411.

The New Irrigation Era

1969. October

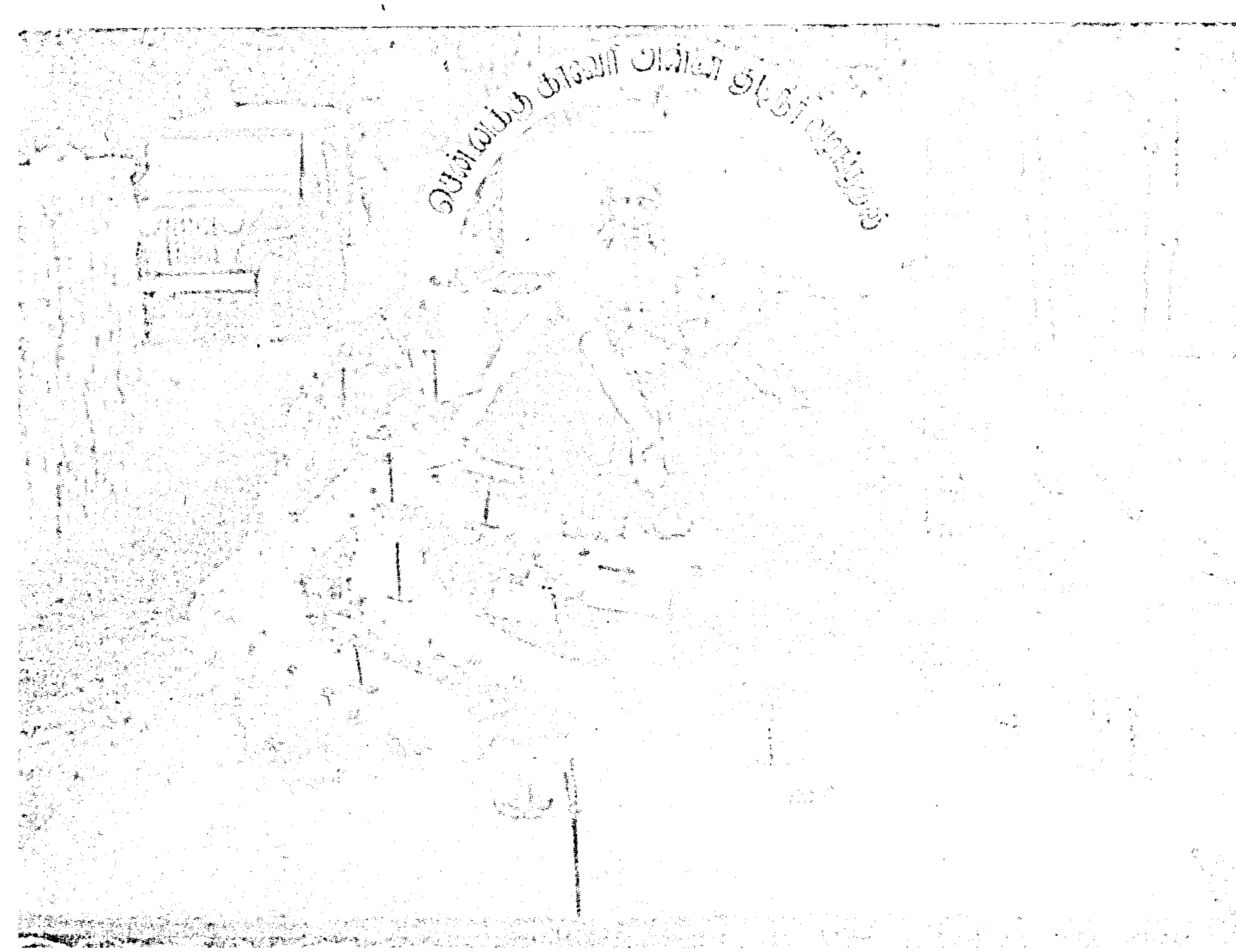
Vol. 11. Issue. 4.

