435

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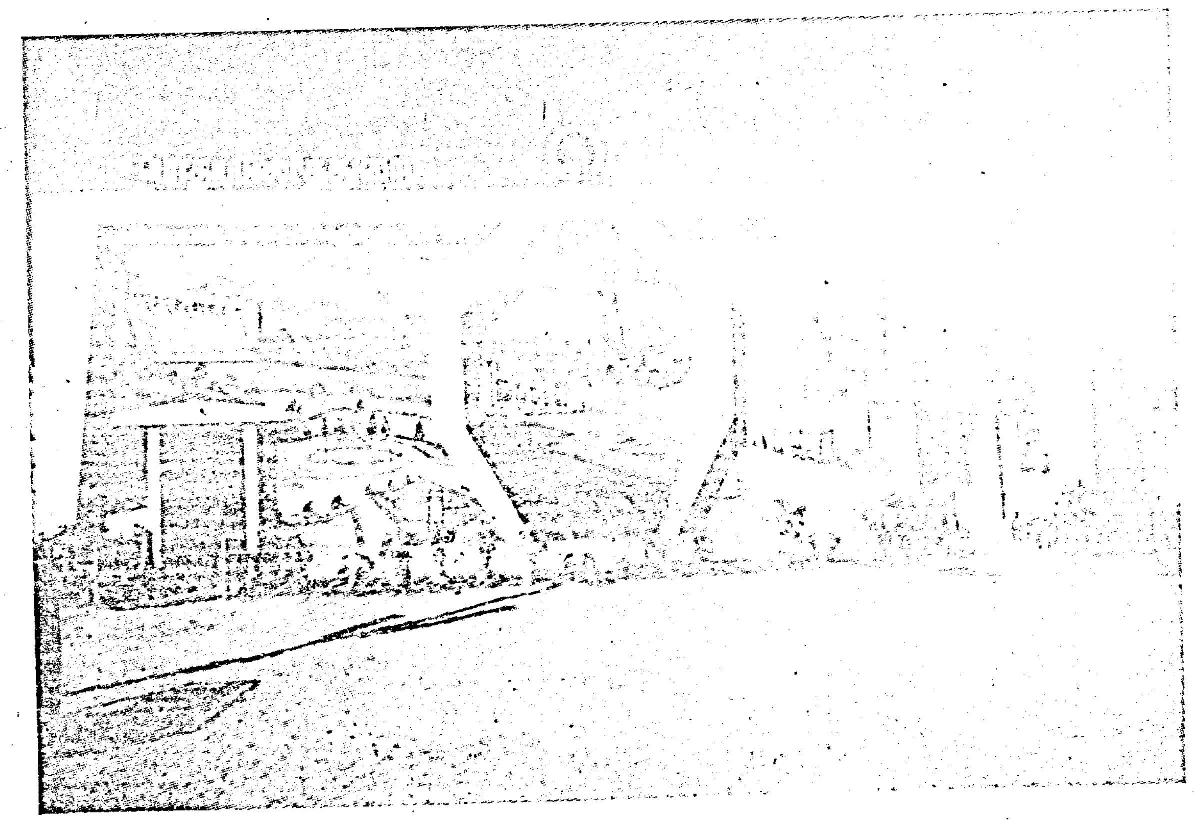

Front View of P.W.D. Pavillion at All India Tourist Trade Fair at Madras—1978.

GOVERNMENT OF TAMIL NADU—PUBLIC WORKS DEPARTMENT—JOURNAL
(For Departmental Circulation only)

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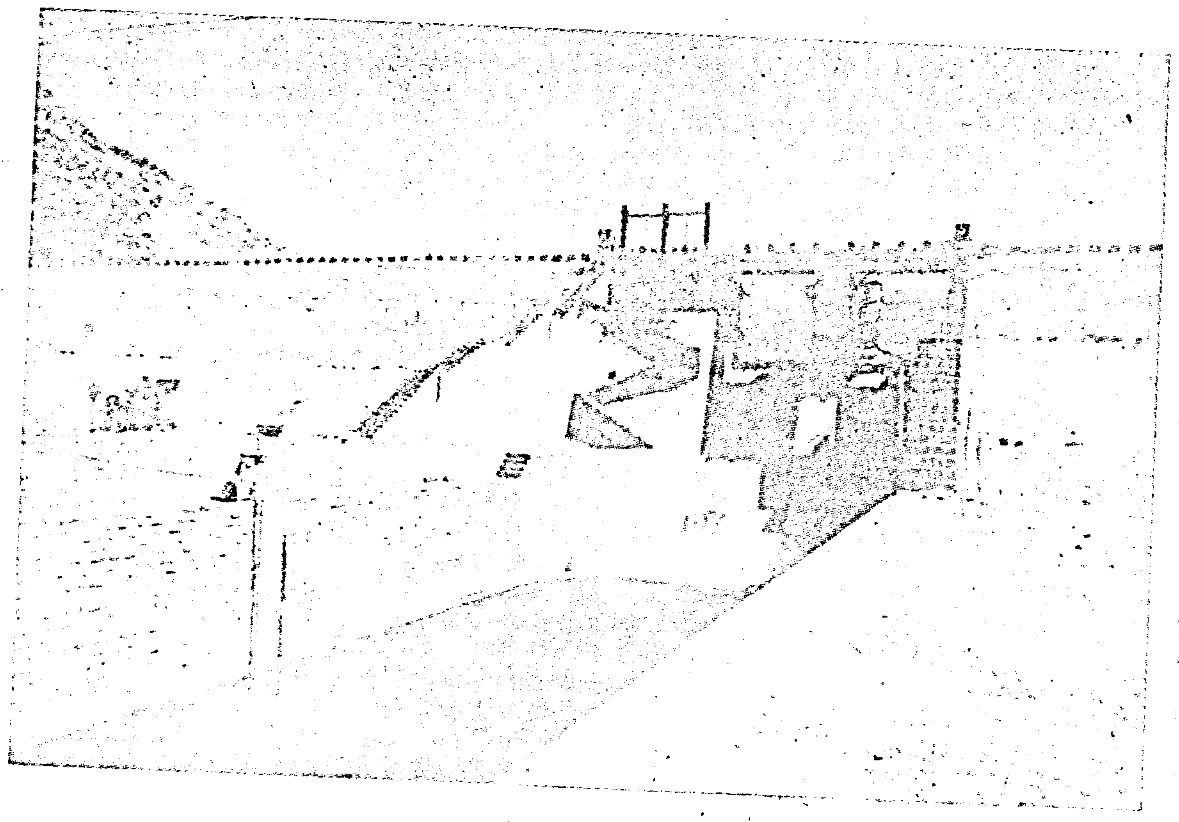

A View of Palar-Porandalar Dam.

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The New Irrigation Era

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CONTENTS.

EDITORIAL

In the first article "Irrigation in India" by Er. P. K. Vedanayagam, Chief Engineer (Irrigation) has outlined Irrigation Development in Tamil Nadu and has explained the possibility of improving the Irrigation in the State and proper utilisation of water.

In the second article "Sedimentation occurs in Reservoirs in dead storage—is it a fallacy?" the author Er. N. C. Krishnasamy, B.E. (Hons.) Research Officer, Institute of Hydraulics and Hydrology, Poondi, has explained that the past practice of providing space for sedimentations in the dead storage of reservoir and deciding its life while designing the reservoir on the presumption that it will occur only in dead storage portion is a fallacy. The author has concluded that due weightage while designing storage reservoirs and estimating its useful life is to be given.

In the third article, namely "Ground Water Control an urgent need" Er. Thirunavukkarasu, B.E., Executive Engineer, M.M.W.S. & S. Project stresses the need for control of Ground Water usage and focusses light on possible legislations that could be made to achieve it.

In the fourth article of Swelling Pressure and their relationship with index properties of soils'the authors Thiru T. S. Krishnamurthy, Research Officer and Thiru P. G. Sampathkumar Junior Research Assistant of Soil Mechanics and Research Division analyses the relationship between swelling pressure of soil and its index properties. The authors describe that a knowledge of swelling potential of the soil is essential for evolving suitable designs and proper use in the embankment. How the swelling pressure and swelling potential of the material can be assessed at site fairly quickly forms rest of the discussions in the article.

In the fifth article by Er. S. Sabanayagam, B.E., M.Sc. (Engg.), M.I.E. Executive Engineer, Soil Mechanics and Research Division the use of fly ash as puzzolonic material in soil cement road constructions is explained. Use of fly ash instead of cement will save cement and cut the cost too.

In the sixth article of the issue, the author Er. V. Gurusamy, B.E.(Hons.), M.Sc. (Engg.), M.I.E., Assistant Executive Engineer, Ground Water, narrates the principles of Remote sensing Technology, and its applications to various branches of Civil Engineering. The Civil Engineering Works are generally taken up for execution after conventional field surveys supported by topo sheets and the author deals in this paper the application of remote sensing, in the field of Civil Engineering along with rudimentary aspects of remote sensing.

In the seventh article "The need and method of recharge of ground Water" Prof. R.K. Sivanappan, Head of Soil and Water Conservation Engineering Department explains the necessity and methods of recharging in Ground Water.

Finally a paper from Courtesy from BRE News about "The Trial Flood Bank for Thames Defences" is reproduced here as it is felt that methods explained to form flood banks in the paper will be useful to the Engineers.

Once again we request all our readers to contribute more articles for our journals.

EDITOR.

IRRIGATION IN TAMIL NADU

by

THIRU P.K. VEDANAYAGAM, B.E. *

In India irrigation plays a major part and equally so in Tamil Nadu. The growth of irrigation in India since the thirties has been considerable mainly due to the many five-year plans under which special emphasis has been given to Irrigation. If we consider 3 points of time in the history of India, that is, 1935, 1950 and 1975, the irrigated area in India as a whole was 433, 515 and 773 lakhs of acres. In Tamil Nadu for the corresponding years, it was 44, 44 and 64 lakhs of acres. In India the growth has been steady as a whole and in the last 40 years irrigation has gone up nearly by 75% whereas in Tamil Nadu from 1935 for a decade and a half there has hardly been any development of ayacut. It is only after Independence that steps were taken to increase the irrigated area by undertaking many major and medium projects.

Though Tamil Nadu had 44 lakhs of acres under irrigation in 1935 and hardly much difference in 1950, these 44 lakhs consisted of 19 lakhs of acres under major irrigation (river systems) 14 lakhs under minor irrigation (tanks) and about 11 lakhs by well irrigation. In 1975 with 64 lakhs of acres, the distribution was roughly one-third for each of the three different types of irrigation. The reason why major irrigation could not increase by a large amount is because the further quantity of water available in the various rivers that flow through Tamil Nadu was very limited. Even before 1935 very well developed irrigated areas under Cauvery, Vaigai and the Tambraparani had been developed and the total surplus available in these rivers was not much. Even as early as the end of the last century the trans-basin transfer of water from the Periyar river (which flows westward in Kerala) to the Vaigai Valley was executed by Col. Pennyquick and the Periyar Vaigai Irrigation for about one-and-a-half lakhs of acres came into existence. Incidentally the history of the Periyar Project as written by Mackenzie is worthwhile reading if not for the engineering aspect, for its beautiful English and to know the problems that were in existence in the British Government for an Irrigation Engineer in those days. Similarly if one is interested, the Barber's history of the construction of the Mettur Dam is also a book that must be read by every Irrigation Engineer.

It would not be out of place here to mention that some of these projects like the Periyar Project completed in the year 1896 took about 77 years from 1808 to 1885 to be accepted and sanctioned. Again the Cauvery Mettur Project started in the year 1834 was finally approved in 1924 after 90 years. The Bhavani Project started in 1856 took another 90 years before it could be sanctioned. Such long and deep considerations were done before projects were taken up and such long gestation period was necessary in these cases as Inter-State talks were also involved. But, today we find that sometimes Irrigation Projects are rushed through and not much of time is given for consideration of the many aspects of an Irrigation Projects. We must not forget that these three projects referred to when they were taken up had considerable amount of data available and in addition the dependability of the water was of high order. Now-a-days with the scarce balance of dependable water one has to be doubly certain that, whether it is a medium project or even a minor works diversion, the Irrigation Engineers are not robbing Peter to Pay Paul.

The rise in cost of the present irrigation works, particularly in Tamil Nadu, is being commented upon. The usual method is to work out a rate per tonne of anticipated additional food production for minor irrigation works and the benefit-cost ratio for major works. In minor works, the area that is benefitted is computed both as new area being brought under the plough and old area stabilised. The additional food production is worked out and based on the value of the food crop produced, the rate per tonne is given. In the case of a medium project, the annual produce from the project is evaluated, priced and set off against the return for the project cost in 10 years or 20 years after deducting the maintenance charge. If the benefit-cost ratio thus worked out is more than 1 to 1.5, then the scheme is proposed.

Though this is the accepted method it would be of interest to know what is the cost of a project with reference to the quantity of water utilised in a Project annually, i.e., in any project where say for example 10,000 acres are irrigated the requirement of water is 2,000 m.c.ft. of water or 2 t. m.c.ft. of water. If we look at it for some of the projects constructed before 1950 and thereafter it reveals considerably the rise in project costs.

	Cost per Mc.ft.	*Year of construction.*
(1)	(2)	(3)
Periyar	1,000	1896
Bhavani	3,150	1952
Vaigai	4,840	1957
Sathanur	3,930	1953
Amaravathy	8,250	1958
Krishnagiri	8,660	1957
Manimuthar	9,160	1953

Medium schemes recently taken up go up from Rs. 50,000 per m. c.ft. to Rs. 1 lakh.

There are many reasons for the rise in the cost of irrigation projects. There has been a general rise in cost of materials. The availability of water in the areas where ayacut is available is not always consistent. Storage works have to be kept small due to submersion of either valuable lands or habitation but they have to provide for the tremendous discharges that flow in the river during the flood days in the monsoon period. Safety devices

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have to be provided because the variations in the monsoon are very high and as irrigated area and habitations become more important, the need to ensure protection to these from unprecedented rains becomes a necessity.

With all these limitations surface water diversion has become costly and much more so the surface water storage. But added to this is the fact that in Tamil Nadu, the availability of water which is dependable is much more limited.

So far we have computed in every one of the valleys in Tamil Nadu the quantity of water that is estimated to be availabale in 75% of the time. For determining this, the availability is taken for a long period of years, more than 40 to 50 years at least, and the assured supply in 75% of the time is taken as the dependable yield. If we see the position in all the valleys in Tamil Nadu given below, we can see that we have already utilised 93.5 per cent of the available dependable water resources of surface flow.

