8 | 1.1 | 6 | 24 | 7.9 | 49 | 5 | 1.1 |
| Madhuban | 59 | 25 | 5.0 | 59 | 11 | 1.5 | 5 | 18 | 4.6 | 12 | 5 | 1.0 |
| Karmatar | 44 | 18 | 3.9 | 161 | 11 | 1.7 | 0 | .. | .. | 9 | 3 | 0.4 |
| Deolbari | 50 | 19 | 3.7 | 320 | 10 | 1.6 | 0 | .. | .. | 112 | 5 | 0.9 |
| Bermo | 17 | 28 | 5.7 | 24 | 7 | 1.1 | 3 | 12 | 2.9 | 16 | 5 | 1.2 |
| Bishengarh | 8 | 27 | 6.7 | 256 | 11 | 1.3 | 0 | .. | .. | 12 | 8 | 1.2 |
| Hazaribagh | 48 | 26 | 5.7 | 168 | 9 | 1.2 | 4 | 20 | 3.5 | 16 | 6 | 1.5 |
| Ray | 40 | 29 | 5.0 | 75 | 11 | 1.5 | 9 | 19 | 3.0 | 33 | 7 | 1.1 |
| Ramgarh | 8 | 19 | 2.7 | 116 | 10 | 1.5 | 10 | 13 | 3.2 | 38 | 8 | 1.6 |
| Rukni | 44 | 15 | 2.7 | 168 | 13 | 1.4 | 0 | .. | .. | 23 | 3 | 0.7 |
| Places | Piyar | | | | | | Asan | | | | | |
| | Trees | | | Saplings | | | Trees | | | Saplings | | |
| | No. | Height | Dia-meter | No. | Height | Dia-meter | No. | Height | Dia-meter | No. | Height | Dia-meter |
| Barhi | 0 | .. | .. | 13 | 5 | 0.9 | 2 | 10 | 3.5 | 1 | 10 | 2.0 |
| Barakar-Giridih | 1 | 15 | 4.0 | 36 | 5 | 0.9 | 0 | .. | .. | 8 | 5 | 1.1 |
| Madhuban | 14 | 18 | 3.7 | 23 | 11 | 1.6 | 11 | 22 | 4.9 | 67 | 7 | 1.0 |
| Karmatar | 0 | .. | .. | 2 | 4 | 1.0 | 0 | .. | .. | 27 | 5 | 0.4 |
| Deolbari | 0 | .. | .. | 112 | 7 | 1.1 | 0 | .. | .. | 0 | .. | .. |
| Bermo | 4 | 19 | 4.3 | 11 | 6 | 1.0 | 0 | .. | .. | 0 | .. | .. |
| Bishengarh | 14 | 18 | 3.5 | 16 | 9 | 1.1 | 0 | .. | .. | 4 | 5 | 0.5 |
| Hazaribagh | 8 | 27 | 6.0 | 20 | 11 | 1.4 | 8 | 23 | 3.5 | 16 | 10 | 1.2 |
| Ray | 2 | 22 | 4.0 | 20 | 8 | 1.5 | 0 | .. | .. | 15 | 8 | 1.4 |
| Ramgarh | 6 | 16 | 3.3 | 28 | 9 | 1.5 | 4 | 15 | 2.6 | 10 | 9 | 1.3 |
| Rukni | 1 | .. | .. | 18 | 7 | 1.1 | 0 | .. | .. | 3 | 11 | 1.7 |
| Places | Bhelua | | | | | | Miscellaneous | | | | | |
| | Trees | | | Saplings | | | Trees | | | Saplings | | |
| | No. | Height | Dia-meter | No. | Height | Dia-meter | No. | Height | Dia-meter | No. | Height | Dia-meter |
| Barhi | 0 | .. | .. | 2 | 6 | 1.3 | 2 | 40 | 17.0 | 91 | 7 | 1.2 |
| Barakar-Giridih | 0 | .. | .. | 5 | 7 | 1.5 | 4 | 18 | 5.2 | 46 | 8 | 0.9 |
| Madhuban | 0 | .. | .. | 7 | 14 | 2.0 | 10 | 24 | 5.1 | 95 | 9 | 0.9 |
| Karmatar | 0 | .. | .. | 2 | 7 | 1.3 | 1 | .. | .. | 8 | .. | .. |
| Deolbari | 0 | .. | .. | 32 | 9 | 1.7 | 16 | 33 | 10.0 | 180 | 8 | 1.3 |
| Bermo | 0 | .. | .. | 0 | .. | .. | 30 | 21 | 6.1 | 33 | 10 | 1.8 |
| Bishengarh | 12 | 13 | 2.6 | 8 | 9 | 1.3 | 11 | 21 | 7.3 | 154 | 10 | 1.0 |
| Hazaribagh | 8 | 14 | 3.5 | 12 | 11 | 2.0 | 13 | 21 | 4.0 | 40 | 9 | 1.2 |
| Ray | 1 | 11 | 2.5 | 4 | 9 | 1.5 | 7 | 36 | 12.0 | 84 | 10 | 1.2 |
| Ramgarh | 8 | 10 | 2.8 | 24 | 9 | 1.5 | 16 | 30 | 7.9 | 131 | 8 | 1.4 |
| Rukni | 0 | .. | .. | 6 | 10 | 1.5 | 1 | 12 | 4.0 | 111 | 6 | 1.2 |