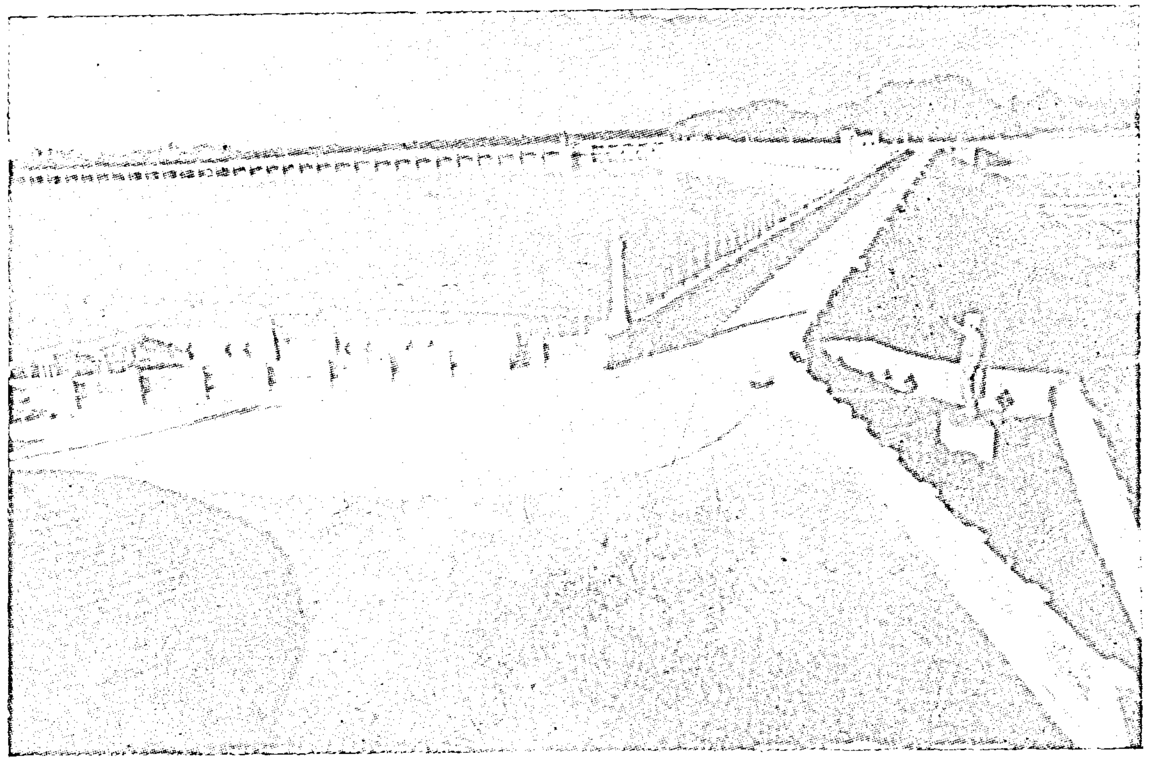
The NEW IRRIGATION ERA

VOLUME XI OCTOBER 1969 ISSUE 4

411

P.W.D. EXHIBIT AT REPUBLIC DAY FLOAT





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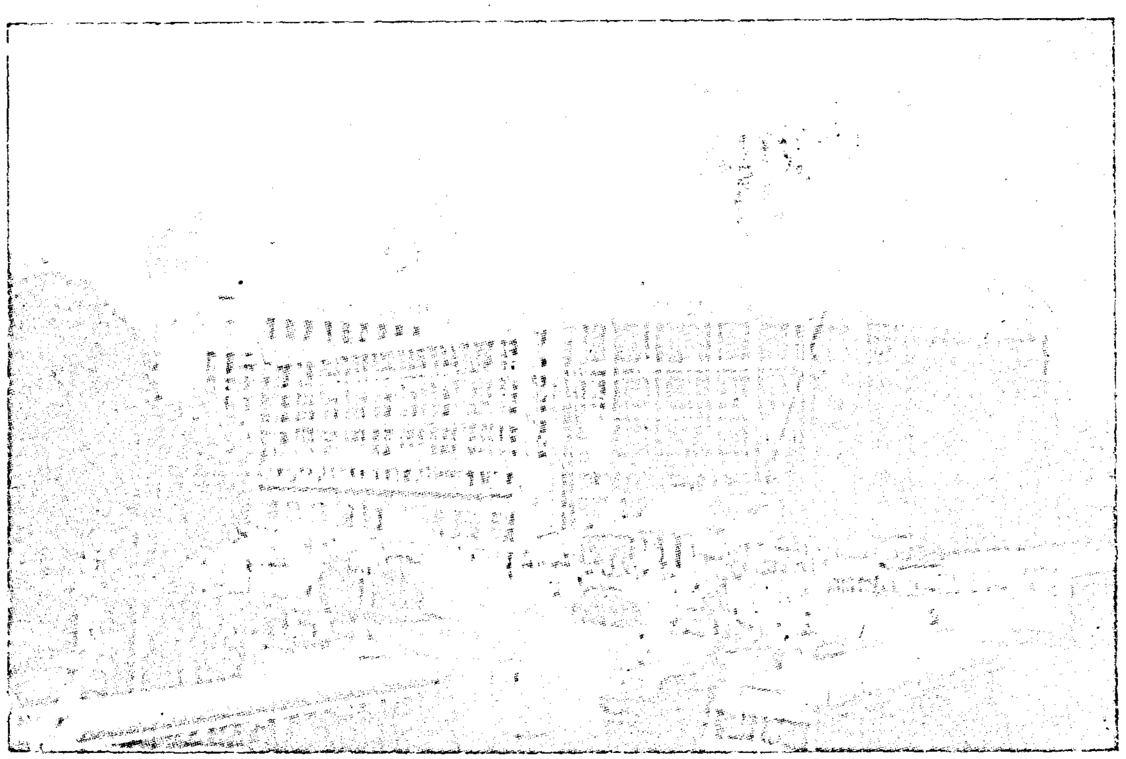

KURALAGAM—KHADI AND VILLAGE INDUSTRIES BOARD BUILDING, MADRAS

THE NEW IRRIGATION ERA

Published by the Irrigation Branch of the Public Works Department, Madras-5, South India.

(For departmental circulation only)

Vol. XI | AUGUST 1969 | No. 4.

PAGE

TRANSITION OF TUNNEL SECTION FROM HORSE-SHOE TO SQUARE SECTION.

BY

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General.

When tunnels are proposed to be driven through rock, the shape of the structure usually preferred is the Horse-shoe shape. The Horse-shoe section has many advantages over the other sections in the normal running. But when we have got to control the flow in the tunnel by means of gate, this has to be changed to rectangular or square shape to suit the size and shape of the gate proposed.