Serial number and River Basin.	*Total yield T.M.C.*	*Utilisation (upto IV Plan period T.M.C.)*	*Percentage.*
(1)	(2)	(3)	(5)
1. Araniar	5.7	4.6	81%
2. Kortalayar	14.7	7.1	48%
3. Cooum	1.2	0.7	58%
4. Palar	17.0	16.8	99%
5. Ponnier	25.6	23.4	88%
6. Vellar	37.0	29.3	79%
7. Cauvery	511.8	499.5	98%
8. Vaigai-Periyar ..	36.3 —26.8	56.6	74%
9. Tambraparani ..	51.3	41.1	80%
10. Kodayar	21.8	21.8	100%
11. Other Minor Rivers.	30.0	28.3	94%
Total ..	780.2	729.2	93.5%

So the development of new areas for irrigation and surface water becomes a difficult question.

It was mentioned previously that a trans-basin diversion was done in Madurai district from the Periyar river of Kerala to the Vaigai river of Tamil Nadu. This work was thought of in 1808, and approved in 1885, taken up for construction in 1887 and completed in 1896. The cost per million cubic feet of water is Rs. 1,000. A second diversion was done in this century by diverting waters from west flowing rivers in Tamil Nadu and Kerala in the Anamalais to the dry lands of lower Coimbatore in Udumalpet, Palladam and Dharapuram Taluks through the Parambikulam-Aliyar Project.

While the diversion in Periyar was 26 t.m. c.ft. the diversion in Parambikulam Aliyar Project contemplated is 28 t.m.c.ft. The work was thought of in the year 1953 and approved in 1959 and the construction is expected to be completed in 1979. The cost per million c.ft. of water is Rs. 20,000. This is mentioned to show the rise in cost within 80 years of a trans-basin diversion. These two diversions are done without very long tunnels for the waters to come from one basin to the other. The maximum length of tunnel in these two basin transfers is only 5 miles. Negotiations are being taken up for diversion of three rivers of Kerala. These projects if they come through may require tunnelling for long lengths, anything between 10 to 20 miles and the cost of tunnelling is going to increase the cost of the transportations of water particularly if the total quantity of water imported is not as much as in these two projects.

Sometimes a question is asked, why do we find a lot of escalation of cost in the pricing of an irrigation project particularly after it is sanctioned and before it is completed. It has always been a moot point as to how much investigation for a project is to be done. If we are to do a complete investigation going into each and every minor detail before a project is to be putup for sanction, the cost of investigation is considerable, the time of investigation is also considerable, particularly if flow details are to be observed for a number of years. With the reduced availability of water in Tamil Nadu many of the schemes which appear worthwhile for a primary look are found to be uneconomical due to many field conditions after full investigation. So it may become then necessary to periodically write off large sums as unprofitable outlay which had been spent on investigation of a project which could not be taken up for execution. Again in any irrigation project, provision has to be made for a flood discharge so that the irrigation work may not suffer any damage. Floods have frequencies of 10 years, 100 years, 1,000 years and million years. Normally a 100 year flood is provided for. But as it has been pointed out, if with a limited capacity a reservoir is constructed over a river which has a high flood discharge, then a very big surplus arrangement will have to be provided which increases the cost of construction. Sometimes if the field conditions allow it, additional escapes are provided to safeguard the structure, but it may not be feasible in all cases. Sometimes a project is investigated and for many years it is not taken up. In most of our irrigation projects there is no provison for escalation of cost if the construction is spread over more than one year. These are areas where a certain amount of flexibility is needed and as already mentioned great care in investigation and in formulation of proposals is necessary, particularly in the future.

In as much as the surface irrigation cannot be very much extended due to paucity of water, the possibilities of improving the irrigation in the State can only be thought of by better utilisation of the avaialble resources. The major irrigation system of Tamil Nadu by the river Cauvery is mostly in the delta in Thanjavur and South Arcot districts and the system of irrigation is very old, more than a thousand years. Prior to the construction of the Cauvery Mettur Project very little attempt had been made to regulate water to the fields excepting to provide regulating arrangements at every point where a river branched into other streams. Headsluices have been provided for channels taking off from these rivers and with these the control stopped. After studying the difficulty in operation of the system a proposal to modernise the system was taken up and by this better control of water in the delta was expected to be done. The scheme has been taken up for execution by the State in a very small manner as centre was not interested in it due to Inter-State problem. In the meantme the World Bank has come forward for the modernisation of Periyar-Vaigai System and as such the modernisation of Cauvery is also now being proposed for aid by the World Bank.

In the 100 years old Periyar Vaigai System the World Bank proposal consists of lining the main canal, the main channels and its branches right upto the 25 acre, blocks, executing on-form works in each of these blocks, providing roads and other facilities in the command area, including the existing unauthorised wet ayacut on a permanent basis and to extend the ayacut by about 20,000 acres by the waters that will be saved. A lined link canal between Vaigai and Peranai the headsluices of the Periyar Main Canal is also proposed. The cost of the Project would be about Rs. 40 crore.

One of the problems with the World Bank assistance is that the standards set by them are higher than what we have for our own State. The Parambikulam Aliyar Project has also been lined as already intimated. But the more used for lining in this, project is considerably less rich than the one propesed in the World Bank Scheme. Hence cost has gone up considerably for taking the World Bank Scheme. However, with the aid of the World Bank, contemplation of even modernising the Lower Bhavani and later on the Tambaraparani is under consideration.

While this is feasible in the surface waters, there are two other areas in which improvements to irrigation can be done whereby the annual food production in the State can be increased. As already mentioned, thank irrigation which is classified as minor irrigation caters for about one-third of the irrigated area of the State. There are about 37,000 tanks with an ayacut of about 21 lakhs of acres. Most of these tanks have been built in antiquity and they have very old types of sluices most of which cannot be closed and water that goes out of these sluices is used by the ryots with hardly any control. Excepting the system tanks i.e., tanks which in addition to getting water from their own catchment are fed by channels from neighbouring rivers and which feed tanks below them with their surpluses, the other tanks hardly ever get water for one crop as most of them depend upon the North-East monsoon. Most of the tanks are located on the eastern plains of the state starting from Chingleput district to Ramanathapuram. It is proposed now to take up at least the bigger tanks which have an ayacut of over 500 acres and which are nearly 500 in number and modernise them by doing considerable amount of on-farm works fixing Varabhandi system of irrigation and having proper regulating arrangement and sluices. A scheme is being taken up as a pilot one immediately and in future the modernisation of tanks at various levels can be formulated as total projects and probably could get assistance from source like the World Bank as they seem to have helped Sri Lanka in a similar situation.

Tamil Nadu being deficient in water, apart from the Inter-State diversions which have been restricted to Kerala so far, the feasibility of importing water from other States may also have to be considered. Ganga Cauvery link has been considered as one such. That has been dropped in favour of a Dastur Canal. But for us who are in the southern most tip of India, waters from the Ganga or the Brahmaputra may not reach up even in 2000 A.D. But we may have to actively consider importing water from Andhra from probably Godavari and that too by Gravity flow. Pumping is tremendously costly. While working out the cost of Krishna waters which are to be brought to Madras for drinking water purposes, it was computed that the cost of pumping the 15 t.m.c.ft. of water from Pennar river which will be for a length of 115 miles, the cost of pumping per year itself would run to about Rs. 12 crores and the cost of initial construction of the pipeline will be about Rs. 200 crores. If pipelines were not used and only a lined canal is to be dug, the cost may not be even Rs. 100 crores, pumping would be tremendously costly and any water for irrigation is better brought by flow. In addition the electricity required for pumping may not be available when it is needed. In the case of Krishna waters, the consideration for bringing water to Madras through a closed conduit has been borne in mind as the waters will pass through the dry regions of Andhra Irrigation waters from Godavari may also pass through similar regions. As such any project for diversion from Andhra and the river Godavari will have to be thought of as a joint venture by Andhra Pradesh and Tamil Nadu. Similarly the diversion of water from Kerala will have to be done bearing in mind the fact that Kerala requires waters more for power production than irrigation and water is their main subject for negotiation. Also their entire flow of water is in the south-west monsoon during the months of June to September and what can be spared at this period over and above their requirements for both irrigation and power production can only be used by us by diversion and storing in our storage reservoirs. This again is not going to be water at a cheap rate. So for future use of water very stringent measures are necessary so that every drop of water that is diverted is spread over as large an area as possible and produces the maximum amount of food.

There is one other area wherein we have not made much effort to increase the food production. That is an area which has as large an ayacut as canal irrigation or tank irrigation-the well irrigation. The ayacut is the same with about 11 lakhs wells which are in existence to-day and 70 per cent of them are electrified. However, in some areas due to the over drawal of water the aquifers are going down. Efforts may have to be made with the present legislation to restrict the amount of water pumped out and also to restrict the number of wells to be dug by any person. We may have to go to each well owner and ascertain his difficulties to find out if the 2 to 3 acres which he irrigates now can be increased to at least 4 acre as per well. This is also to be seen in the future.

Probably the most demanding work to be done in the near future regarding the growth of water potential in Tamil Nadu is the proper utilisation of the water so that each drop of water that is given for irrigation is fully used. Now measures will have to be adopted, quantitative supply of water given the revenue realised, etc., controlled as is done in some of the Northern States by the authority who supplies water.

SEDIMENTATION IN RESERVOIRS OCCURS ONLY IN DEAD STORAGE IS IT A FALLACY?

by

N. C. KRISHNASAMY, B.E., M.I.S.A.E.*

INTRODUCTION:—

Storage Reservoirs are the resort of Hydraulic Engineers for irrigation, water-supply, power generation, and flood-control, etc. Vertical allocation of stored water is made for different purposes, leading aside some dead storage below certain level with the hope that sediment-laden river-water will drop the transported-sediment in the dead storage, and live storage will stand unaffected. This is the usual assumption made in the design of storage Reservoirs.

Systematic model and prototype studies conducted in Reservoir Sedimentation do not fully support this presumption, and sediment-deposition occurs in the live-storage portion and upper reaches also, causing general rise of reservoir-bed and river bed.

MECHANISM OF RESERVOIR SEDIMENTATION.

Sediment-transported by streams may be in the form of suspended load and bed load. According to Rouse(1), vertical distribution of suspended load is given by :—

$$\frac{C}{Ca} = \left\{ \frac{D-Y}{Y} \cdot \frac{a}{D-a} \right\}^{\frac{W}{KU}} \quad \ldots\ldots (1)$$

which shows that concentration of suspended load varies with depth 'y', fall velocity 'w', and implicity with velocity of flow 'V'. Similarly, bed load transport is influenced by flow velocity among other variables involved. Reference may be made to Meyor-Peter equation, Einstein's equation, Kalinstte's relation and several other bed and total load estimation relations.

Dynamic equation of gradually varied flow (2) can be expressed in the form :—

$$\frac{dy}{dx} = So \left\{ \frac{1 - \left\{ \frac{x}{yn} \right\}}{1 - \left\{ \frac{y}{yc} \right\}^{M}} \right\} \quad \ldots (2)$$

where :—

yc —critical depth

yn —Normal depth

y—Depth of water at any distance x from the dam.

So —Bed slope.

A solution of this equation for the backwater curve in upstream of a dam shows that as depth of flow increases, velocity decreases in the back-water reaches of a dam.

Please see Fig. 1 (a diagrammatic sketch (3) of different deposits in the upstream of a dam).

Whenever an alluvial stream enters a reservoir, influenced by backwater effect, and flow-velocity, etc., coarser sediment gets deposited in the upper reaches, medium and finer in the next reach partly above Full Reservoir Level and partly below Full Reservoir Level, and still finer sediment within the reservoir itself. Suspended load is carried down to the dam and partly settles down and partly goes out with the outflows, depending on the detention period of the reservoir. Sediment deposits thus formed may be classified as topset bed, forester bed and bottom-set bed. In case of vide variation in density of the transported-sediment with the water phenomenon of density-current will occur. Therefore, it can be seen that theoretically every opportunity is there for the transported-sediment to get deposited in the upper-portion and upper-reaches of the reservoir, in addition to the lower portion (i.e., dead storage) of the reservoir.

Reservoir Sedimentation surveys and Analysis of Data.

Systematic sedimentation suveys (4) have been conducted in India and abroad to assess quantity of sediment-deposits and their vertical distribution in the storage reservoirs. Please see Table-1, which gives the data on Indian Reservoirs. See also the Fig. 2 and 3, which are plots of % sediment deposit with % depth of the reservoirs. Also superimposed on these plots is the data of Krishnagiri Reservoir, collected by the recent survey during 1975-76. All these plots, on perusnal, reveal that sedimentation occurs in the upper portion also and considerable quantity deposited in the upper portion of majority of the reservoirs like Mayurakshi, Panchet, Maithon, and Krishnagiri Reservoir Project of India. Only in hill and gorge types reservoirs, deposition in lower depths is more, which is logical. Similar is the case of U. S. Reservoirs. But in no case, Sedimentation occurs exclusively in lower depths of the reservoirs. This fact was also stressed by B. N. Murthy, in his paper on "Reservoir Sedimentation" to the Seminar on Hydrological problems held at Indian Institute of Technology, Kanpur, India.

Conclusion.

Analysis of present-day data on Reservoirs Sedimentation reveal that the past practice of providing space for sedimentation in the dead storage and deciding its life while designing the reservoir on the presumption that it will occur only in dead storage portion is a fallacy. In future, this fact is to be given due weightage while designing storage reservoirs and estimating its useful life.

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* Research Officer, Institute of Hydraulics & Hydrology, Poondi.

TABLE 1.

SEDIMENTATION STATISTICS OF SOME RESERVOIRS IN INDIA.