Vegetation other than forests.—The species which are frequently met with outside the forests are given in Table VII. Of these *Mahua* and *Dhak* occur most frequently on the waste lands.

Mango and *Kathal* occur usually in groves. *Lantana camara* can safely be termed as the shrub of the coal areas.

The statistics collected on waste lands is presented in Table VIII. As regards the vegetation along road-sides, the distance between trees as well as their size are very varying. Table IX however, gives some approximate estimate of these. Table X gives approximate length of roads covered by the catchments calculated from one inch to four miles top sheets.

TABLE VII

List of species commonly seen outside the forest areas.

| Local names | Botanical names | Local names | Botanical names |
|--------------|---------------------------------|--------------|--------------------------------|
| Asan | <i>Terminalia tomentosa</i> | Karanj | <i>Pongamia glabra</i> |
| Am | <i>Mangifera indica</i> | Khajur | <i>Phoenix sylvestris</i> |
| Bargad | <i>Ficus bengalensis</i> | Mahua | <i>Bassia latifolia</i> |
| Ber | <i>Zizyphus jujuba</i> | Munga | <i>Moringa pterygosperma</i> |
| Dumai | <i>Ficus glomerata</i> | Nim | <i>Azadirachta indica</i> |
| Dhak | <i>Butea frondosa</i> | Pipal | <i>Ficus religiosa</i> |
| Imli | <i>Tamarindus indica</i> | Semal | <i>Bombax malabaricum</i> |
| Jamun | <i>Eugenia jambolana</i> | Siris | <i>Dalbergia lanceolaria</i> |
| Kusum | <i>Schleichera trijuga</i> | Sisam | <i>Dalbergia sisso</i> |
| Karam | <i>Adina cordifolia</i> | Tun | <i>Cedrela toona</i> |
| Kond | <i>Diospyros malanoxylon</i> | Tar | <i>Borassus flabelliformis</i> |
| Kathal | <i>Artocarpus intergrifolia</i> | | |

TABLE VIII

Most prominent species of plants met within an area of 10,000 square feet of waste land sampled at each of the following places and their mean height in feet and diameter inches.

| Places | <i>Mahua</i> | | | <i>Dhak</i> | | | | | | <i>Miscellaneous</i> | | |
|---------------|--------------|--------|-----------|-------------|--------|-----------|----------|--------|-----------|----------------------|--------|-----------|
| | Trees | | | Trees | | | Saplings | | | Saplings | | |
| | No. | Height | Dia-meter | No. | Height | Dia-meter | No. | Height | Dia-meter | No. | Height | Dia-meter |
| Karmatar .. | 16 | 25 | 14.4 | 2 | 32 | 12.0 | 2 | .. | .. | 7 | 4 | 0.4 |
| Topchanchi .. | 1 | 35 | 13.0 | 17 | 28 | 13.0 | 42 | 6 | 1.2 | .. | .. | .. |
| Gumia .. | 3 | 29 | 20.0 | 31 | 21 | 10.0 | 5 | 5 | 1.4 | 13 | 6 | 0.8 |
| Hendegir .. | 7 | 46 | 14.7 | 2 | 28 | 11.0 | 14 | 5 | 0.7 | 59 | 10 | 1.5 |
| Rukni .. | .. | .. | .. | 49 | 19 | 6.0 | 53 | 5 | 1.6 | 171* | 9 | 0.4 |

* Out of these 170 shrubs were of *Lantana camara*. This shrub is very common in the Manbhuma area. It is of course found in other parts also in isolated patches.