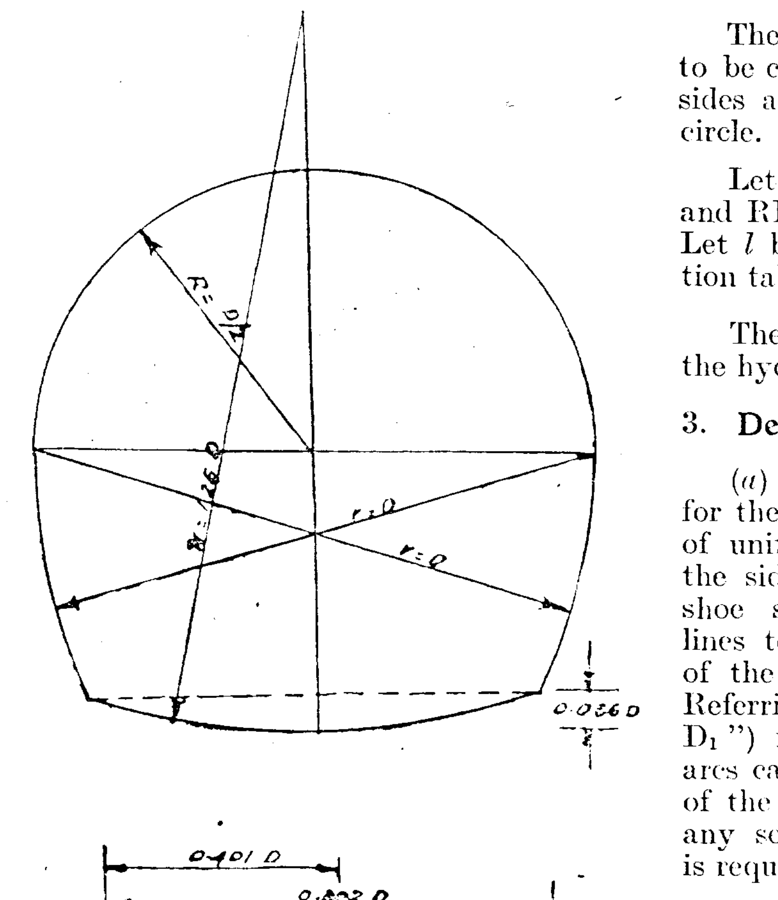

Fig. 1.
Horse shoe Section.

For the transition of the horse-shoe section to any other shape, the better way of transition is to first change the horse-shoe section to square and then to the required form. This can be seen by the fact that square can envelope the horse-shoe section perfectly and the transition of other sections from square is fairly easy.

2. Theory Enunciated.

Fig. 1 gives the geometrical properties of a Horse-shoe section and Fig. 2 gives a lay-out for transition.

The transition of the top portion is proposed to be carried by quarter circle and the bottom sides and bottom are to be carried by arcs of circle.

Let A B C D be the final square section and RL' R' K' LK be the Horse-shoe section. Let l be the length through which the transition takes place.

The length of transition can be fixed to suit the hydraulic performance.

3. Derivation of General formulae.

(*a*) *Transition for top portion.*—Transition for the top may be assumed to be in the form of uniform quarter circular arc tangential to the side and top tangential lines of the horse-shoe section. Incidentally, these tangential lines to the horse-shoe section form the sides of the square at the end of the transitions. Referring to figure 2, the circular arc ("D, D_1") is tangential to DL' and DR. Similar arcs can be constructed for the other quadrant of the top portion. Let x be the distance of any section for which the radius of the arc is required, from the final square section.

$$\text{The radius } R = \frac{Dx}{2l}$$

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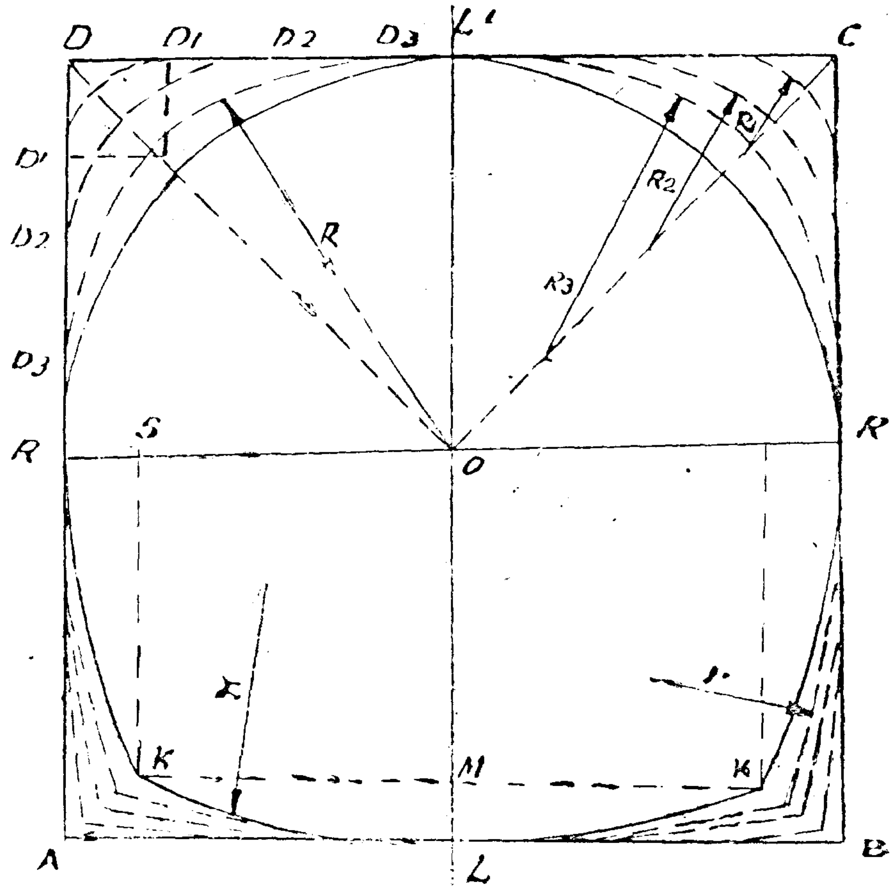
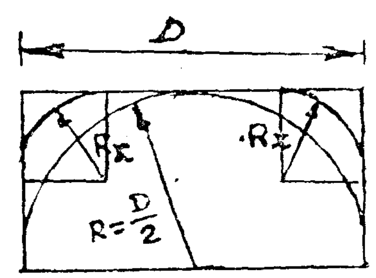