Reservoir.	*Catchment. Sq. km.*	*Capacity M.M.^{3}*	*Average inflow M.M.^{3}*	*G.I. ratio %*	*Annual loss —*	*C/w*	*Annual rate of deposition. M.M.^{3}/100 Sq. km.*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Bhakra	56800	9870	19700	0.5	0.57	0.17	0.080
Hirakud	83000	8140	40800	0.2	0.30	0.10	0.033
Gandhisagar	22600	7750	4700	1.65	0.05	0.34	0.019
Panchet	11000	1500	1875	0.8	0.14	..	0.122
Maithon	6300	1360	3023	0.45	0.6	0.22	0.155
Mayurakshi	1860	1665	..	..	0.4	0.33	0.036
Matatila	20750	1135	4936	..	0.7	0.55	0.035
Tungbhadra	28200	3700	12900	0.3	1.4	0.13	0.180
Lower Bhavani	6150	930	..	..	0.2	0.15	0.041

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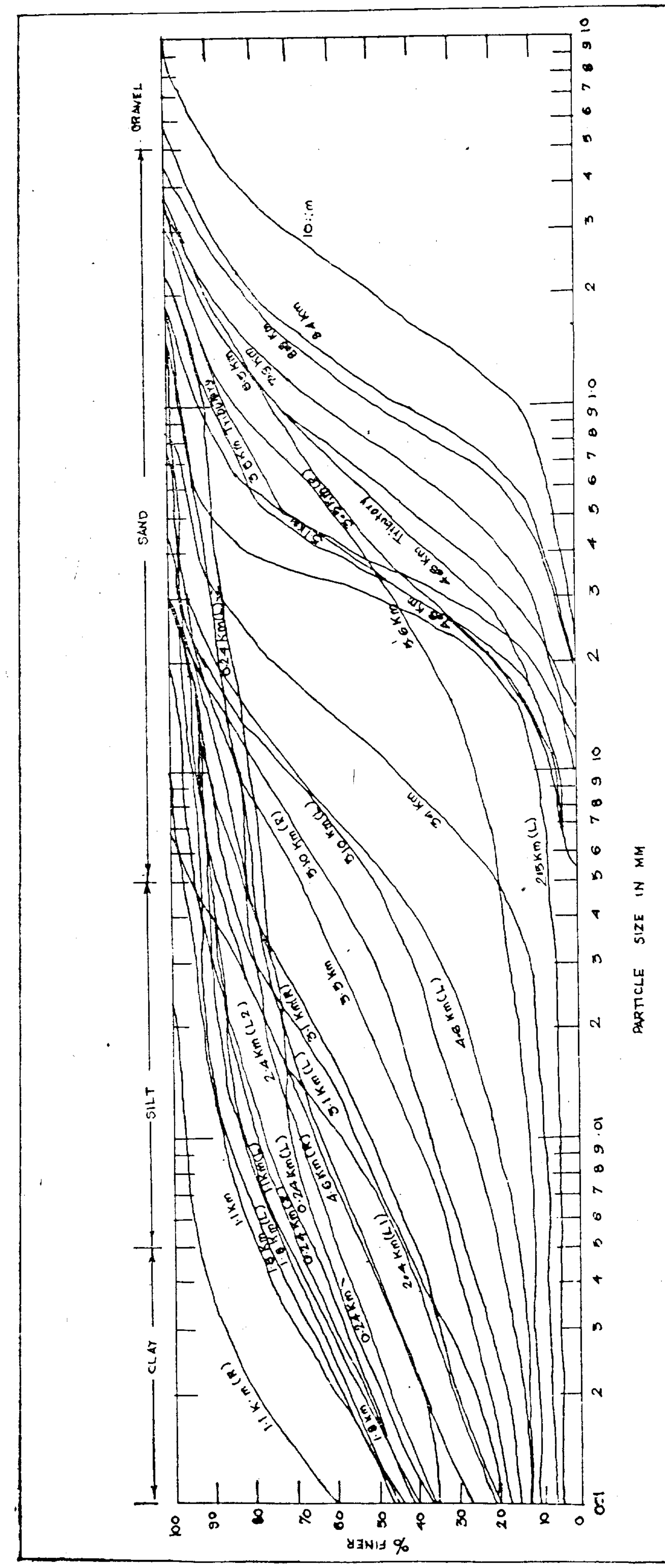
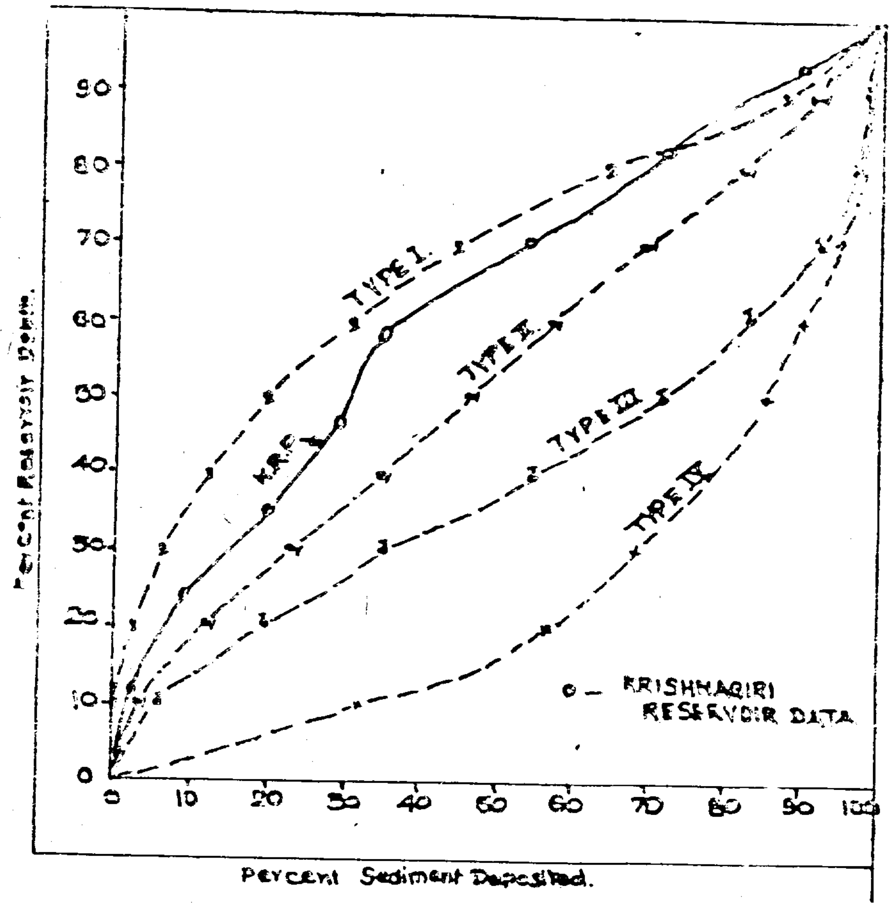
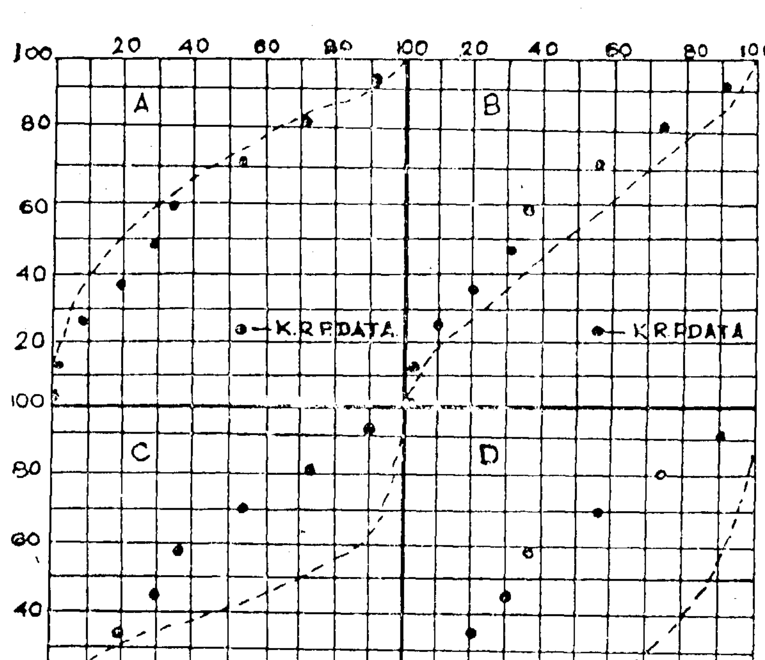


FIGURE: 1 GRAIN SIZE DISTRIBUTION OF SEDIMENT DEPOSIT



KRISHNAGIRI RESERVOIR PROJECT DATA PLOTTED ON RESERVOIR TYPE CURVES

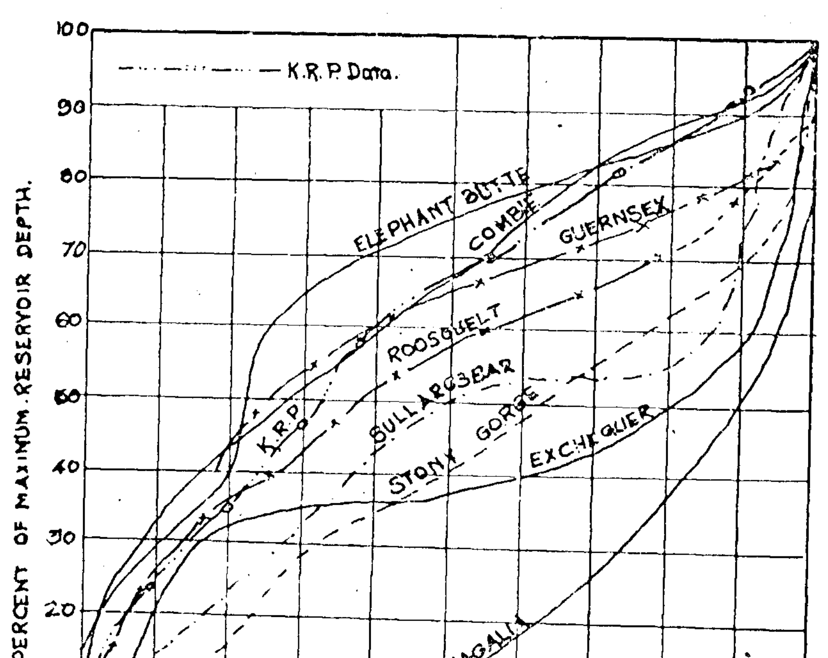
FIGURE No. 2



- - - - -Indicates. meanglocation of deposits for groups.

COMPARISON OF KRISHNAGIRI RESEVOIR DATA WITH DEPOSIT—GROUPS OF RESERVOIRS.

FIGURE NO : 3(i)



COMPARISON OF KRISHNAGIRI RESERVOIR WITH CERTAIN SELECTED U.S. RESERVOIRS

FIGURE NO.: 3(ii)

GROUND WATER CONTROL—AN URGENT NEED

by

Er. A. S. THIRUNAVUKKARASU, B.E.*

The area of Tamil Nadu is 1,29,901 sq. km. It has an average annual rainfall of 945.7 mm. About 76% of the area of Tamil Nadu is crystalline and the remaining 24% is sedimentary. It has been roughly estimated that the Ground Water available for extraction annually in the whole State is about 11.5 M.Ac.ft. This figure is based on the probable annual recharge during a normal year. About 78% of the available ground water is already utilised and there is only a balance of about 3.5 M.Ac. ft. available for future exploitation. There are about 11.5 lakhs of wells in the State of which about 7 lakhs have been energised. The number of energised wells is the highest in a State in India. The very high development of the ground water has resulted in over development in certain areas of the state. Taking the districts as units, it is seen that there is over extraction of ground water than the recharge in the districts of Coimbatore, Salem, North Arcot and Madurai. However if smaller geographical units like blocks and villages are considered in these districts it is possible that in some blocks or villages over extraction is very acute and in some other blocks or villages there is yet balance of ground water available for exploitation. Similarly in the remaining districts in the State though there is balance ground water available for extraction when the districts are considered as a whole, there are pockets in these districts which are over extracted.

In the over developed areas the water levels are going down progressively year after year as the extraction is more than replenishment. The farmers are competitively deepening their wells year after year infructuously. There is at present no statutory control for the exploitation of ground water and for regulation of water rights.

In the year 1971, the World Bank Project came into operation in the State. Under this Project, assistance was provided to the farmers for sinking wells for Minor Irrigation purposes. In the agreement entered into with the World Bank for the project, conditions were stipulated by the World Bank that the assistance should be provided only based on the certificate of availability of ground water issued by the State Ground Water Department. It was also contended that for other loan assistances from State Funds or Central Funds similar ground water disciplines should be applied. By the implementation of these conditions the sinking of new wells and extraction of ground water by the farmers with the help of the institutional finances are subjected to regulation and control. But the farmers who sank their wells with their own finances were free to do so anywhere in their lands. The poor farmers who cannot sink their wells with their own finances are alone controlled and there was no control over the rich farmers. This amounts to discrimination. In the absence of legislation the Government is helpless in arresting further exploitation even in the already over exploited areas as the farmers who sink wells with their own finances are free to do so. Unless the situation is brought under control by enacting a suitable legislation, the situation in regard to the ground water, particularly in the over exploited areas will get further worsened bringing disaster to several poor farmers. The discrimination now in existence between those who sink wells with their own finances and those who sink wells with institutional finances also can be rectified only if legislation is enacted.

The proposed legislation should deal, among other things, the following important aspects:—

(1) Ground Water Rights.

(2) Declaration of critical area and permit,

(3) Registration of existing ground water users,

(4) Registration of well drillers.

(5) Ground Water Authority.

Ground Water Rights—

The Ground Water Rights in the U. S. A. are governed by four different doctrines.

(a) Absolute Rights Rule or English Rule.

(b) Reasonable Use Rule or American Rule.

(c) Correlative Rights Rule.

(d) Appropriation Rule

These doctrines are briefly explained below :—

(a) *Absolute Rights Rule*—

Under this Rule, the land owner own all the water underlying his land and has an absolute right to use such water or to interfere with its flow and it made no difference whether he acted wastefuly, wantonly or maliciously.

(b) *Reasonable Use Rule*—

In this rule the rights of the owners on the water underlying his land are recognised ; but limitations are imposed on the rights so that he could not act wastefully or maliciously or negligently.

(c) *Correlative Rights Rule* —

This rule gives the land owner a right in percolation waters in the exact proportion which his land bears in relation to all other land overlying the underground basin. The overlying owners with respect to each others will have equal right and in times of insufficient supply each will be given a just and fair proportion.

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d) *Appropriation Rule*—

Under this rule, all appropriation, prior to the commencement of regulation are treated as vested rights and recognised and subsequent appropriation are decided on 'first in time, first in right' basis. In this rule, the person who initiates action to abstract water first has preference over the subsequent new comers.

Ground Water Doctrines—

The adoption of a particular doctrine or rule in the administration of water rights in the U.S.A. is governed by specific provisions in their respective statutes in some of the states and in others they are based on prior court decisions.

In Tamil Nadu, there are not many litigations on water rights and there are no court decisions relating to water rights. Hence it may be necessary to spell out in clear terms, the nature of rules which will govern the water rights, in the law itself. There are advantages and disadvantages in all the above doctrines. It is better the law makers incorporate the doctorine or doctorines to be adopted in the proposed legislation. The absence of such a clear cut stand in the law, may lead to inconsistant decisions varying from place to place depending on the local personnel administering the statutes. What sort of rule will be best suited to our conditions. is to be decided after detailed discussions between the ground water scientists and the attorneys.

2. *Declaration of Critical Area and Permit System*

There are several areas in the State where annual ground water extraction exceeds annual replenishment causing progressive lowering of water level in wells. The Ground Water authority is to identify such areas in the extents of administrative units like blocks, collect full details of sub-surface geology of the area. the aquifer characteristics, the details of ground water extraction, etc. and recommend to Goverment for declaring the area as critical area. The Government should notify such areas for being subjected to strict control. The future-extractions of ground water in such areas should be controlled effectively to arrest further lowering of water table in the area. No new wells, except domestic wells, should be allowed to be sunk in the critical areas except with a permit from the authority to be specified in the law.