TABLE IX

Some observations on the trees which are found along the roads.

| Description | Length in miles |
|--------------------------------------|-----------------|
| Distance between trees | 30 feet |
| Over-all height of the trees | 40 feet |
| Breast-height diameter | 20 inches |

The groves are commonly seen around the populated localities and in the agricultural surroundings. It would be quite a fair approximation to consider 25 trees per orchard and three such orchards per square mile of the areas under cultivation, fallow and not available for cultivation (refer to Table II). The average size of the trees may be taken as (i) over-all height equal to 25 feet and (ii) breast-height diameter equal to 12 inches.

TABLE X

Length of the roads of the catchment in miles.

| Description | Length in miles |
|------------------------|-----------------|
| The main roads | 500 |
| Other roads | 730 |
| Total .. | 1,230 |

Enumeration of plant-population—The plant population has been worked out on the basis of the above considerations for the whole of the catchment. It is given in Table XI.

TABLE XI

Estimated total number of plants in millions (1,000,000) in the catchment and their average size.

| Description of the area | Extent in square miles | No. of plants | | | Size of plants | | | |
|--|------------------------|---------------|----------|---------|----------------|--------------------|----------------|--------------------|
| | | Trees | Saplings | Total | Trees | | Saplings | |
| | | | | | Height in feet | Diameter in inches | Height in feet | Diameter in inches |
| Forests | 2,380 | 380 | 2,056 | 2,436 | 21 | 4.9 | 8 | 1.3 |
| Waste lands | 880 | 61 | 176 | 237 | 29 | 12.7 | 6 | 1.0 |
| Roads | 1,230 | 0.4 | .. | 0.4 | 40 | 20.0 | .. | .. |
| Cultivated, fallow and not available for cultivation | 2,960 | 0.3 | .. | 0.3 | 25 | 12.0 | .. | .. |
| Total | .. | 441.7 | 2,232 | 2,673.7 | 115 | 49.6 | 14 | 2.3 |
| Total in round figures | .. | 442 | 2,233 | 2,674 | | | | |
| | | | Mean | | 29 | 12.4 | 7 | 1.1 |

ESTIMATION OF THE PROBABLE WATERLOSSES THE RAINFALL FACTOR

The factors controlling rain water are (a) interception if rain falls on vegetation before reaching the ground, (b) surface run off, (c) percolation through the soil : (i) retention by the soil, (ii) underground drainage, and (d) transpiration and evaporation.

A certain percentage of the rain drops is intercepted by the vegetation before reaching the ground. The extent of interception would, of course, depend upon the species of trees, their density of stand and many other factors. Kittredge (1937) states that for the average forest conditions the seasonal interception may be of the order of 10 to 25 per cent. of the precipitation. Horton (1923) puts this figure as 15 per cent. of the rainfall.

A part of whatever reaches the ground runs off directly from the surface creating lakes, *nalas* and rivers and finally discharges itself into the sea. Some portion sinks into the ground and is retained in the soil. The other portion sinks still deeper to form the underground water which serves as a source of water supply to wells and springs.

The water which is held freely on the surface (lakes, reservoirs and rivers) and that which is held by the soil is subjected to the process of evaporation. The moisture contained by the soils bearing vegetation has yet another source of depletion, *viz.*, transpiration.

The average annual evaporation from the free surfaces of water on the catchment area of the Damodar river is of the order of 70 inches.

TRANSPIRATION

Transpiration is generally measured by the plant physiologist with isolated plants under controlled conditions. The problem of assessing transpiration loss of plant communities in their natural habitat has really not been tackled so far. Attempts at estimating this factor from the scanty data now available must therefore be treated as *mere guess-work* intended to show up at least very roughly the order of magnitude of this phenomenon.

Transpiration through vegetation other than crops—

Little is known regarding transpiration from trees.

Hohnel in Austria had experimented between 1878 and 1880 with five to six years old seedlings of forest plants transplanted in potometers. The size of these potometers was very small so as to contain only about 11 lbs. of soil. The number of plants tried per species was also limited.