Fig. 2.

Where D is the Diameter of horse-shoe section. l is the length in which transition takes place.



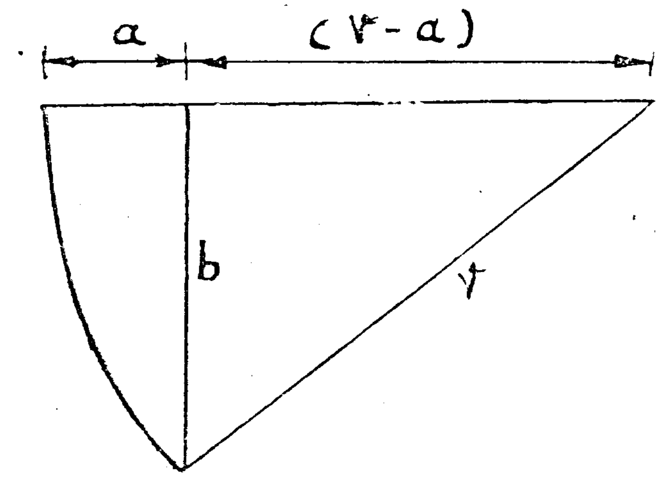
When $x=l$, $R=D/2$
That is horse-shoe section
When $x=0$, $Ro=0$
There is square section.

But for the arc at the corners the top confirms to the line DC.

That is when the section is horse-shoe the arc is a quarter circle of the diameter of horse-shoe. Therefore there is no straight line either at the top or at the sides. But when the magnitude of the arc reduces we get straignt line formation.

(b) *Transition for bottom sides.*—The bottom sides of horse-shoe section are arcs of radius D.

To find the radius at any section in the Transition.



Let r be the radius of the sides.
With reference to fig. 1 and 2

$$ML=0{\cdot}066\ D$$
$$PM=1{\cdot}25\ D-0.066\ D$$
$$=D\ (1{\cdot}25-0{\cdot}066)$$
$$KM=\sqrt{(1{\cdot}25)^2\ D^2-(1{\cdot}25-0{\cdot}066)^2\ D^2}$$
$$=\left[\sqrt{1{\cdot}25^2\ -1{\cdot}25^2-0{\cdot}66^2+2\times1{\cdot}25\times0{\cdot}066}\right]\times D$$
$$=0{\cdot}4007\ D$$
$$Rs.=\frac{D}{2}=0{\cdot}4007\ D$$
$$=(0{\cdot}5-0{\cdot}4007)D$$
$$=0{\cdot}0993\ D$$

"a" for the section at a distance x from the Square Section

$$a=\frac{0{\cdot}0993\ D}{l}\times x$$

When $x=l$, $a=$R.S. (Horse-Shoe section)
When $x=0$, $a=0$ (Square section)

$$b \text{ for the section}=\left(\tfrac{1}{2}\ D+\frac{0{\cdot}066D\ x}{l}\right)$$
$$=D\left(\frac{0{\cdot}5-0{\cdot}066x}{l}\right)$$

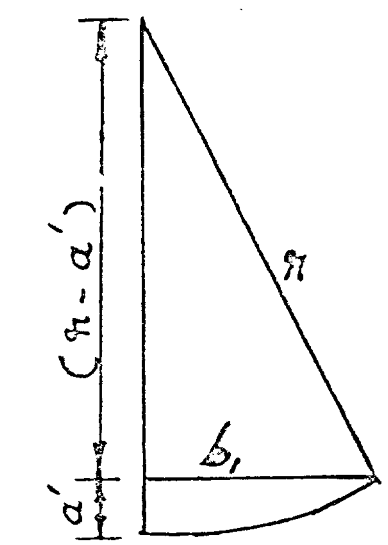
When $x=0$, $b=0{\cdot}5D$ (Square section)
When $x=l$, $b=D+(0{\cdot}5-0{\cdot}066)$
That is $b=OL-OM=SK$ (Horse-shoe Section).

$$r^2=\frac{a^2+b^2}{2a}\quad\therefore\ b^2+(r-a)^2=r^2$$

$$=\frac{\left(0{\cdot}0993\ D\ \frac{x}{l}\right)^2+\left[D(0{\cdot}5-0{\cdot}066\ \frac{x}{l}\right]}{2\times\frac{0{\cdot}0993\ D}{l}\times x}$$

$$r=\frac{0{\cdot}0993^2+\left(\frac{0{\cdot}5}{x}l-0{\cdot}066\right)^2}{2\times0{\cdot}0993x\ l/x}\times D$$

To find the radius for bottom.