3. *Registration of existing users*

As a first step in the control of withdrawals, it is essential that the existing users of ground water in an area is inventoried. This is possible only by insisting on the users to get their uses registered by filing applications to the authority in the forms prescribed. There is at present no reliable data on the existing uses of ground water in any department of Government and this causes difficulty in estimating the withdrawals correctly which may impede the firm assessment of the balance ground water available on an area for abstraction. It is therefore desirable that the existing users not only in the notified critical areas but in other areas also, are insisted to get their uses registered. The Administering authority may issue certificate of registration to the users or refuse registration for valid reasons after giving due opportunity to the applicant. All unregistered wells should be treated as unauthorised wells and penalty imposed for use of such wells.

4. *Registration of Well Drillers* :

In the U. S. A. almost all wells are bore wells. By keeping track of the activities of the well drillers, the well sinking and thereby the fresh exploitation of ground water is effectively controlled in U. S. A. well drillers in the U.S.A. are insisted on getting licence for carrying on the trade. They are insisted on filing well logs to the competent authorities and this helps the States to keep a correct record of wells. In the legislation proposed for our State, there should be provision for licensing of well drillers. No one without well drilling licence should be allowed to undertake well drilling and it should be made conditional on the licence that well logs should be furnished to the ground water authority and when new wells are completed. In this State, apart from private drillers, wells are drilled by Government Departments like Agricultural Department, Ground Water Department, etc. and Quasi-Government Organisations like Tamil Nadu Water Supply and Drainage Board, Tamil Nadu Housing Board, etc. It should be insisted that these organisations should also be insisted on filing well logs to the appropriate authorities.

The above arrangement alone will not be sufficient to bring into account all the new ventures of ground water exploitation. Apart from bore wells, open wells of large diameters or open square wells are also constructed for extracting large quantities of ground water. In the notified areas, such wells will be brought into record as permits are insisted for any new wells in these areas and we well drillers are insisted to fire well logs under the licensing system. But in other areas there is no way to bring such open wells into account. It is therefore necessary that provision is made in the bill to register such open wells dug for other than domestic purposes with ground water authority. This will enable keeping up-to date record of ground water abstraction in non-notified areas also. which will enable keeping track of possible over extraction and taking timely action to bring such areas under control. All unregistered wells should be treated as unauthorised wells and dealt with accordingly.

5. *Ground Water Authority*

At present ground water is dealt with by several agencies like Agricultural Department, Ground Water Department, Tamil Nadu Water Supply and Drainage Board, etc. First the various agencies should be brought together and there should be one organisation for all the acts connected with ground water. The administration of ground water statute should be entrusted to a single authority headed by a Technocrat who may be called Chief Engineer or Director who has sound knowledge on ground water technology. There can be an Advisory Board consisting of representatives of Departments concerned with the ground water and a few public-men who have practical experience in the field of ground water development. The Chief Engineer or the Director as the case may be will be mainly responsible for the

Administration of the legislation. The Advisory Board can meet at suitable intervals and deliberate their views on broad principles without involving themselves in the day to day administration. The Chief Engineer will be provided with necessary infra structure for implementing the provisions of the law.

In the State of New Mexico in U. S. A. there is a State Engineer who administers ground water as well as surface water in the State. This is twice our State in extent having abundant ground water. There are two divisions under him-One is Technical Division and the other is Water Rights Division. The former is attending to the Technical side and the later is attending to the Administration of Water Rights including issue of permits etc. Of course. in this State there is legislation for the use of surface water also by which existing uses are registered and permits are issued for fresh uses. Legal Attorney are attached to the State Engineer for assisting him in the Administrstion of the rules. Such a pattern of administration may be suitable for the State of Tamil Nadu. The Chief Engineer or Director who is entrusted with the enforcement of the statute can be attached with the ground water monitoring and planning work also.

These are some of the major repuirements of the proposed legislation though three are many more points to be considered carefully and becided, The earlier the legislation is enacted the better will be for the ground water management in the State.

SWELLING PRESSURES AND THEIR RELATIONSHIP WITH INDEX PROPERTIES OF SOILS

by

* Thiru T. S. KRISHNAMURTHY, B.Sc., and ** Thiru P. G. SAMPATHKUMAR, B.Sc.

SYNOPSIS

Soil as a foundation material contributes considerably to the stability and behaviour of structures founded on it. In the field of earth dams/expansive soils are in use as hearting material in the core of the dams. These soils exhibit high swelling pressures when in contact with water with large volume changes causing severe damages and failures of the structures. A knowledge of the swelling potential of the soil is therefore desirable for evolving suitable designs and proper use in the embankment. Determination of swelling pressure of the soil in the laboratory is time consuming and cumbersome as well and hence a relationship between the swelling pressure and index properties of soils and also with free swell has been evolved and presented in this article.

1. *Introduction.*

1.1. Some clay soils depending on their clay mineral composition have a tendancy to swell on absorption of water developing high swelling pressure when confined resulting in decrease in strength. These pressures cause extensive damages to the super-structures and in earth dams and embankments, the swelling has caused failures. Hence in order to evolve safer and suitable design, a knowledge of this property is quite essential.

1.2. The swelling pressure of clayey soils generally depends on the mineral composition of the soil, its initial moisture content and placement density. Estimation of swelling pressure of the soil in the laboratory is a very cumbersome process and the test is time-consuming. However, determination of physical and engineering properties such as liquid, plasticity index, optimum Moisture content and maximum dry density etc. is comparatively easier. A relationship between these properties and the swelling pressure, if obtained will be much useful to have a quick and fair assessment of the swelling potential of the soil before it is put to any use.

1.3. Free swell which is the ratio of the increase in volume to the original volume represented as percentage when the soil is allowed to swell without any load is a very simple test and can be done at any site. The relationship between this property and the swelling pressure has also been evolved and presented in this article.

2. *Discussion.*

The clay mineral predominantly present in the soil influences its sewelling characteristics. The basic criteria for evaluating the activity of the clay particles is the specific surface area. However determination of specific surface area. in the laboratory is very complicated and laborious process. GRIM (1) from his studies on pure clays has come to a conclusion that liquid limit and to some extent plastic limit provides a satisfactory indication of the type of clay mineral. PLATERIFF has also come to the conclusion that a fairly good relationship exists between plasticity Index and Specific Surface areas. SEED et al, LADD et al (2, 3) from their study on swelling characteristics of compared clays have shown the significance of initial moisture content and density as indicative parameters for assessing the swelling behaviour of the soil.

Of late in the field of earth dams and embankments, expansive soils are in use as hearting materials in the core of the dams for water tightness. These soils are placed at optimum moisture content and compacted to the maximum density. Hence swelling pressures were determined at optimum moisture content and maximum density and the relationship with Liquid Limit, Plasticity Index and a multiple correlation between the swelling pressure and optimum moisture content and maximum dry density has been evolved for Tamil Nadu Soils and the regression equations obtained are given below

1. *Relationship between Swelling Pressure and Liquid Limit of Tamil Nadu Soils :*

S. P. = 0.046 L. L — 1. 572.

2. *Relationship between Swelling Pressure and Plasticity Index of Tamil Nadu Soils —*

S. P. = 0.057 P. I. — 0.566.

3. *Relationship between Swelling Pressure and Optimum Moisture Content and Maximum Dry Density for Tamil Nadu Soils.:*

S. P. = 0.102 O.M.C. = 1.455 M.D.D. = 1.186.

Where S.P. ..	Swelling Pressure in kg./cm.
L.L. —	Liquid Limit %
P. I. ..	Plasticity Index %
O.M.C..	Optimum Moisture Content %
M.D.D. ..	Maximum Dry Density gms./c.c.

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Free swell test is a very simple test and can be determined very easily at the site and does not require much of equipment or techincal skill. The test procedure is briefed below :

Test sample at site is collected, overdried and sieved through 425 micron sieve. Two samples of equal weight of the same specimen are placed in two graduated jars. Kerosene is added to one jar and distilled water is added to the other jar. The soil is allowed to swell freely and final volume shown in the jar to which water is added is recorded. The volume as shown in the kerosene jar is taken as the initial volume. The increase in volume expressed as percentage over the initial volume gives the Free Swell.

$$\text{i. e. F.S.} = \frac{Vw - Vk}{Vk} \times 100$$

where F.S. = Free Swell %

Vw — Volume shown in water jar C.C.

Vk — Vol. shown in kerosene jar C.C.

In view of its simplicity in determination in the field, the Free Swell values are also correlated with the Swelling Pressure values and the equations obtained is as follows :

S.P. — 0.023 F.S. — 0.696

where S.P. — Swelling Pressure in Kg./cm.2

F.S. —Free Swell %

Besides, since density is the factor governing the Free Swell, the relationship between the Swelling Pressure and and the ratio of Free Swell. to maximum density is worked out and the equation obtained is

$$\text{S. P.} = 0.031 \times \frac{\text{F. S.}}{\text{M.D.D.}} - 0.521$$

where S.P. = Swelling Pressure in Kg. /Cm.2

Where F.S. = Free Swell %

M.D.D. = Maximum dry density in gms./cc.

Thus from the significant correlations obtained between Swelling Pressure and Index Properties and especially Free Swell, Swelling Potential of the material can be assessed at site fairly quickly so as to decide the suitability for use in the core of earth dams and embankments.

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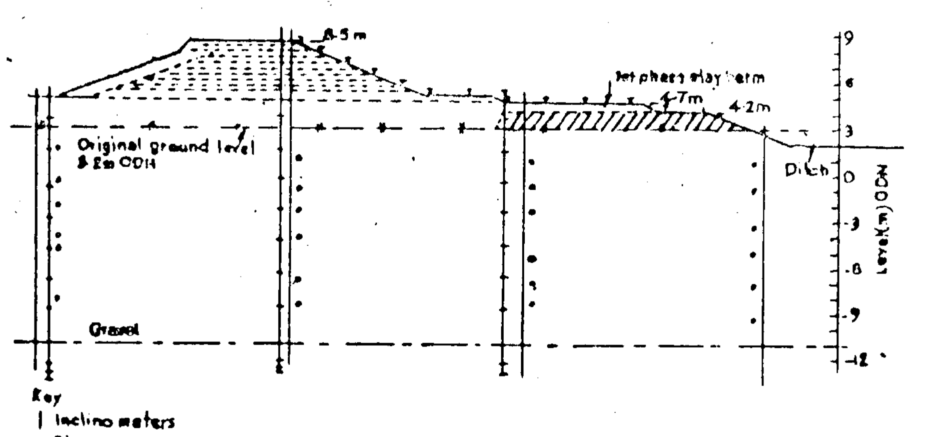
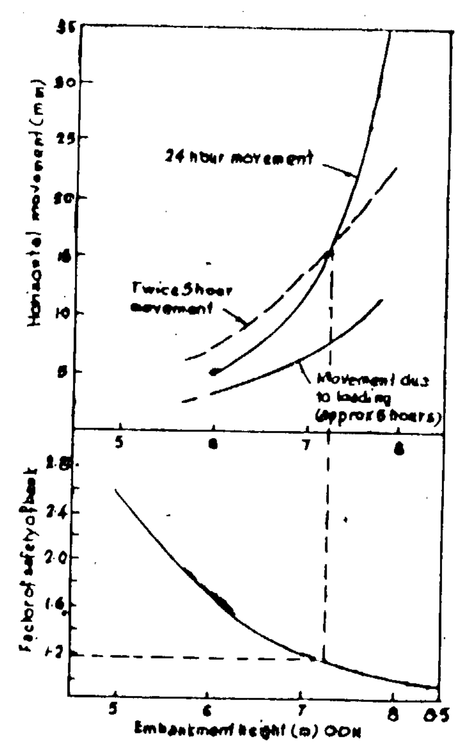


Key
| Inclinometers
• Piezometers
† Magnet extensometer
╤ Horizontal mole tube and magnets
+ Surface survey targets

Vertical section through the bank shows the location of the instruments and the Sequence of construction.

VERTICAL SECTION THROUGH THE BANK SHOWS THE LOCATION OF THE INSTRUMENTS AND THE SEQUENCE OF CONSTRUCTION



HORIZONTAL MOVEMENTS OF THE BERM FOLLOWING THE PLACEMENT OF AN ADDITIONAL LAYER WERE FOUND TO BE THE MOST SENSITIVE MEANS OF PREDICTING THE ONSET OF FAILURE.

THE USE OF FLY ASH AS A POZZOLANIC MATERIAL IN SOIL CEMENT ROAD CONSTRUCTIONS.

by

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I SYNOPSIS—

The Primary objective of this paper is to analyse the behaviour of fly ash obtained from Neyveli Thermal Power Station, in relation to its use as a Pozzolana, in combination with cement in soil-stablized road construc-tions, thereby serving as one of the outlets for the disposal of flyash and at the same time, reducing the cost of road laying by conserving cement. To assess the suitability, a test reach of soil stabilized sub-base coarse was laid with the pre-determined mix of soil, cement and flyash at the optimum moisture content.

II Preamble—

Soil stabilization is the answer to speedier and economic rural road construction. Despite the successful results obtained in recent years, soil cement construction has not made much headway in India. It is imperative that cement should be conserved for more important constructions and initial cost of roads kept down, without unduly impairing the quality.

Fly ash is a concomitant of coal fired boilers, produced in profusion in thermal power stations and can be pro-cured at a cost little over haulage. Partial replacement of cement in Soil cement construction is found to accele-rate pozzolanic action. The fly ash produced from the boilers of 300 MV thermal Station at Neyveli is about 80,000 tonnes per annum and expected is go up to 1,50,000 tonnes when the third stage is also completed. The production of flyash at the existing thermal power stations in India is about 1 million tonnes and this is expected to rise to about 4.5 million tonnees. In deltaic areas, where the soil is soft clay or alluvial and where trans-portation of materials for concrete is high, stabiliza-tion of local soil with cement and flyash can be resorted, to obtain hard and durable surface.

A predominatly sandy soil has been chosen for study. The procedure for preparation and testing of various specimens of soil cement and soil cement fly ash has been followed according to the standard specification drawn by the Standing Committee of Indian Standards Institution for Soil Cement Work.

The quantity of water to be added to various mixtures has been determined from the optimum moisture content of the respective mixture, as determined by Dietert compaction apparatus. A series of specimens of the soil with progressively increasing cement content were prepared and from the unconfined compressive strength of 250 psi as the criterion, the optimum cement content was found out. Another series of specimens were prepar-ed with cement content fixed at the optimum value, and gradually adding increasing percentages of fly ash by weight of soil. A comparative study of these two series of stabilizer combinations have been made with respect to the Engineering Properties such as; Unconfined compressive strength, durability as ascertained from standard wetting and drying tests, permeability C.B.R., lineal shrinkage consistency limits, and particle size gradation analysis.

An experimental reach of sub-base course was laid to study the field performance of the mix. Study was undertaken to determine the modulus of sub-grade re-action of the natural sub grade and also of the laid sub base. After 21 days curing, a surface course of 10 cms was laid over the sub base. The effect of vehicular and other traffic is to be studied as a time process, so as to provide ample data for recommending this procedure for large scale construction.