Horton (America, 1923) tried to make use of Hohnel's data by collecting some more information. His main object was to establish some kind of relationship between the height and diameter of trees on the one hand and the amount of water transpired through those on the other. Horton worked out the following empirical formula :—

$$\frac{T - d \times N}{10,000} \times \frac{E}{45}$$

where T = transpiration loss expressed as a depth in inches per acre.

d = the breast height diameter in inches.

h = the height of the tree in feet.

N = the number of plants per acre, and

E = the annual evaporation in inches.

It is to be emphasized once more that the basis of the above formula is only Hohnel's individual work and the defects inherent therein would be present in Horton's formula. The position with

regard to this subject so far as India is concerned is indeed most unsatisfactory but to get some very approximate idea of the order of magnitude the transpiration loss from trees over the Damodar Catchment as estimated from the above formula is given in Table XII.

TABLE XII

Water transpired off by the vegetation, other than crops, of the Damodar Catchment worked on the basis of Horton's formula. Data of Table XI have been utilized here. The annual evaporation has been taken as 70 inches.

| Loss through | Amount of water transpired off | |
|------------------|--------------------------------|--|
| | in acre— inches | in inches spread over the whole catchment |
| Trees | 24,724,498 | 5.3 |
| Saplings | 2,673,440 | 0.6 |
| Total .. | 27,397,938 | 5.9 |

Transpiration through crops.—The work here again has mostly been limited to isolated plants under unnatural conditions of exposure.

Transpiration loss has invariably been expressed in terms of the amount of water lost per unit dry weight of plants excluding the roots and has been variously termed, e.g. coefficient of transpiration, transpiration ratio and water-requirement of plants, etc. The most important work on this problem is that of Briggs and Shantz (1914) and Briggs and Piemeisel (1927). Leather initiated similar work in India in the year 1906. The following main points may be noted in connection with his work :—

- (i) to start with only one pot was used per species of plants, later on the replications used were two per species,
- (ii) the plants were exposed to sun during the day and were kept under roof in the night,
- (iii) many sizes of pots were used in the study in order to know the effect of the size of pots on transpiration rate,
- (iv) two sets of pots were maintained, one with plants and the other without the rest of the conditions remaining identical. With the first was recorded the combined effect of transpiration and evaporation, while the latter gave evaporation only. Thus by deducting the evaporation loss from the first set was obtained the loss due to transpiration.

The average transpiration ratios for some crop plants as found out by Leather are given in Table XIII

Transpiration from plants depends, besides the physical factors, upon the nature of plants, their density, the amount of moisture present in the soil, etc. The ideal way, therefore, would be to consider each crop separately under different environments which are met with in the catchment in order to work out the actual transpiration loss. However, for the present, the transpiration loss has been worked out as indicated below.

It has been seen earlier that paddy is the main crop of the catchment. Then assuming that

- (i) paddy grows in the whole cultivated area,
- (ii) it grows as a dry land paddy,
- (iii) its average total dry weight (excluding roots) per acre is 80 maunds (20 maunds of paddy grains and 60 maunds of straw) or 6,400 lbs., and
- (iv) the average transpiration ratio is 730, the water-loss due to transpiration through the crops of the catchment would work out to be 6.2 inches if spread over the whole catchment area of 7,200 square miles.

TABLE XIII

The average transpiration ratios for some crop plants according to Leather.

| Crops | Transpiration ratios |
|-----------|----------------------|
| Sugarcane | 470 |
| Wheat | 850 |
| Barley | 480 |
| Linseed | 000 |
| Sarson | 740 |
| Gram | 1,400 |
| Jowar | 400 |
| Murree | 250 |
| Koda | 300 |
| Arhar | 1,000 |
| Guar | 1,100 |
| Rice | 1,000 |
| Maize | 450 |
| Mean | 726 |

Thus it will be seen that the total amount of water lost annually by the process of transpiration through vegetation and crops of the catchment may be of the order of 12 inches.

EVAPORATION FROM SOIL

The studies on soil evaporation have been going on in the Agricultural Meteorology Section at Poona for a number of years. Some of the results have been summarised by Dr. Ramdas in a recent report on "Soil Moisture and Evaporation Investigations". These are reproduced here in Tables XIV and XV.