$ML=0{\cdot}066D=a'$ for horse shoe section at any section at a distance x feet from the Square section.

$$=\frac{0{\cdot}066D}{l}\ x$$

$$b' \text{ for the section}\left(\tfrac{1}{2}\ D-0{\cdot}0993\ D\times\frac{x}{l}\right)$$

When $x=l$, $b'=(\frac{1}{2}D-0{\cdot}0993D)$

$$=\frac{D}{2}-RS=K.M.=b$$

This refers to horse-shoe section
When $x=0$ $b'=\frac{1}{2}D$ (Square section)

$$\text{Radius } r=\frac{a'^2+b'^2}{2a'}$$

$$=\frac{\left(\frac{0.066x}{l}\right)^2 D^2+(0.5-0.0993x/l)^2 D^2}{2\times\frac{0.066x}{l}xD}$$

$$=\left[\frac{0.066^2+(0.5\,l/x-0.0993)^2}{2\times0.066\times l/x}\right]D$$

Summing up

Radius of Top curve $Rx=\frac{Dx}{2l}$

Radius for bottom sides

$$Rx=\left[\frac{0.0993^2+\left(0.5\frac{l}{x}-0.066\right)^2}{2\times0.0993\;l/x}\right]$$

Radius for bottom

$$Rx=\left[\frac{0.066^2+(0.5\,l/x-0.0993)^2}{2\times0.066\times l/x}\right]$$

By the above formulae we can find the radius of arcs required for any section in between the transition length.

Number of sections in between the transition may be chosen depending upon the degree of transition required.

4. The above principle is fully illustrated by means of a problem below.

Problem.—Work out the magnitude of the arcs required for the transition of 9′ dia. horse-shoe to 9′ square section, at three section in between the transition.

D=9, assuming the transition to take place in a distance $l=15'$

To find the section at distance 5′ from the Horse shoe section, x=the distance from the Square section

$$=15-5=10'$$

$D=9;\ l=15$

Top arcs

$$Rx=\frac{Dx}{2l}=\frac{9}{2}\times\frac{10}{15}=3'$$

Bottom sides curve

$$\text{Radius}=\frac{0.0993^2+\left(\frac{0.5}{x}l-0.066\right)^2}{2(0.0993)\;l/x}\cdot D$$

$$=\frac{0.0993^2+\left(\frac{0.5\times15-0.066}{10}\right)^2\times 9}{2\times(0.0993)\times15/10}$$

$$=\frac{0.4778}{0.0331}=14.43'$$

BOTTOM CURVE:

$$r=\frac{0.0660^2+(0.5\;\;l/x-0.0993)^2\times D}{2\times0.066\times l/x}$$

$$=\frac{0.066^2+\left(\frac{0.5\times15}{10}-0.0993\right)^2+9}{2\times0.066\times15/10}$$

$$=\frac{0.004356+(0.75-0.0993)^2\times9}{0.198}$$

$$=\frac{0.427856}{0.022}=\frac{0.4279}{0.022}$$

$$=19.45'$$

Radius of Top arcs at the corners=3′

Radius of sides at bottom 14.43′

Radius of bottom=19.45′

To find the section at 10′ from the Horse shoe section

$$x=15'-10'=5'l=15,\quad D=9$$

Radius of the top curves

$$=\frac{D\times x}{2l}=\frac{9}{2}\times\frac{5}{15}=1.5'$$

Radius for bottom sides-

$$=\frac{0.0993^2+(0.5\;\;l/x-0.066)^2\times D}{2(0.0993)\,l/x}$$

$$=\frac{0.0993^2+(0.5\times15/5-.066)^2\times 9}{2\;(0.0993)\times15/5}$$

$$=\frac{0.0993^2+(1.5-0.066)^2}{0.0662}$$

$$=\frac{0.009858+1.434^2}{2\times0.0331}=\frac{2.066}{2\times0.0331}=31.22$$

Radius of bottom

$$=\frac{0.066^2+\left(\frac{0.5\,l}{x}-0.0993\right)^2}{2\times0.066\times l/x}$$

$$=\frac{0.066^2+\left(\frac{0.5\times15}{5}-0.0993\right)^2\times 9}{2\times(0.066)\times15/5}$$

$$=\frac{0.066^2+(1.5-0.0993)^2}{0.044}$$

$$=\frac{0.004356+1.4^2}{0.044}$$

$$=\frac{1.9644}{0.044}=44.64'$$

Radius of curves at top=1.5′

Radius of bottom sides=31.22′

Radius of bottom=44.64′

To find the section at a distance of 7.5′ from the horse-shoe section (mid-section).