III PROPERTIES OF MATERIALS

Characteristics of Soil—

The soil at a depth of 1' 0" to 1'6" at the test location was collected. The clods were crumbled, the soil dried in the oven, and the soil fraction passing No. 200 S.O. Sieve (A.S.T.M. 10), was used for laboratory tests. The results of tests on this Soil are furnished below :—

1. Specific gravity		2.56
2. Liquid Limit	..	26 per cent.
3. Plastic limit	..	17 perc ent.
4. Plasticity Index	..	9
5. Shirnkage Limit	..	28 per cent.
6. Natural porosity	..	0.38
7. Natural void ratio	..	0.61
8. Degree of saturation	..	16.7 per cent.
9. Colour at natural water content	..	Dark Brown.
10. Colour of oven dried soil	..	Light brown.
11. Natural moisture content	..	4 per cent
12. Natural dry density	..	99.42 lb./cft.
13. Optimum moisture content (Dietert)		14.3 per cent.
14. Maximum dry density (Dietert)	..	120.7 lbs/cft.
15. Maximum proctor dry density	..	117.5 lbs./cft.
16. Permeability at maximum dry density.		44.7 x 10 cm./sec.

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17. Highways classification (U.S.Public Road administration.)		A4
18. Unconfined compressive strength	..	45 psi.
19. Cohesion	..	1.2 psi.
20. Angle of internal friction	..	39°
21. Uniformity co-efficient	..	2.00
22. California bearing ratio Compacted)		5 per cent.
23. Lineal shrinkage	..	5.5 per cent.
24. Loss in wetting and drying cycles	..	100 per cent
25. Modulus of sub grade reaction	..	18 psi per inch.
26. Grain size analysis	..	Gravel 1 per cent. Sand 98 per cent. Silt 1 per cent.

FLY ASH.

Physical properties of Neyveli Flyash :—

Specific Gravity	..	2.26
Specific surface (Blaine's)	..	2300 sq.cm/gm.
Residue on B.S. Sieve 170 (I.S.No. ( ).:		34 per cent.
Normal consistency	..	40 percent.
Initial setting time	..	8 minutes.
Final setting time	..	14 minutes.
Fineness modulus (Sieve Analysis)		1.68
Tensile strengrth (7 days curing)		45 psi.
Compressive strength (7 days curing).		116 psi.
Colour	..	Bluish grey.
Unit weight	..	85 lb/cft.

Chemical properties of Neyveli Fly ash —

Silicon dioxide	..	35.8 per cent to 42.3 per cent.
Aluminium oxide	..	1800 per cent to 26.5 per cent.
Iron oxide	..	6.3 per cent to 8.2 per cent.
$SiO_2 + Al_2O_3 + Fe_2O_3$	..	60.1 per cent to 77 per cent.
Magnesium Oxide	...	3.5. per cent to 4.1. per cent.
Sulphur trioxide	..	2.2. per cent to 3.5. per cent.
Calcium Oxide	..	18.8 per cent to 19.8 per cent.
Loss on Ignition	..	1.3 percent to 1.9 per cent.
Lime reactivity	..	75 kgm/sq. cm.

Cement :—

Ordinary A.C.C. portland cement was used.

Properties :—

Specific gravity	..	2.99
Fineness (Blaine's)	..	2020p sq.c./gm.
Initial setting time	..	28 minutes.
Final setting time	..	10 hours 40 minutes.
Unit Weight	..	90 lb/cft.

IV. EXPERIMENTAL PROCEDURE

1. *Finding the O.M.C. for each specimen*

Various selected cement percentages by weight of soil were added to the oven dried soil and for each mixture the O.M.C. was determined with the help of Dietert apparatus. For a particular soil cement combination, a suitable percentage of water by weight of soil was added and the wet density after compaction was found out. From the wet density and known percentage of moisture the value of dry density was obtained. The moisture content was varied and the corresponding dry densities were determined. From the observation, moisture density relationships were plotted and the O.M.C. and maximum dry density of each mix was arrived at.

2. *Compacting the soil cement in the proctor mould with the water at O.M.C.—*

The soil with the requisite percentage of cement was dry mixed, and the water corresponding to the O.M.C. was added and intimately mixed. The mixture was transferred to the proctor Mould, with the collar on, and compacted in the automatic tamping machine.

3. *Extraction of samples—*

The proctor mould with the compacted sample is transferred to the soil ejector, and a sampling tube 11/2" diameter and 6" long is penetrated into the sample by screwing down the spindle on to the top of the sampling tube. The tube is then taken out and the sample more than 3" in length was extracted by the use of soil ejector.

4. *Preparation of specimens—*

The specimens were cut to 3" length and chamfering was done on both ends to be in conformity with the standard for the unconfined compressive strength test. The specimens were wrapped in polythene sheets, secured to them, and then placed under wet sand in a tray for curing. After 7 days curing, the specimens were taken out, air dried for one day and sun dried to constant weight.

5. *Finding the optimum percentage of cement —*

The unconfined compressive strength of the specimens were determined in the (motorised) unconfined compression testing machine. After plotting the values, the optimum cement content to give the design compressive strength of 250 psi . was determined.

6. *Finding the optimum soil cement fly ash mix—*

Another series of specimens with soil optimum cement content and progressively increasing percentages of flyash were prepared and tested as described above. The optimum design mix was found out after plotting the values of unconfined compressive strength and the fly ash content,

7. *Durability test —*

Soil specimen extracted from proctor mould using soil ejector was weighed after 7 days wet curing, air drying and sun drying. Then the specimen was placed in a tray containing water to keep it completely immersed. After 5 hours of wetting the specimen was taken out and drained for 5 minutes. Then it was dried in an oven to constant weight at 70. C for 42 hours and then weighed. 12 such wetting and drying cycles were performed as specified by the A.S.T.M. standards. Similar test was conducted for the specimen out of the optimum soil cement fly ash mix.

7. OBSERVATIONS AND RESULTS —

O.M.O. and maximum dry density of various soil cement mixes—

Number particulars.	O.M.C. by Dietert test.	*Dietert dry density lbs./cft.*	*Proctor dry density lbs./cft.*
1. Soil: ..	14.3	120.7	117.5
2. Soil+1 percent cement.	14.5	117.0	112.7
3. Soil+2 percent cement.	14.5	118.2	113.9
4. Soil+3 percent cement.	15.0	118.8	115.5
5. Soil+5 percent cement.	15.0	119.2	116.7
6. Soil+7 percent cement.	15.5.	119.2	117.4

O.M.O.and maximum dry density of various soil cement fly ash mix —

(1)	(2)	(3)	(4)
1. Soil	14.3.	123.7	117.6
2. Soil+5.8 percent cement.	15.0	119.4	11.70
3. Soil+5.8 percent cement 5 per cent fly ash	13.5	117.5	113.8
4. Soil+5.8 cpercent cement 10 per cent flya sh.	14.8	116.7	112·8
5. Soil+5.8 percent cement -15 per cent fly ash.	15.0	116.2	111.5
6. Soil+5.8 percent cement 20 per cent fly ash.	17.5	114.9	110.4
7. Soil+5.8 percent cement 25 per cent fly ash.	16.3	118.7	114.0

Comparative statement of physical properties of soil and soil cement, fly ash (optimum) mix 77: 4.5 : 18.5.

Number of properties.		*Soil.*	*Soil cement fly ash optimum mix.*
(1)		(2)	(3)
1. Colour	..	Dark brown.	Grey
2. Specific gravity	..	2.56	2.48
3. Liquid limit	..	26 per cent.	21 per-cent.
4. Plastic limit	..	17 per cent.	18 per cent.
5. Plasticity index	..	9	3
6. Shrinkage limit	..	14 per cent.	18.8 per cent.
7. Optimum moisture content	..	14.3 per cent.	16.5 per cent.
8. Max dry density (Dietert)	..	120.7 lbs./cft.	117.0 lbs cft.
9. Maximum dry density (Proctor		117.9	117.2 lb/cft.
10. Uniformity co-efficient by grain size analysis.		2.C0 :	3.40 :
11. Unconfined compressive strength (7 days curing)		45 psi.	250 psi.
12. Permeability at maximum dry density		44.7 x 10 cms/sec.	32.4 x 10^5 cms sec.

13. Lineal shrinkage	5.5 per-cent.	2.7 per cent.
14. Less in wetting and drying	100 per-cent.	8 per cent.
15. Modulus of sub grade reaction:	18 psi inch.:	216 psi inch.

IV. ANALYSIS OF TEST RESULTS

1. *Specific Gravity—*

There is no appreciable difference between the values for the soil and the optimum soil cement flyash mix.

2. *Atterberg limits —*

By the addition of cement and flyash to soil, the liquid limit has decreased, the plastic limit increased, and the plasticity index has decreased. The shrinkge limit has increased. The cause of this increase may be due to the greater affinity of water towards cement and flyash, the excess water required for hydration of cement and pozzolanic action of flyash because of its contents suchas Sio_2, SO_3 and Na_2 which react with CaO.

3. *Permeability —*

There is considerable improvement of impermeability of the optimum mix over that of the soil. Cement and flyash being extremely fine, may fill in the voids in the soil to a certain extent and act as binder materials.

4. *Linear Shrinkage —*

The percentage lineal shrinkage of the optimum mix has improved to the value of 2.7 from the value of 5.5 for the pure soil. This is due to the hydration of cement and setting action of cement and flyash.

5. *Moisture density relationships :—*

There has been an increase of O.M.C. of soil with the addition of cement or cement and flyash. This may be attributed to the tendency of cement and flyash to absorb water (hydration of cement and pozzolanic action of flyash). Evidently the maximum dry density values fall consequent on the increasing tendency of O.M.C. of soil cement and soil cement flyash mixtures. Addition of cement and flyash increased the O.M.C. to 16.5 per cent and decreased the maximum dry density to 117.2 lbs/cft. the corressponding values for soil being 14.3 per cent and 117.9 lb/cft.

6. *Unconfined compressive strength—*

The unconfined compressive strength for pure soil was only 45 psi addition of 5.8 per cent gave the required design strength of 250 psi. Further additions gave higher unconfined compressive strength. The same 250 psi strength was obtain able when 5.8% of cement and 24 per-cent of flyash, by weight of soil, were added to the soil. This is in effect partial replacement of cement in soil cement mix by fly ash.

From figure it is seen that for the same strength, there are two possible percentages of flyash, keeping the cement content constant at 5.8 per cent. The content of flyash in the design mix has been fixed as 24 per cent for obvious reasons.

7. *Effect of curing on strength —*

There had been a steady increase of strength with the curing period. This is analogous to the age hardening property of cement concrete.

8. *Wetting and drying test —*

The soil specimen could withstand only 2 cycles of wetting and drying and it failed during wetting in the third cycle whereas the optimum mix of soil cement fly ash withstood all the 12 cycles of wetting and drying and the cumulative percentage loss was only 8 percent as against a permissable value upto 10 pet cent for the mixture. The durability of the mix is thus increased by the addition of cement and flyash. This might be due to the coherence and well-knitting of the particulars of the mix which is able to withstand the detrimental effect of water on the specimens.

9. *Modulus of subgrade reaction :—*

The modulus of subgrade reaction for natural sub grade and for the sub base laid with the optimum mix of soil-cement and fly ash were 18 psi per inch and 216 psi per inch respectively. Thus there has been a considerable improvement in the supporting power of the optimum mix compared to the natural subgrade. The loads observed for the soil and for the mix for 0.05" deformation were 0.28 ton and 3.53 tons respectively.

VII. CONCLUSIONS —

1. Fly ash as a pozzolana reduces the maximum dry density and increases the optimum moisture content.

2. Compressive strength of 250 psi after 7 days curing for soil cement is obtained with an optimumcement percentage of 5.8 Further addition also improve the strength beyond 250 psi.

3. Soil containing 5.8 per cent and cement and 24 per cent flyash gives the requisite strength of 250 psi after 7 days curing the proportion by weight being 77:4:4 77.4:4:13.5 (or 78:4:18 by volume) of soil cement and flyash. Further addition of fly ash reduces the strength.

4. The compressive strength of the optimum soil cement flyash mix increases steadily with the curing period. The strength after 5 weeks curing is nearly 1.5 times that after 1 week curing period.

5. Addition of flyash reduces the plasticity index and makes the mix better workable.

6. Since there is improvement in the lineal shrinkage characteristic, occurance of shrinkage cracks is expected to be altogether eliminated by the use of fly ash.

7. Incorporation of flyash with cement improves the impermeable character of the soil.

8. The resistance to softening action by water is minimised in the case of soil cement fly ash mixture, and the loss in weight during standard wetting and drying test is within allowable limit.

9. The percentage of cement saved by the addition, of flyash to soil cement works out to 18.2 percent.

10. By the addition of cement and flyash, the modulus of subgrade reaction has been improved over the value for pure soil.

CIVIL ENGINEERING APPLICATIONS OF REMOTE SENSING

by

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SYNOPSIS :

Remote Sensing Technology which is an outgrowth of air photo studies is now gathering momentum rapidly and its application to assess, monitor and manage earth resourees is proving highly useful. This powerful, new technology envisages speed, accuracy and economy during its applications to the various disciplines and adds much to the conventional field surveys qualitatively and quantitatively. Air Survey technique is considered as one of the essential items to be referred to while finalising projects in some of the countries. The Civil Engineering Works are generally taken up for execution after conventional field surveys supported by toposheets and this paper deals with briefly the applications of Remote Sensing in the field of Civil Engineering along with the rudimentary aspects of remote sensing.

I. INTRODUCTION —

1.1 Remote Sensing may be defined as the art of collecting information about an object at distance without actually coming in contact with it. This definition broadly covers the air and space photography, X-ray studies etc., Remote Sensing is not a new one and it is as old as the evolution of the human civilization. In the olden days, people used to see and sense the objects at farther distance by climbing a tree or a hill top.

1.2. The energy involved in Remote Sensing is that of light. Two systems of radiations are generally used in the imaging techniques and they are (i) active radiation wherein the energy is sent towards the target in electric pulses as in the case of Radar and (ii) Passive radiation where in the solar energy is the source of radiation.

The whole phenomenon of remote sensing using passive system of radiation is illustrated in the Remote Sensing model in figure 1. The remote sensing model has four components(i.e.)the Radiation source, transmission paths; target and sensor. The radiation emanating from the sun's photosphere reaches the atmosphere with a velocity of about $3 \cdot 0 \times 10^8$ M/Sec. The radiation of a 6000°K black body closely approximates the solar extra terrestrial radiation characteristics. This radiation forms later on, high speed link between the objects on the ground and sensors.

1.3. Referring to figure 2, the electromagnetic spectrum has the panchromatic visible portion at the centre flanked by the non-visible portions on either side(i.e.) the gamma ray, X-ray, ultraviolet rays up to 0.375 micrometer in the lower wave length portion and the visible portion between 0.375 to 0.75 micrometer and the infra red and other micro waves beyond the wave lengths of 0.75 micrometer.