TABLE XIV

| Month 1939 | Types of soil* | Mean daily evaporation in inches when the distance between the water table and the evaporating top surface of the soil column is | | | | | Mean daily evaporation in inches from the U.S.A. evaporimeter |
|-------------|----------------|--|--------|----------|--------|--------|---|
| | | 6 inches | 1 Foot | 1.5 feet | 2 feet | 3 feet | |
| January .. | A | 0.30 | 0.26 | 0.17 | 0.11 | 0.01 | 0.25 |
| | B | 0.29 | 0.23 | 0.21 | 0.18 | 0.09 | |
| | C | 0.05 | 0.02 | 0.02 | 0.01 | 0.01 | |
| February .. | A | 0.38 | 0.34 | 0.22 | 0.15 | 0.02 | 0.35 |
| | B | 0.37 | 0.25 | 0.22 | 0.18 | 0.09 | |
| | C | 0.06 | 0.02 | 0.02 | 0.02 | 0.01 | |
| March .. | A | 0.48 | 0.41 | 0.23 | 0.16 | 0.02 | 0.43 |
| | B | 0.43 | 0.30 | 0.21 | 0.17 | 0.08 | |
| | C | 0.05 | 0.03 | 0.03 | 0.02 | 0.01 | |
| April .. | A | 0.48 | 0.40 | 0.23 | 0.16 | 0.01 | 0.48 |
| | B | 0.51 | 0.31 | 0.23 | 0.18 | 0.09 | |
| | C | 0.05 | 0.03 | 0.03 | 0.02 | 0.01 | |
| May .. | A | 0.49 | 0.39 | 0.21 | 0.14 | 0.03 | 0.57 |
| | B | 0.51 | 0.32 | 0.24 | 0.18 | 0.08 | |
| | C | 0.04 | 0.03 | 0.03 | 0.02 | 0.01 | |
| June .. | A | 0.22 | 0.09 | 0.08 | 0.07 | 0.02 | 0.34 |
| | B | 0.22 | 0.16 | 0.13 | 0.12 | 0.07 | |
| | C | 0.03 | 0.03 | 0.02 | 0.02 | 0.01 | |

*A—Black cotton soil of Poona.
 B—Alluvial soil from the Punjab (normal).
 C—'Bari' (alkali) soil from the Punjab.

TABLE XV

| Month | Types of soil* | Mean daily evaporation in inches when the distance between the water table and the evaporating top surface of the soil column is | | | | | Mean daily evaporation in inches from the standard U.S.A. evaporimeter |
|---------------|----------------|--|-----------|-----------|-----------|-----------|--|
| | | 8 inches | 1.25 feet | 1.75 feet | 2.25 feet | 3.25 feet | |
| December 1941 | A | 0.31 | 0.21 | 0.14 | 0.09 | 0.01 | 0.24 |
| | D | 0.27 | 0.13 | 0.12 | 0.06 | 0.01 | |
| | E | 0.02 | 0.01 | 0.01 | 0.00 | 0.00 | |
| January 1942 | A | 0.31 | 0.20 | 0.14 | 0.08 | 0.01 | 0.23 |
| | D | 0.26 | 0.17 | 0.11 | 0.06 | 0.01 | |
| | E | 0.03 | 0.01 | 0.01 | 0.00 | 0.00 | |
| February | A | 0.40 | 0.22 | 0.16 | 0.10 | 0.03 | 0.31 |
| | D | 0.33 | 0.19 | 0.13 | 0.07 | 0.02 | |
| | E | 0.06 | 0.02 | 0.01 | 0.01 | 0.00 | |
| March | A | 0.53 | 0.24 | 0.19 | 0.14 | 0.05 | 0.44 |
| | D | 0.40 | 0.20 | 0.15 | 0.09 | 0.04 | |
| | E | 0.09 | 0.01 | 0.01 | 0.01 | 0.00 | |
| April | A | 0.61 | 0.27 | 0.20 | 0.15 | 0.05 | 0.50 |
| | D | 0.46 | 0.22 | 0.17 | 0.12 | 0.04 | |
| | E | 0.14 | 0.02 | 0.02 | 0.02 | 0.00 | |
| May | A | 0.62 | 0.28 | 0.20 | 0.15 | 0.05 | 0.53 |
| | D | 0.48 | 0.23 | 0.18 | 0.12 | 0.04 | |
| | E | 0.14 | 0.02 | 0.02 | 0.01 | 0.00 | |

*A—Black cotton soil of Poona
D—Red soil of Bangalore.
E—Sandy soil of Trivandram.