x = the distance from square section = 7.5′

$D=9$ and $l=15$

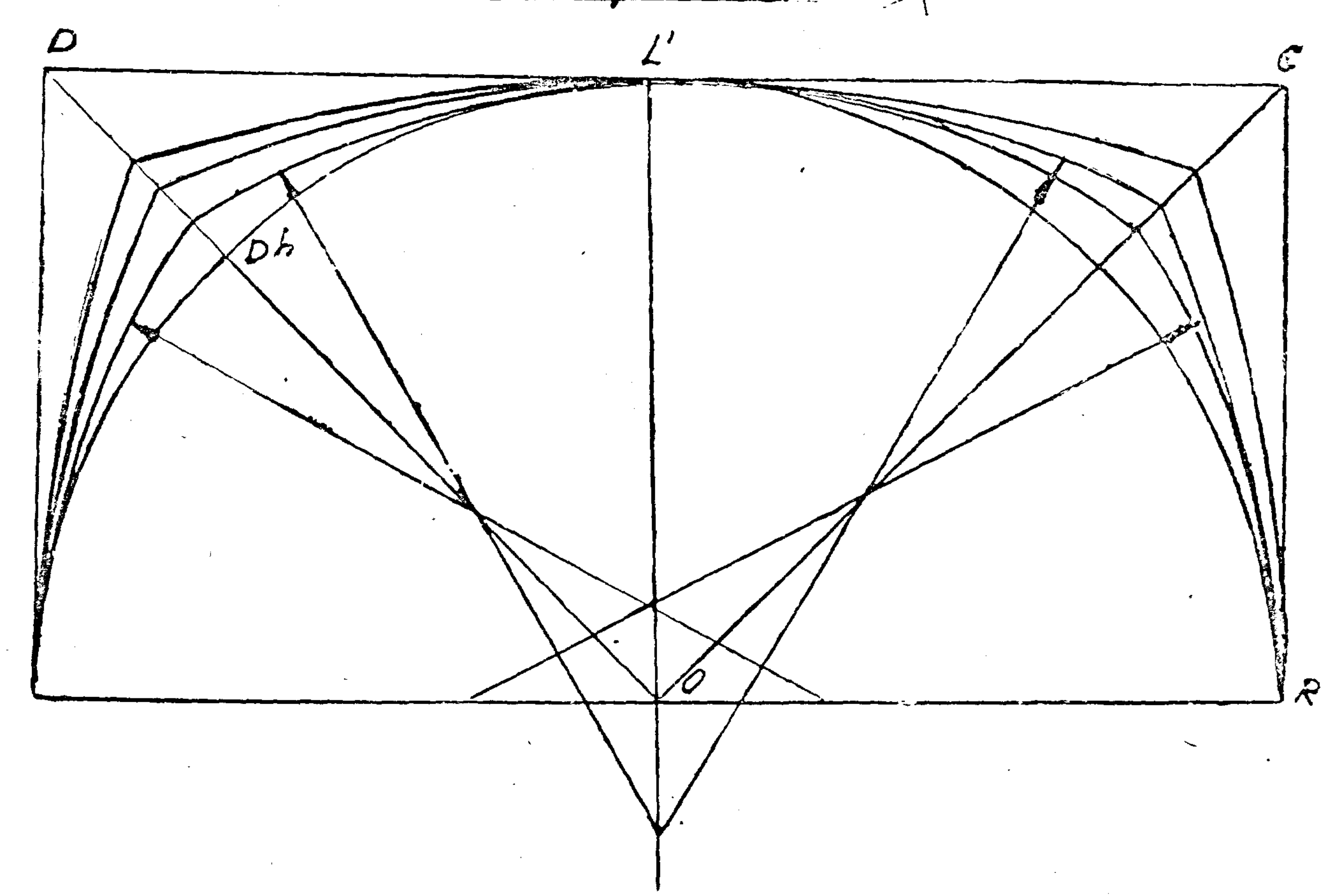
Top arcs $R\,x=\frac{D\times x}{2l}=\frac{9\times7.5}{2\times15}=2.25'$

Radius of arcs of bottom sides-

$$r=\frac{0.0993^2+(.5l/x-0.066)^2\times D}{2\times0.0993\times l/x}$$

$$=\frac{0.0993^2+\left[\frac{(0.5\times10)}{7.5}-0.066^2\right]\times 9}{2\times0.0993\times\frac{15}{7.5}}$$

Alternate Method for the top Portion



$$= \frac{0{\cdot}009858 + 0{\cdot}8722}{0{\cdot}3972} \times 9 = 19{\cdot}98'$$

Radius of bottom

$$= \left[\frac{0{\cdot}066^2 + (0{\cdot}5 \times l/x - 0{\cdot}0993)^2}{2 \times 0{\cdot}066 \times l/x}\right] D$$

$$= \frac{0{\cdot}00435 + \left(0{\cdot}5 \times \frac{15}{7{\cdot}5} - 0{\cdot}0993\right)^2 \times 9}{2 \times 0{\cdot}066 \times 15/7{\cdot}5}$$

$$= \frac{0{\cdot}00435 + 0{\cdot}8110 \times 9}{0{\cdot}264}$$

$$= 27{\cdot}80'$$

Radius of Top $= 2{\cdot}25'$

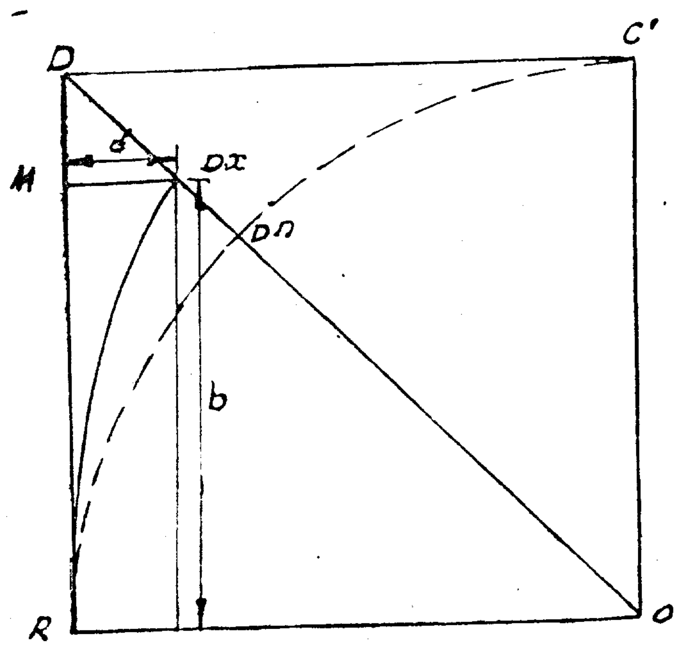
Radius of bottom sides $= 19{\cdot}98'$

Radius of bottom $= 27{\cdot}80'$

Alternate-method for the top portion.