1.4. The transmission paths have two segments (i.e) one between the radiation source on the space and target on the ground and the other between the target to the sensor on the space. The outgoing radiation in the second segment has change in its magnitude and this change in magnitude of the outgoing radiation enables the study of the objects on the ground. A complex process of scattering, reflection and absorption of the radiation by the atmosphere alters the amount of the solar energy, impinging on the earth's surface. Similar alteration occurs when the energy reflected from or emitted by a feature on the earth's surface travels back through the atmosphere and gets recorded in the sensor. As regards scattering, Rayleigh's scattering and Mie scattering are considered important in the visible portion of the Electromagnetic spectrum. According to Rayleigh, scattering is inversely proportional to the fourth power of the light wave length. Thus, the shorter wave lengths like those blue waves generally get scattered more than the red waves. Mie scattering occurs when the size of the atmospheric aerosols, dust, haze/smoke particles, etc. is approximately between 0.1 C λ C 25 where is the light wave length.

1.5. The physical and chemical properties of the target objects control the reflection, absorption and emission characteristics of the incident solar energy striking the target objects. The reflected energy in the visible spectrum infra red portion and thermal infra red portion is unique for each object for a particular wave length and each object has its own reflective signature which is responsible for identification of the objects subsequently. This phenomenon is illustrated in figure 3 wherein the reflection characteristics of soil, water and vegetation are typically represented for varying wave lengths.

1.6. The sensors that are used in remote sensing are generally optical, electrical and mechanical type and they are broadly classified as multispectral scanners, photographic and Radar Sensors.

2. APPLICATIONS OF REMOTE SENSING TECHNOLOGY TO CIVIL ENGINEERING.

2.1 Remote Sensing Technology has two broad aspects, one being the photogrammetric aspects and the other being the photo-interpretation aspects. Photogrammetry deals with making measurements with air or space photos. The photo-interpretation is made visually on air or space photos using several photocharacters like tone, texture, size, shape, pattern, association, etc. In the case of satellite photos taken by multispectural scanners, computer-aided interpretation is possible using the principles of pattern recognition and suitable computor programmes.

2.2. Before discussing the applications of remote Sensing in the field of Civil Engineering it is relevent to discuss the salient utility aspects of the conventional toposheet and the sophisticated air/space photos.

2.3. The toposheet map is of orthographic projections. It is of symbolised and generalised nature; it does not have any three dimensional effect. In as much as it does not reproduce the ground features faithfully, it may not be useful for resource inventories.

2.4 Due to parallax effects in the common overlap portion of the adjacent airphotos, stereovision is possible and this enables the photo-interpretor to view the relief aspects of the terrain. It reproduces faithfully all the informations of the terrain. The air photo taken by air cameras is a perspective projection and is subject to

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the eventual image displacement defects (which could also be corrected). Due to tilt in air craft movement, the image is also subject to distortion (which could also be rectified). The air photos require annotation. The air photo covers generally to visible portion of the electomagnetic spectrum. The resolution of air photos is more than that of satellite as the air-craft flies in lower altitudes.

2.5. The satellite photos are taken from higher altitudes and they cover larger areas synoptically, for example, the remote sensing lands at orbits the earth at about 920km. above earth and covers 185 k.m. X 185 k.m. The satellite will record sequential photos automatically (i.e.) the land sat makes 14 revolutions every day and it comes over the same area once in 18 days after covering the entire globe in that period. It scans the earth in difference bands in the visible and infra red portions of E.M.R., each band revealing certain features clearly, for example, 4th band of landsat 1 & 2 is for water quality studies and band 7 for surface water mapping, band 5 for cultural features and band 6 for soil and vegetation studies, etc. Due to the high altitude of orbit, stereovision is difficult and the satellite imagery (photos) are to be studied in singles and also the resolution is low as compared to the air photo (the ground resolution is about 1.1. acre for landsat imagery).

2.6 The integrated use of the toposheets, air and space photos results in better interpretation. The air and space photos are useful for local and regional analysis respectively. Some annotation details like geographical co-ordinates, cultural features, etc., are taken from toposheets. Toposheets are referred while sealing the air photos. (The geographical co-ordinate are generally furnished in the satellite photo itself). The two important factors (i.e.,) the stereovision and the tonal changes are considered as most useful in airphoto-interpretation techniques. Similarly, the tonal changes and the multispectral, synoptic view available for space photos are used for extracting thematic information.

2A. IRRIGATION ENGINEERING.

2A.1. The stereoscopic study of the air photos could be used for selection of major, medium and minor irrigation project sites. The narrow, deep river gauges with proper stable river bed and banks without scouring and silting could be selected for location of storage dams or diversion anicuts across rivers. The watershed ridge line bordering the catchment area for the selected dam site could be traced on the air photos accurately under mirror stereoscope. Borrow pits required for earth dam and quarry sites required for masonry works could be located near the dam sites interpreting the surface expression of the terrain. The canal alignment (contour and ridge canals) could be proposed from air photos, using the three dimensional view that gives the relative ground level differences. The ayacut that could be commanded by the dam/anicut may be localised with reasonable accuracy. Different alternatives for a dam/anicut alignment and canal alignment could be tried and preliminary report with limited field check could be prepared before taking up detailed field surveys. For existing storage works, waterspread areas could be worked out from air/space photos and this waterspread areas could be used for computing capacity of the storage works if calibrated capacity curves are available. The ayacut area and the type of crops, crop disease, etc.) under dams could be worked out from the multispectral air and space photos.

2A.2. The stream network in a watershed could be traced from air photos and the morphometric analysis dealing with the basin geometry in respect of linear, aerial and relief parameters correlated to the erosion, discharge, permeability of soil, etc., could be worked out.

2A.3. For groundwater studies inferences are made about sub surface from surface expression. The recharge areas could delineated from air photos. The linements, river, alluvium, old burried channel courses weathered mantle etc., where groundwater is normally trapped could be detected from air photos.

2B. HIGHWAYS AND RAILWAYS.

2B.1. Different Roadways and Railways alignments (ghat or plain) could be tried using air photos. The river/streams portions could be studied from air photos under mirror stereoscopes and suitable bridge sites could be located across rivers, steams where the river section is narrow, stable without scouring and silting.

2C. WATER SUPPLY.

2C.1. Alignment of water-supply mains from head work to different towns/villages could be proposed from air photos. Similar proposals could be made for drainage networks also.

2D. AGRICULTURAL ENGINEERING.

2D.1. Some upland areas are subject to constant active erosion due to wind, terrain slope, high temperature, low rainfall, etc., and such areas could be deducted from air photos and suitable measures to conserve soil from erosion in such areas could be proposed.

3. CASE HISTORY.

3.1. Fig. 4, is the computer generated map showing the water spread area of lower Bhavani Reservoir as on February 27,1973. The volume of water stored in the reservoir on this date of scanning can be read off from the already calibrated capacity curve of the reservoir.

3.2. Fig. 5, is another computer generated map showing the soil erosion phenomenon actively taking place in Bhavani Noyyil basin. The top soil is being removed exposing the bottom pegmatite rock consisting of highly light reflective quartz and felspar.

3.3. The above were extracted from the multispectral lands at scanner data using computer aided interpretation techniques at the Laboratory for Application, of Remote Sensing (LARS) Purdue University, U.S.A. by the author.

4 CONCLUSION.

4.1. Air photo or the landsat data analysis is not an end but it is a powerful means to an end. The interpreted results require limited ground truth verification in the field for final evaluation.

4.2. The quality of conventional field surveys for Civil Engineering Works could be improved by making use of the air and space photos. The applications of remote sensing could be effectively used economically with speed and accuracy at the investigation, execution and maintenance levels.

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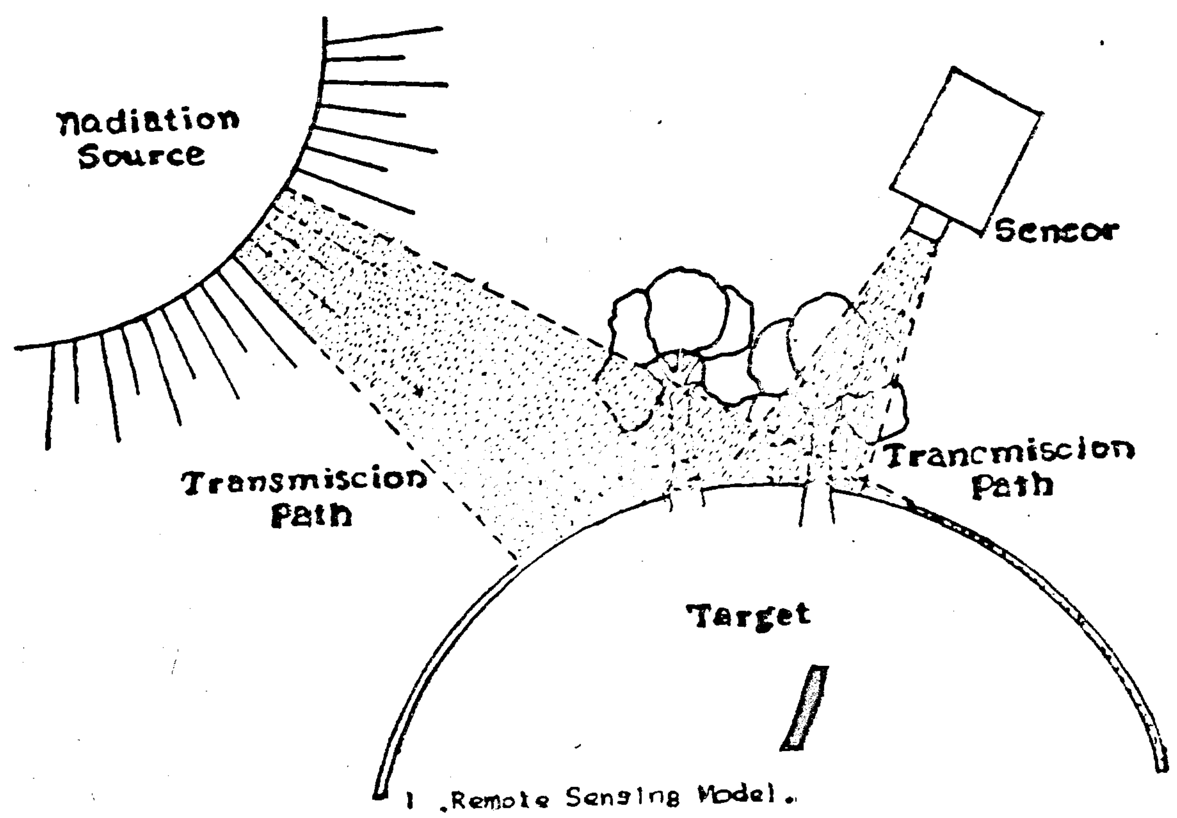
1. Manual of Remote Sensing by the American Society of Photogrammetry.
2. Aerial Photographic Interpretation by LUEDER.



1 .Remote Sensing Model.