The tables indicate that the evaporation varies (i) from season to season and (ii) from soil to soil and that the same soil evaporates at very much different rates depending upon the distance between the surface of the soil and the saturated level of moisture below the soil surface. Dr. Ramdas has worked out a formula for calculating the evaporation loss from any given soil. It is given below :—

$$E_z = E_o 10^{-\alpha z}$$

where z = the distance in centimeters between the surface of the soil and the water-table (or the saturation zone),

E_z = the evaporation in inches when z is the distance as explained above,

E_o = the evaporation from a free water surface, and

α = a constant.

Calculation of evaporation from this formula is easy once we know the α value of the particular soil as well as the value of z .

The soils predominantly occurring in the Damodar Catchment are of red and whitish colours. The former is most probably derived from the decomposition of the gneiss. It is the soil of the forest area and is also found in agricultural lands. The colour of the white soil is probably due to excess of lime. This soil is found outside the forests mostly as a mixture with the red soil. The ratio in which the two soils are found mixed varies greatly with the locality.

Samples of these soils were collected from three places during the tour of the Catchment. The places are Barakar (Giridih), Barhi and Ramgarh. The mechanical and chemical composition of these soil samples are being analysed in the Laboratories of the Agricultural Chemist to the Government of Bombay. The Central Agricultural Meteorological Observatory at Poona will investigate the α values of these soils. It is difficult to attempt the estimation of the evaporation from the bare portions of the catchment as we have no reliable information of the area which can be designated as "bare".

We may, just for making a very rough guess, make the following assumptions —

- (a) 30 per cent. of the catchment can be assumed to be effectively "bare" during the year.
- (b) evaporation from a free water surface or saturated soils 20 inches during June to September, 15 inches during October to January and 35 inches during February to May.
- (c) the depth z of the wet zone in the soil is, say, 50 centimeters during June to September, 50 centimeters during October to January and 100 centimeters during February to May, and
- (d) the value of α is of the order of, say, 0.015. Then, the total annual evaporation from the "bare" soil may be estimated as about 33 inches. If this amount is spread over the whole catchment the contribution of direct soil evaporation will be of the order of ten inches approximately.

The total annual loss by evaporation and transpiration from the catchment as a whole is of the order of about 22 inches or roughly about 40 per cent. of the annual precipitation of about 95 inches.

Variation of the moisture content of plants with locality in the catchment area.

It was attempted during the tour to study the moisture content of the plants, as indicated by the leaf-moisture, at the various places of visit. Three trees, viz., *Sal*, *Mahua* and *Piqar*, were selected for the purpose. Five pounds of green leaves of each of these trees were collected in duplicate, dried and then re-weighed. The loss in weight represented the moisture. This was

expressed as the percentage of the fresh weight of the leaves. The least count of the spring balance used was 2.0 ounces or 0.13 lbs. The mean percentages thus obtained are given in Table XVI.

TABLE XVI

Mean percentage of moisture found in the leaves of certain trees

| Places of sampling | Trees | | |
|---------------------------|-------|-------|-------|
| | Sal | Makua | Piyar |
| Barhi | 54 | 50 | 51 |
| Barakar (Giridih) | 55 | 51 | 55 |
| Madhuban | 56 | 49 | 51 |
| Karmatar | 59 | 56 | 55 |
| Bermo | 59 | 56 | 56 |
| Bishongarb | 63 | 51 | 56 |
| Ray | 57 | 56 | 55 |
| Ramgarh | 53 | 47 | 60 |
| Rukni | 63 | 59 | 55 |

It can be seen that on the whole there appears to be little difference amongst the trees as to their moisture content. The trees show more or less the same moisture content at all the places where samples were taken, at the time of this survey.

CONCLUSION

The total loss of moisture on account of transpiration and evaporation from the Damodar Catchment is perhaps of the order of say about 22 inches per year or 40 per cent. of the annual precipitation. As has been already emphasized, this figure should be taken as a rough guess. Only a thorough investigation of the many problems involved can yield more reliable estimates. Besides these scientific investigations, an aerial survey of the whole catchment area is also essential if some idea is to be obtained of the actual distribution of different plant communities in the Damodar Catchment.