An alternate method is discussed in the following lines of the Transition of the top portion in the transition of Horse-shoe section to Square section.

In the already discussed one, the transition is in the form quarter circle at corners. Now it is proposed to be in the form circular arcs at top and sides.



The centres of the arcs of top sides lie on the line OR' for RD and OR for RC respectively. The centres of the arc for top portion lie on the extension of the line L' O.

The circular arcs for sides and top at the line oo and oc respectively. For any section the radius of the arcs will be the same for both sides and top. In general the raidus of circular arc may be found as follows :—

D=Diameter of horse-shoe

l=length of transition

x=the distance of the C.S from the Square section,

$$OD = \frac{D}{2}\sqrt{2} \qquad ODh = D/2$$

$$\frac{D}{2}(\sqrt{2}-1)$$

$$a = D/2\,(\sqrt{2}-1)\cos 45^\circ \times \frac{x}{l} \text{ at any section}$$

$$MD\,x = MD$$

$$b = RD - MD$$

$$= \frac{D}{2} - a$$

$$= \frac{D}{2} - \frac{D}{2}(\sqrt{2}-1)\frac{1}{\sqrt{2}} \times \frac{x}{l}$$

$$= D\left(\tfrac{1}{2} - \frac{(\sqrt{2}-1)}{2}\frac{x}{\sqrt{2}l}\right)$$

R = Radious of the circular arcs.

$$R = \frac{a^2+b^2}{2a}$$

$$= \frac{\left(\frac{D}{2}(\sqrt{2}-1) \times \frac{x}{\sqrt{2}\,l}\right)^2 + \left(D\left(\tfrac{1}{2} - \frac{\sqrt{2}-1}{2\sqrt{2}}\frac{x}{l}\right)\right)^2}{2 \times \frac{D}{2} \times \frac{(\sqrt{2}-1)}{2} \times \frac{x}{l}}$$

$$= \frac{\left[\left(\frac{\sqrt{2}-1}{2\sqrt{2}}\right)^2 + \left(\frac{\frac{1}{2}l}{x} - \sqrt{2}-1)\,2\right)\right] D}{\frac{(\sqrt{2}-1)}{2} \times \frac{l}{x}}$$

$$= \frac{\frac{(0{\cdot}414)^2}{4 \times 2} + \left(0{\cdot}5\,\frac{l}{x} - \frac{0{\cdot}414}{2\sqrt{2}}\right)^2}{\frac{0{\cdot}414}{1{\cdot}414} \times \frac{l}{x}}$$

$$= \frac{0{\cdot}02142 + (0{\cdot}5\, l/x - 0{\cdot}464)^2}{0{\cdot}2927 \times l/x}$$

It is to be noted that the same magnitude of radius holds good for top portion also but the centre is different. For sides, the centres lie on the line CR and OR' and for the top, it lies on the extension of line L' O.

Problem 2.—An example is worked out for the transition of 9' D. Horse-shoe section to 9' D square section for the alternate proposal for top portion alone.

The sleekness of the two transitions suggested has to be decided by model studies and the best one to be decided based on best hydraulic performances.

Alternate Proposal -

To find the Radius of arcs at 5' from he Horse-Shoe section.