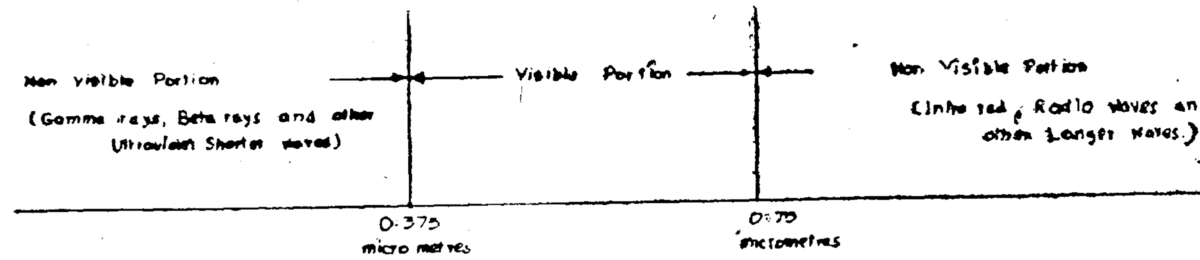


Fig 2. ELECTROMAGNETIC SPECTRUM

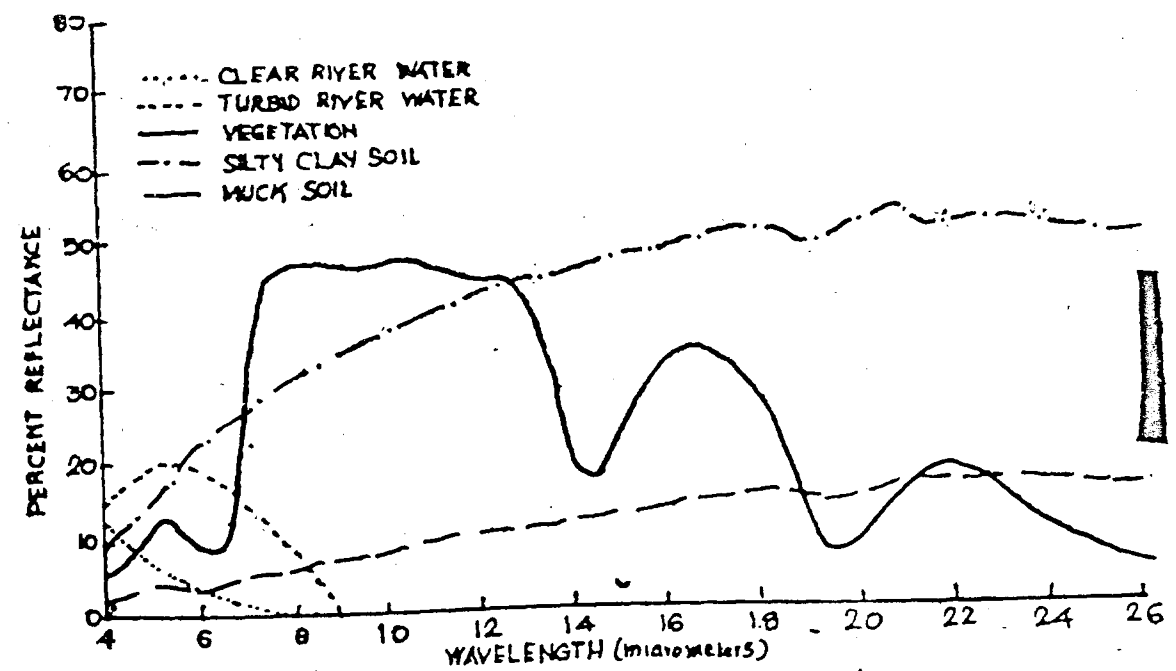
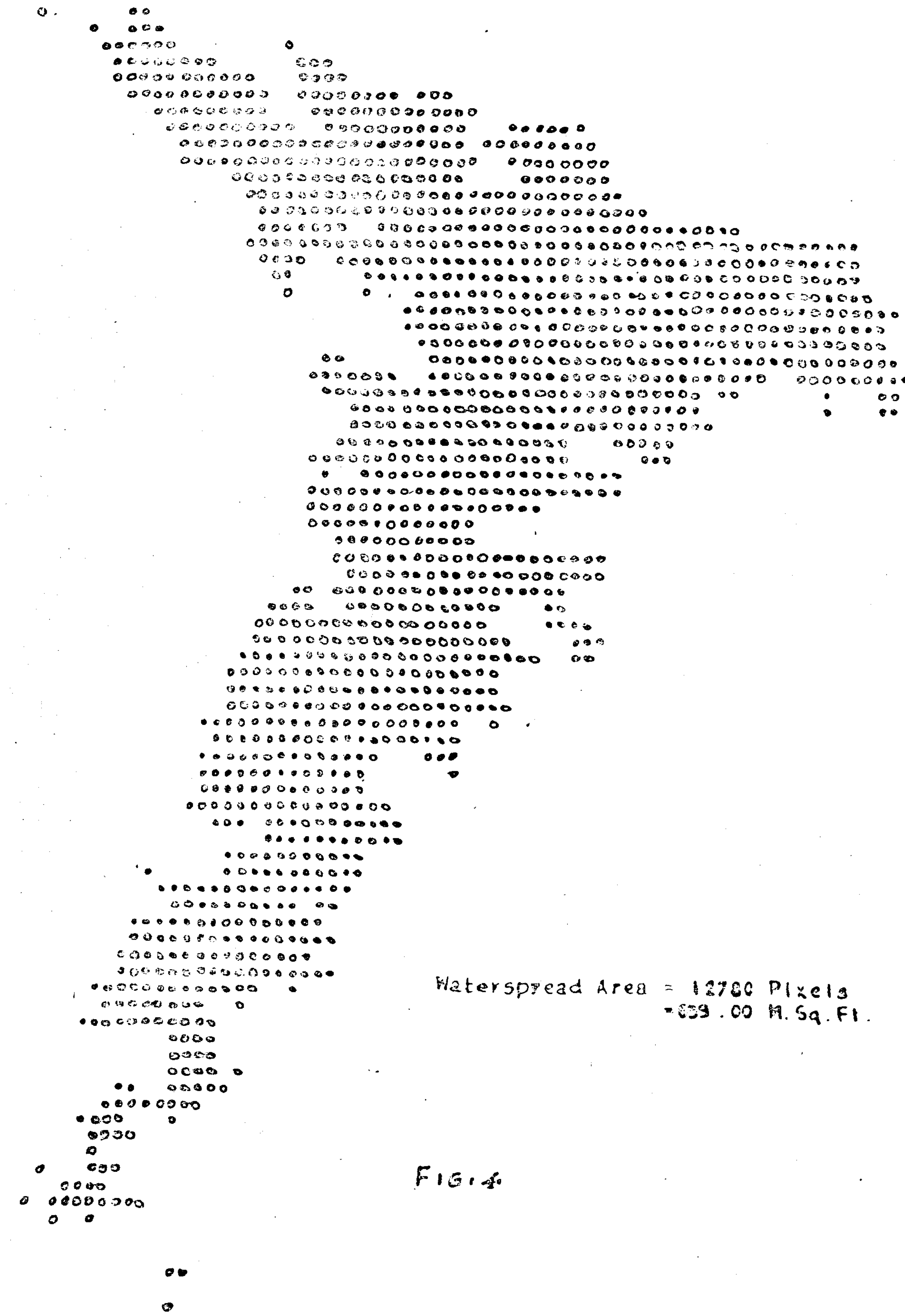


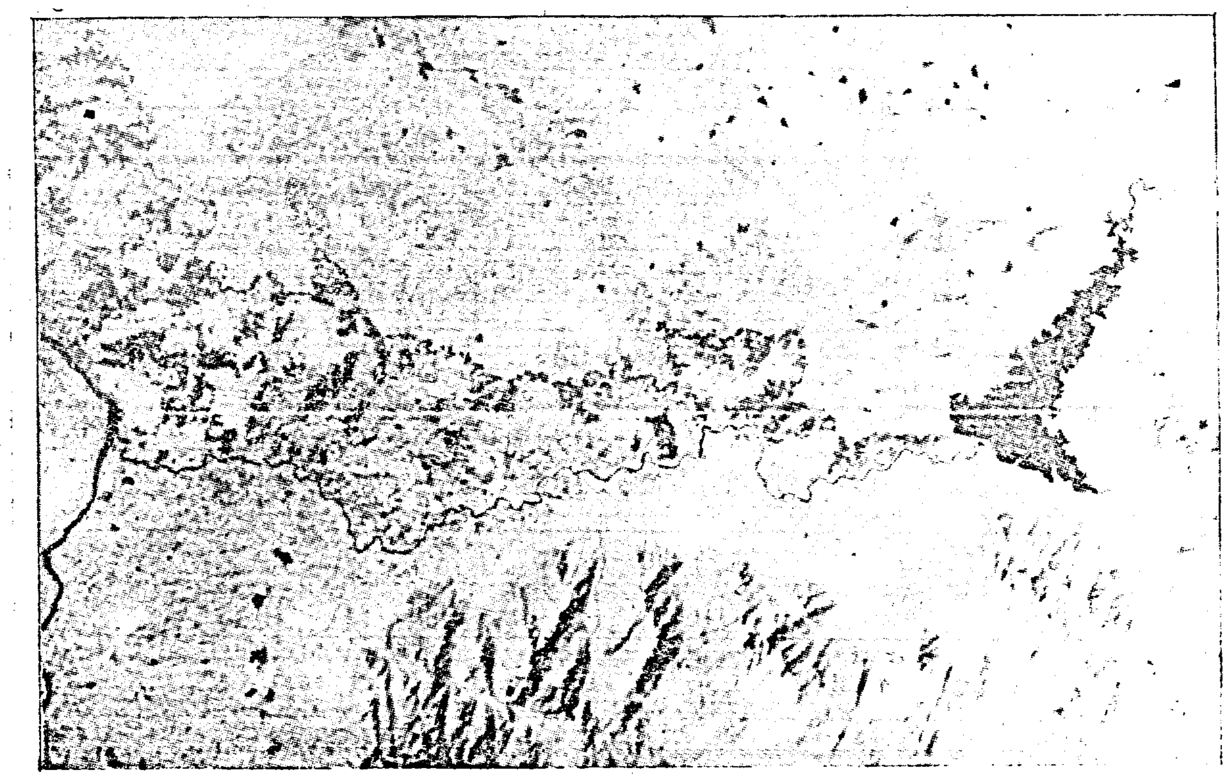
Fig-3 Spectral reflectance of basic cover types

Waterspread Area Of LOWER BHAVANI RESERVOIR On. Feb 27, 1975.



Waterspread Area = 12780 Pixels
=639.00 M.Sq.Ft.

FIG. 4



(Fig. 5)

THE NEED AND METHODS OF ARTIFICIAL RECHARGE OF GROUND WATER IN COIMBATORE DISTRICT, TAMIL NADU.

by

Prof: R. K. Sivanappan.

INTRODUCTION:

Coimbatore district, one of the leading districts in Tamil Nadu in the industrial field is also outstanding in the field of agriculture and is well known for its enterprising agriculture. But it is a deficit district in the food production. Out of 15,67,900 hectares, only 7,26,880 hectares are cultivated. The net area irrigated is 2,55,700 hectares forming about 35 per cent of the area sown. Most of the areas, the rainfall is around 500—600 mm. and this is erratic and failure of rains in these areas are more common. Since there is no scope for expanding irrigation facilities, the only way to increase irrigation is by tapping ground water source. There are about 1,50,000 wells in the district irrigating about 1,40,000 hectares which forms about 40 per cent of the total area irrigated.

To bring more lands under irrigation, farmers are going for new wells and also deepening the existing wells. In the whole of Coimbatore District, there were only 53,540 wells in 1895, which had increased to 1,14,638 in 1955 and then to 1,50,000 in 1972. The water levels in many parts of the district receded steadily because pumpage exceeded replenishment by natural recharge. This is more true in the area around Coimbatore City. In other parts of the district, though the water level has gone down considerably in years of good rain, the level rises up.

1. PURPOSE AND SCOPE.

As stated early, the farmers are hard working and can produce more per cm. of water/hectare/unit time compared to other farmers in the State. The land is very fertile and the Major constrain for them is to get water. A saturation has reached in constructing wells in this part. A comparison of ground water table of 1928-29 and 1969 indicates an average depletion of 16.5 m. The depletion in ground water level of individual wells is shown in Fig. 1.

The district has about 120 tanks which is lowest in the State and consequently surface water storage hardly exists. Natural storage is limited to solely the amount which the sub-soil is capable of holding. Further a large area comprises of black cotton soil and hence the rain water runs off immediately without storage. The main storage space in the hard rock is constituted by surface fissures and cracks, generally existing to a depth of 30 m. The storage volume of these rocks is in the order of 1 to 3 per cent of the total volume. The storage potential is sufficient only for 100—200 mm. rain for 10m. depth in the ground.

2. IMPORTANCE OF ARTIFICIAL RECHARGE OPERATIONS.

The area irrigated is only 35 per cent of the total area sown. The average rainfall in the plain is about 600 mm. and in the hills about 1,000 mm. The total water received from the rain is 11,000 m. cum. and assuming 50 per cent is lost by evaporation and evapotranspiration through trees, dry areas, etc., the available water for irrigation will be about 5,500 m. cum. From the various crops grown in the district, it is found that the water used comes to about 39,000 m. cum. The water used by people, livestock and industry is about 100 m. cum. Hence the total water consumed is only about 4,000 m.cum. whereas the usable water is 5,500 m. cum. (*vide* Appendix I). This water is either lost as runoff during heavy rains or not properly and economically used. Hence the water which is not utilised during rainy period is to be collected and recharged so that the same could be tapped by constructing more number of wells to irrigate additional areas in the future and also to augment water supply to the existing wells.

The practice of depositing water in sub surface storage basin is called artificial recharge. It conserves water and raises water table levels. The effectiveness of this practice can often be measured in rupees and paise. The graph showing how pumping costs and pumping depth are related to each other (Fig. 2). Assume that the water level is 150' beneath the surface. By providing recharge, the water table has raised by 50' (100' from ground level). Pumping costs are then reduced at least by Rs. 1.25 for each acre inch or hacm of water pumped. This will reduce the Electric charge by Rs. 40 per acre of cotton crop in addition to saving of energy is also envisaged.

To bring the dry land under irrigation, wells are constructed at huge costs. Since the extracted water is more than the recharged water even if the depth is more, water is not found in the wells. Heavy sums of money are being invested every year in this process. This district is having more number of wells but very less number of tanks. Hence there is no possibility of storing more water for irrigation and recharging; but the extraction is more than the recharge through these wells and it is increasing year after year.

The entire rain water fallen has not been utilised fully even during the normal years and hence more water is lost during abnormal heavy rainfall years. It is advisable to employ the ground water reservoir before monsoon starts, so that the emptied under ground reservoirs could be filled up during the rainy period by artificial means. The water thus collected in the underground reservoir can be profitably used in summer.

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'It is necessary to prepare a comprehensive master plan for the control, protection, conservation, distribution and utilisation of the available rainwaters in this district. This plan has to meet the present and estimated future needs of the district to the maximum feasible extent. The role of artificial recharge plays an important part in the over all water resources planning. In this plan, the water source both surface and underground could be identified and redistributed the excess waters from one basin to other basins. There are many mountains in this part and it is possible to construct surface storage tanks in a series at the foot hills for recharging and irrigation purposes. The operation of these surface and ground water reservoirs would be co-ordinated to achieve optimum conservation. Recharging of ground water reservoirs would be accomplished by artificially recharging local and imported water (from Kerala and Karnataka States) through facilities provided for this purpose by percolation and excess of applied irrigation water and of precipitation during water years and by seepage of water from surface distribution canals, most of which would be unlined to increased percolation opportunity.

3. METHODS OF ARTIFICIAL RECHARGE AND SOME DESIGN CRITERIA.

Artificial recharge of ground water includes a number of methods by which the rate and the amount of natural infiltration are increased. In the broad sense, contour farming (dry lands) and irrigation (wet lands) might be considered as method of recharge content of the upper, unsaturated strata for agricultural use rather than raise the saturated ground water level. The following are the methods used to recharge in the various parts of the world.

(i) Land flooding.

(ii) Ditches and furrows.

(iii) Recharge wells.

(iv) Recharge pits.

(v) Recharge basins.

(vi) Nalla bundings.

(vii) Percolation tanks.

(viii) Contour bunding in the dry land with contour cultivation.

(ix) Contour trenching in the upper catchment basins.

(i) *Land flooding*—

Flooding is a very effective and low cost method of recharge in areas in which slopes are gentle and uniform and where gullies or ridges are small. Land flooding involves inundating a tract of agricultural or waste land which is bounded by adjoining hills or levees. Water is allowed to flow over the land surface in a thin sheet. Weir type embankment with control arrangements are provided to the gullies to divert the water to spread the areas. Since most land flooding basins are used to capture excess storm water, rates of inflow varies considerably. The initial infiltration rate may be high and the rate may be reduced as low as 1''/day. Averege rates of recharge for this method may be 0.5 to 1.5/day. Land flooding method is practised in the western side of Perianaickenpalayam area of this District for two reasons. 1. To recharge the ground water in the basin and 2. To get silt from the flood water to their lands. The flood water is diverted to the cultivated land even if crops are in the land and arrangements are made in the lower portion to remove the excess water safely again to the gulley. Since the land is ploughed and cultural operations are done every now and then, the silt deposited is disturbed and thereby the infiltration rate is maintained without affecting in the next flooding. This practice can be followed in many places in the district especially in the foot hills of the mountains.

(ii) *Ditches and furrows (Channel)*—

The ditch and furrow method consists of a system or flat bottomed ditches that serve to transport water and provide percolation opportunity. Pass the flood water through a series of furrows and ditches with flat bottoms. Space them closely in order to utilise the greastest possible percolating area. Slope the ditches to make the water flow freely and hold in suspension any silt.

The farmers in Avanashi, Coimbatore and Palladam taluks are requesting the Government to take water in an unlined earthern channel through their lands without allowing it for irrigation, so that this will facilitate their wells get recharged.

Several systems of furrows and ditches are available for this purpose. 1. Contour type, 2. Lateral type 3. Tree shaped. The design usually corresponds to the site. 'The width of the ditches may vary from 1' to 6' depending on the terrian and the velocity desired.