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APPENDIX II

Suggested Procedure for Inducing Precipitation from Clouds*

INTRODUCTION

The procedures suggested for inducing precipitation are based upon best authentic experimental evidence available to date, but no assurance whatever can be given that precipitation will occur on every occasion when the technique described herewith is employed. Further, although precipitation may be produced at the base of a cloud, significant amounts may not reach the ground in all cases.

PRE-REQUISITE METEOROLOGICAL CONDITIONS

Specific cloud types are essential for the success of the technique.

Either layer or cumulus type clouds may be used providing that the tops of the cloud layer extend above the freezing level and consist of supercooled water droplets at temperatures below freezing. Clouds consisting of ice crystals or snow flakes do not respond to artificial stimulation. Clouds consisting of water droplets at temperatures above freezing do not normally produce precipitation.

It should be pointed out that the cloud conditions suitable for "seeding" are those which can also lead to the natural production of precipitation.

Under critical atmospheric conditions, it is possible that inoculation of the cloud may produce thunderstorms with accompanying hail and lightning.

Cloud Identification :—

Clouds of supercooled water droplets can be identified by the following characteristics :—

- (1) The temperature must be at or below freezing (32°F or 0°C).
- (2) Ice forms on the leading edges and windscreen of aircraft when flying through the supercooled portion of the cloud.
- (3) A glory (coloured halo) is seen around the shadow of the aircraft on the cloud.

* A note read by Dr S. K. Banerji Director of Observatories, India Meteorological Department, Govt. of India at the nineteenth annual meeting of the Central Board of Irrigation in December 1948 during discussion on the subject "Artificial Rainfall".

- (4) With cumulus type clouds the outline is clear and hard when viewed from a distance as contrasted with the fibrous, diffused outline when the cloud is composed of ice crystals. This is illustrated in Figure 1.