(iii) *Recharge wells*—

Recharge wells or injection wells are used to increase the flow into an aquifer. (Fig. 3.) This is largely confined to those areas where surface spreading is not feasible due to the presence of extensive and thick impermeable clay layers overlying the aquifers. This is more suitable near the cities as the land values are too high to utilise the basin, flooding or furrow methods. Old and abandoned wells may be used for recharging the ground water. Successful recharge well should receive filtered water otherwise in a period of short time, it may lose 50 per cent of its initial capacity. The spacing of the wells depends on the range of influence of a well, that is in turn dependant on the amount of water to be recharged and the acceptance rate of the aquifer. The acceptance rate s a function of the aquifer permeabilities, hydraulic gradient, the length of casing penetrating the aquifer, and the number of casing perforation.

In general, the water to be recharged should be maintained at a relatively constant pressure, and should not be allowed to fall freely in this well, because the resulting aeration greatly affects acceptance rates.

(iv) *Recharge pits*—

There may be abandoned gravel and sand pits or the pits constructed for the purpose of recharging the ground water. The initial cost of both of the type is low since all that is required in a conduct leaching to the soil for delivering of water. Since the ground water level is very deep in the district, the pit will be very effective. Pits will have higher rate of inflow and occupy smaller total area than land flooding. Since there may be many pits spread over the entire area, the same could be used for recharging purpose. In this method the silt settles and the bottom leaving the side walls relatively free continued infiltration of water.

(v) *Recharge basins*—

This is the common method used for recharging. Water is impounded in a series of basins that are formed by a net work of artificial dykes or levees. The basins are usually so arranged that the entire area between the dykes can be submerged during spreading. The dykes may follow the contour (Fig. 4).

In this method the silt is deposited in the upper most pond and when the water flow to the lower basin, it becomes relatively clear. The silt can be removed from the upper most basins between intervals of recharging. In this method, the wetted area is usually greater than other methods and the water is also controlled.

(vi) *Nalla bunding*—

In the basin method, flood waters are diverted to the nearby basins through channels formed from the reservoir or storage places. To operate this, sufficient land at suitable places are required and it may be difficult to get it especially in this district. But in the Nalla bunding system, there is no land required for recharging purposes. In this method, small earthern bunds or masonry weirs are constructed across the Nalla at short intervals. These bunds will obstruct the flow and store to a depth of 5'-6'. Since the bunds are formed at 400—500m. intervals, the entire flood water is stored at the place the rain falls and there will not be any water joining from the Nalla to the river. Natural outlet will be provided in one side of the Nalla in order to remove the excess water. This will be very effective especially in the jungle streams that flow in great velocity after a heavy rain. This can be practised in most places in this district to store and recharge the ground water. The cost for constructing the bunds are very cheaper and the villagers themselves can also do it without any technical skill. This kind of arrangement is being adopted in some places in Maharashtra and Karnataka State and the same is functioning very satisfactorily. There is no extra land required in this method for recharging purposes. The gully or stream courses itself is used as the recharging basins.

(vii) *Percolation tanks*—

Runoff water from the stream is collected and stored in a tank constructed for this purpose. When water is stored, percolation takes place and the water table in the surrounding wells are raised. Quite a number of tanks are constructed recently in this district, but it is not sufficient. These tanks help in raising water table to a distance of 600—1000m. The capacity of the tank and other details are to be worked out by knowing the catchment and rainfall of the area. Tanks cannot be constructed in all places across the stream. Hence this method is having some limitation. However, where the land value is less, this could be adopted.

(viii) *Contour bunding and contour cultivation*—

Earthern bunds are constructed across the slopes on contour in dry lands in order to conserve soil and water. Since these bunds are formed at 30—60m. interval, the rain water is obstructed and stored in between the bunds and this water percolates in the soil and join the ground water. Necessary waste weirs or surplus escapes are to be provided to remove the excess runoff as it is not economical to construct bunds to store the entire rain water. After the formation of bunds, the entire farming operations should be on the contour in order to restrict the flow in between the bunds. It is reported that by following this practice, in Tamil Nadu and Maharashtra the water table has been increased in the wells. This method helps not only to recharge the ground water but also conserve the soil which helps to get more production in dry land cultivation. However, this work should be taken up on a catchment basis, otherwise, bunds may be breached.

(ix) *Contour trenching in the foot hills of mountains and upper catchments*—

When the slope is more in the foot hills and in the upper catchments, the erosion will be more as the lands are not suitable for cultivation. In order to prevent erosion and to arrest the runoff, trenches may be excavated, on contour and runoff water may be collected in the trenches. The collected rain water will percolate and will help in improving the water table in the locality. Further, by aforestation works, the wealth of the area can be improved (See Fig. 5).

4. ARTIFICAL RECHARGE WORKS CARRIED OUT AT PRESENT.

No systematic artificial recharge is being carried out in this district, but the Government through Public Works Department, Highways and Agricultural Department have constructed number of tanks, i.e., under famine relief programme in many places. The work done so far has not touched the fringe of the problem. During rainy season, even now large quantity of water is flowing as runoff and in the next summer, wells are becoming dry. There are numerous tanks in other districts of the State, but the number of tanks in this district is very meagre and hence the recharge is very less. In this connection, if it is not out of place to mention that many agencies are tackling this problem in advanced countries, but this work has not been taken up so far in scientific manner in this part of the country. In the Los Angles County (Taluk) where the rainfall is only 14", there is a flood control board whose work is to collect, store and recharge the flood water. The staff strength is about 2,000 including 400 engineers in the year 1969. Considering this, the work done here is negligible. In California, State, U.S.A. as of October 1958, there were fifty four agencies actively practising artificial recharge. The majority of the agencies are public agencies such as irrigation district, water conservation districts and flood control districts. Hence, action should be taken to work out the details for recharging the ground water in Coimbatore district without further delay.

5. SELECTION OF METHODS AND LOCATIONS OF SITES.

Numerous factors govern the selection of a potential recharge site. The engineer and geologist must carefully evaluate these factors individually and collectively. The factor are :

1. The availability and character of local and imported water supply ;

2. Factors affecting infiltration rates, ground slope, surface soils and geological and sub surface hydrological conditions ;

3. Operation problems ;

4. Net benefits.

Though there are different methods to recharge, all methods are not suitable for a particular place. The method which is suited to a specific locality should be selected and adopted. Since this district is having numerous mountains and hills, it is possible to find many locations to use as recharge sites.

6. FUTURE PROGRAMMES.

There is great scope for improving the water supply position in this district. Further the surplus water flowing to the Arabian Sea through Kerala State originating from Nilgiris may be diverted for recharging and irrigation purposes. The water which is not used at present may be conserved and stored in order to utilise for more areas and during drought years. The pond schemes may be intensified and this work may be taken up in a systematic scientific basis instead of doing it in a haphazard way only as a famine relief work. In addition, the Nalla banding work may be taken up to start within the scarcity areas. The Panchayats, Municipalities and farmers co-operation can also be involved in conserving water. These agencies can identify the sources and plan for individual localities, if necessary they can levy some amount from the beneficiaries to execute the work. Agencies like water conservation or flood control boards may be formed and aids and grants may be obtained from the State and Central Governments to take up the work. The recharge work should be taken up on warfooting basis for this district, otherwise, in another 15—20 years there may not be any water even for human living. At the same time, legislation should be brought to regulate the water resources of this district. Further, the available water should be used to get the maximum benefit. To achieve this cropping pattern should be evolved in order to get maximum return/cm of water/hect. of land/unit time. The farmers and public should be educated in the need for conservation of the source commodity namely, water.

7. SUMMARY.

Artificial recharge of ground water is one of the important conservation practices which is very necessary for Coimbatore District. The rainfall is meagre and runoff is less hence it is all the more important. In addition, the possibilities of diverting surplus water from neighbouring state for recharging may be explored. Though some work has been done in this direction, yet a lot has to be done. Cheap methods like Nalla bunding contour bunding and percolation tanks may be taken up for the entire district in order to raise the water table in the wells. In addition, the available water should be allocated in order to get maximum profit per/cm. of water/hectare of land in unit time. These objectives could be achieved if sincere efforts are taken up as stated in a systematic and scientific manner by all the concerned.

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APPENDIX I.

	hectare.
Total area in the district	15,68,000
Area in plains	12,00,000
Hills and mountains	3,68,000
The average annual rainfall (Plain)	650 mm.
The average rainfall (Mountains)	1,000 mm.

Total rain obtained in the plain $\dfrac{12{,}000 \times 650 \times 10{,}000}{1{,}000}$ = 7,800 m. cum.

Total rain obtained in the Mountains: 3,68,000 × 1000/ 3,680 m.cum.

Therefore total rainfall over the district —11,180 or 11,000 m.cum.

Assuming that 50 percent of the water is lost by interception, evaporation and in dry land forest area etc., the available water.	$\frac{11,000 \times 50}{100}$
	= 5,500
The total water used for irrigation . . .	3,900
Water used for industry, municipal supply, livestock.	100
	4,000

Therefore the balance available : 5,500—4,000 = 1,500 m.cum.

Area irrigated by different sources :

	hectare.
Canal irrigated area..	1,10,000
Well irrigated area	1,40,000
Tank irrigated area	5,000
Well irrigated area	2,55,000
More than once	65,000
Gross irrigated area	3,20,000

Area of crops irrigated :

Paddy ..	97,659
Sugarcane ..	23,319
Cotton ..	49,551
Other food and non food crops	1,49,471
	3,20,000 hect.

Water used for irrigation :

(1) By sources—

Canal $\frac{1,10,000 \times 250}{100}$ = 2,200 m. cum.

Well $\frac{1,40,000 \times 120}{100}$ = 1,680 m.cum.

(double crop for 50 per cent of the area).

Tank $\frac{5,000 \times 400}{100}$ = 20 m.cum.

3,900 m.cum.

(2) By crops—

Paddy $\frac{97,659 \times 200}{100}$ = 1,450 m.cum.

Sugarcane $\frac{23,319 \times 250}{100}$ = 582 m.cum.

Cotton $\frac{49,551 \times 75}{100}$ = 375 m.cum.

Other crops $\frac{1,49,471 \times 65}{100}$ = 970 m.cum.

3,20,000 — 3,877 or 3,900 m. cum.

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TRIAL FLOOD BANK FOR THAMES DEFENCES

As part of the site investigations for the new Thames flood defences, a fully-instrumented trial flood bank, 130m long was constructed to study failure on soft alluvial soil at Dartford. The aim was to assess the problems likely to arise in constructing the new flood banks, to check the various methods of measuring the properties of the ground and to look at possible ways of anticipating failure.

BRE Geotechnics Division designed the trial bank and the instrumentation, the Southern Water Authority Commissioned the construction and helped with the instalation of the instruments. and the Property Services Agency carried out the detailed survey work. The data obtained is being used in finalising the designs of the flood banks.

New flood defences are being built to protect London and the low-lying areas along the Thames down stream from London. They comprise a movable barrier across the Thames about 7 km east of Central London, and the raising or reconstruction of about 100 km. of of river defences downstream of the barrier. A large proportion of these will be earth banks built on soft alluvial soils.

Earth banks have been used to protect low-lying areas along the Thames since the twelfth century. They have been progressively raised and widened as the flood levels and subsidence of the ground have gradually increased. The last major improvement followed the severe floods of 1953, when many of the banks were raised by a metre and their cross-sectional areas almost double. The stability of these reconstructed banks was very low, and base failure were fairly common.

The new designs call for an increase in bank height of 1.5 m to 2 m. to withstand a maximum water levels, including waves, of 6.9 m ODN. This cannot be achieved by building on top of existing banks because of the risk of slips, and it will therefore be necessary to build many new banks on virgin marsh land by the side of the existing banks. Measurements of the properties of the clays in the marshes and below existing river banks provided data for preliminary designs, but it was decided to confirm these by field trials including the construction of trial banks. A scheme for reclaiming a small area adjacent to little brook power station, about 27 miles east of London, provided an excellent opportunity. The permanent scheme for this site is to construct a new clay bank towrds the edge of the high ground on the riverward side of the existing bank and to increase the ground level between the new and existing banks by pumping in sand and gravel. The trial bank, similar in profile to the permanent one, was built using the sandy gravel fill material later used to complete the reclamation.

Monitoring instruments, some of them developed specially for the trial were first installed and tested, and then the task of gradually building up the bank began. First sand and gravel were pumped in, and then horizontal layers of sandy gravel 0.33 m. thick were added and compacted by bulldozers. These lifts were added on a regular time schedule as far as possible; during the critical stages—between 6.5 m and 7.5 m—they were added at about 2 days intervals with the major portion of each layer added in less than five hours. This allowed some consolidation to take place between lifts. There was some horizontal movement of the bank each time a layer was added, and the amount and rate increased as the bank grew higher. First signs of failure were observed as the height was increased to 8.5 m. ODN (overall bank height 6.3 m) and a full slip developed over the next 10 hours.

The results showed that the triaxial tests carried out before the trail provided a reasonable basis for the preliminary designs, but that field vane tests can seriously over estimate the strengths which can be mobilised under an embankment. It also showed that localised failure through surface layers of recently deposited organic clays can be prevented by allowing shorterm consolidation to take place during the early phases of construction.

Pore water pressure measurements cannot be used to provide a direct indication of the onset of critical conditions. The best indicator was found to be measurements of horizontal movements on and under the berm. Regular monitoring of these movement with inclinometer tubes would provide a reliable accurate and quick means of controlling the construction of the permanent banks. A tentative rules is that the ratio of the horizontal movement during the 24 hours period starting with the placement of a layer to the movement during placement should not exceed two.

COURTESY

(BRE NEWS 41)

INVITATION TO READERS

Kind attention of Engineers of Tamil Nadu Public Works Department and other readers of the journal "NEW IRRIGATION ERA" is drawn to the meagre response to repeated requests for contribution of articles to the journal.

As all are aware the objective of the journal is two fold viz., to promote the interest of Engineers and assisting their specialised work by placing before them the different problems of technical importance and ways and means of solving them and secondly to offer to all Engineers to express their own experience in various fields. It is desired that the Engineering fraternity will come forward in large numbers to utilise this medium to its best advantage by offering their valuable contribution.

The scope of articles to the journal can be mostly on Irrigation, but articles which have direct bearing on subjects as noted below are also welcome :—

1. Technical aspects of Foundation soils and foundation Engineering.
2. Auxiliary works in the fields of Irrigation and other water retaining structures and works.
3. Practical solution to Hydraulic Problems in canals and distribution.
4. Soil erosion problems and conservation and reclamation.
5. Silt problems in Rivers and Reservoirs.
6. Sanitation and Public Health Problems-Possibilities of utilisation of service.
7. Inland water ways, Navigation Lining Schemes and protection of land against sea erosion, etc.
8. Problem of drainage in deltaic tracts and entrance of rivers into the sea.
9. Run-off studies in catchments and evaporation studies.
10. Other subjects.

The Executive Engineers of the State Public Works Department are specially requested to encourage their Subordinate Officers to come forward with articles and enable the journal to flourish and serve a good cause.

The Engineers of other departments are also requested to contribute articles liberally.

Editor.