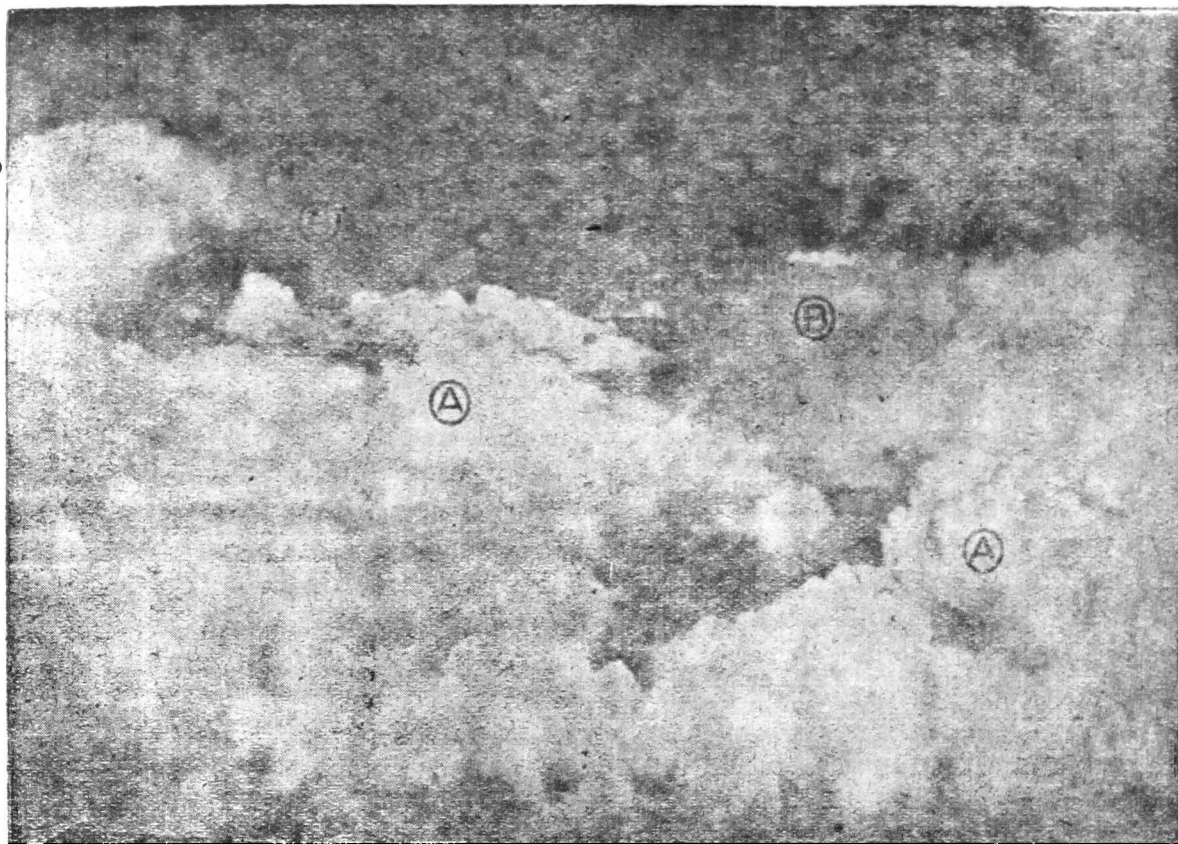


Figure 1 : *Typical cumulus cloud formation.*

- A.—*Composed of water droplets (note hard outline).*
 B.—*Composed of Ice crystal (note diffused outline).*

- (5) The sun, when viewed through cloud, is sharp edged.

Cloud Limitations

Observations to date indicate that a cloud depth of at least 4,000 feet is required to produce significant amounts of precipitation. Further, the base of the cloud should not be much more than 5,000 feet above the ground. For each additional 2,000 feet of cloud depth, the base of the cloud can be about 1,000 feet higher.

The foregoing information applies to summer cloud. For winter cloud, because of the lower water content, much greater cloud depths are required.

PREPARATION OF DRY ICE

Although other ingredients, such as silver iodide, volcanic dust, etc., have been found to initiate precipitation in the laboratory, only the use of "dry ice", which has been most successful in flight tests to date, will be described in this note.

"Dry ice" (solid carbon dioxide) can be obtained commercially in 50 lbs. blocks, approximately 10 inches \times 10 inches \times 10 inches. Since dry ice evaporates at -110°F. , it should be stored in a well insulated container and kept at as low a temperature as possible to prevent excessive loss. The rate of disappearance of a 50 lb. block, of dry ice in commercial packing, when stored at 32°F. is approximately 9 lb. in the first 24 hours.

Crushing

The dry ice for seeding must be crushed. A practical size is a pellet of approximately 3/8 inch diameter, which will fall approximately 14,000 feet before evaporating completely. Larger diameters are wasteful and may constitute a hazard to persons on the ground. Smaller sizes are not as effective because they evaporate after a short fall. Standard commercial ice crushers are suitable for this purpose, although the crushing of dry ice is a more severe process.

In order to prevent 'caking' of the granules after crushing, the granulated dry ice should be sieved through an 8-mesh (approximately) screen to remove the powder. The pellets may then be packed in canvas bags or other similar containers for stowage on the aircraft.

To avoid excessive evaporation, the crushing should be carried out in as short a time as possible before use.

Handling

Because of the extremely low temperature of the dry ice (-110°F .), it should be handled only with heavy gloves.

FLIGHT TECHNIQUE

Whenever possible, seeding should be carried out above the cloud. If this is not possible the seeding should be carried out as high as possible in the cloud, and at least 500 feet above the freezing level. In cumulus type cloud, where it is not desirable to enter the central "build-up", the seeding may be carried out around the periphery of the "build-up", but must be over the cloud.

Seeding Pattern

The seeding should be carried out upwind of the area in which the rainfall is desired. It is recommended that, over stratus-type clouds, the seeding be carried out in lines at right angles to the wind and approximately 3 miles apart, since experience has shown that the precipitation area spreads laterally at the rate of approximately 2½ miles per hour. Over cumulus clouds, the flight path should pass over or near the highest build-ups.

AIRCRAFT REQUIREMENTS

The following requirements are suggested for the aircraft to be used for this work:

(1) *Blind Flying*

Since the aircraft must operate in cloud, it must be fitted with blind flying equipment.

(2) *Oxygen Supply*

To remain at altitudes above 10,000 for more than a short time, oxygen equipment is essential.

(3) *De-icing*

Since icing is associated with supercooled clouds, adequate de-icing for engines, propellers and wings is desirable.

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