l=length of transition$=15'$

Diameter of horse-shoe D$=9'$

x=the distance from square section

$$= 15' - 5' = 10'$$

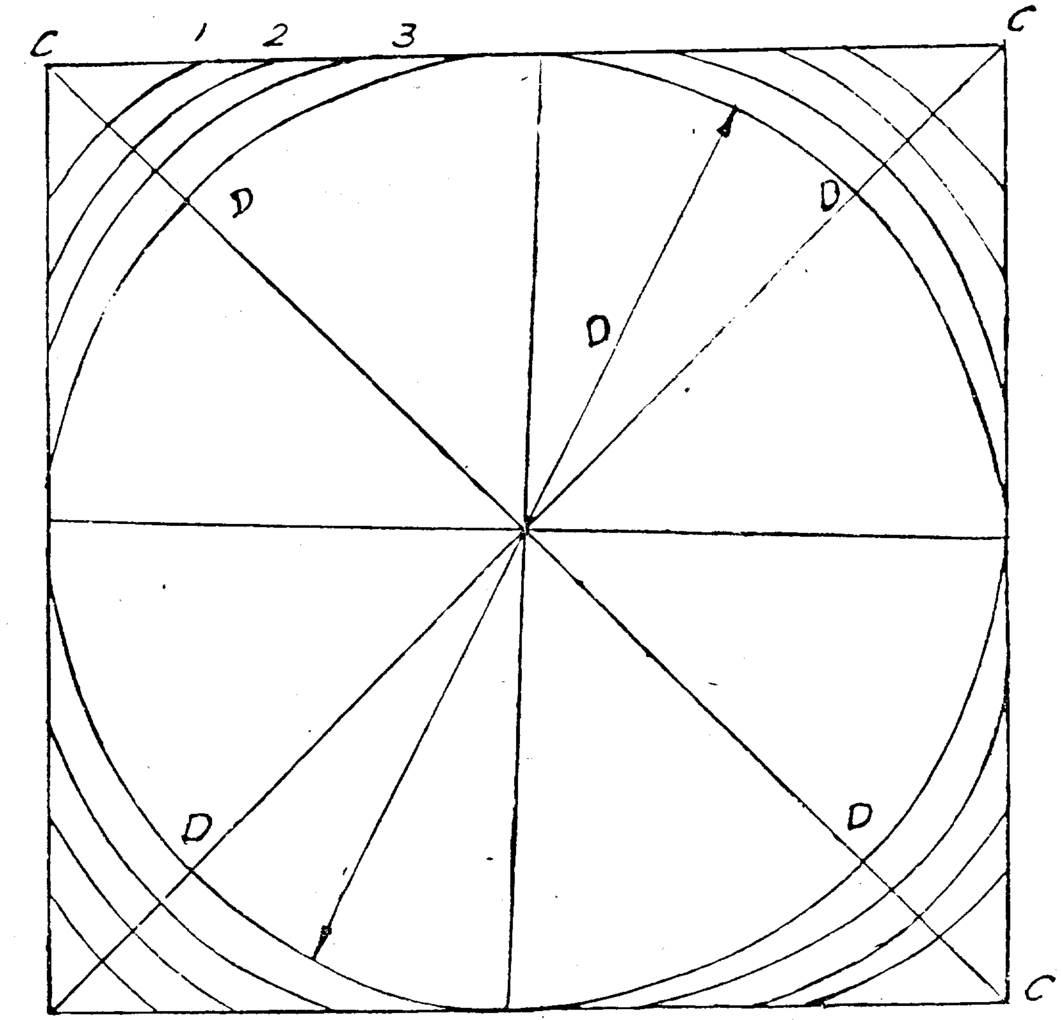
Radius of arcs $R = \frac{0{\cdot}02142 + (0{\cdot}5\, l/x - 0{\cdot}1464)^2}{0{\cdot}2927 \times l/x} \times D$

$$= \frac{0{\cdot}02142 + (0{\cdot}5 \times 15/10 - 0{\cdot}1464)^2 \times 9}{0{\cdot}2927 \times \frac{15}{10}}$$

$$= \frac{0{\cdot}02142 + (0{\cdot}75 - 0{\cdot}1464)^2 \times 3 \times 2}{0{\cdot}2927}$$

$$= \frac{0{\cdot}38562}{0{\cdot}2927} \times 6 = 7{\cdot}907'$$

Radius of Top arcs $= 7{\cdot}907'$



To find the Radius of Arcs at a distance 7·5 from the Horse-shoe section.

$$D = 9; \quad l = 15; \quad \times = 7{\cdot}5$$

$$R = \frac{0{\cdot}02142 + \left(0{\cdot}5 \times \frac{15}{7{\cdot}5} - 0{\cdot}1444\right)^2}{0{\cdot}2927 \times \frac{15}{7{\cdot}5}} \times D$$

$$= \frac{0{\cdot}02142 \div (1 - 0.\ 1464)^2}{2 \times 0{\cdot}2927} \times 9$$

$$= \frac{0{\cdot}02142 + 0{\cdot}7386}{0{\cdot}5854} \times 9$$

$$= \frac{0{\cdot}75}{0{\cdot}5854} \times 9$$

$$= 11{\cdot}53$$

To find the Radius of arcs at a distance of 10′ from the horse-shoe section.

The distance from square = 15′—10′ = 5′ section.

$$R = \frac{0{\cdot}02142 + (0{\cdot}5\ l/x - 0{\cdot}1464)^2}{0{\cdot}2927 \times l/x} \times 9$$

$$= \frac{0{\cdot}02142 + (0{\cdot}5 \times 15 - 0{\cdot}1464)^2}{0{\cdot}2927 \times \frac{15}{5}} \times 0$$

$$= \frac{0{\cdot}2142 + (1{\cdot}5 - 0{\cdot}1464)^2}{0{\cdot}2927 \times 3} \times 9$$

$$= \frac{(0{\cdot}02142 + 1{\cdot}833)}{0{\cdot}2927} \times 3$$

$$= 19{\cdot}00$$

DOWSING IN SEARCH OF GROUND WATER

BY

*Thiru B. A. Rahman

"THERE IS A PRINCIPLE WHICH IS A BAR AGAINST ALL INFORMATION WHICH IS PROOF AGAINST ALL ARGUMENTS AND WHICH CANNOT FAIL TO KEEP A MAN IN EVERLASTING IGNORANCE THAT PRINCIPLE IS CONTEMPT PRIOR TO INVESTIGATION."

—*HERBERT SPENCER.*

The present day urgent problem 'THE SEARCH FOR WATER FOR IRRIGATION' is sought to be solved by various means. Nearly 21·84 million ha. (54 million acres) are being irrigated by means of surface flow. About 7·28 million ha. (18 million acres) are being irrigated by water supplied by wells. The water for surface irrigation is got from the waters stored in multi purpose reservoirs, tanks and spring channels. The vagaries of monsoon has a say in the cultivation of land that are fed by surface flow. The entire Indian sub-continent is not subjected to the same intensity of rainfall. There is not only variation in the intensity of rainfall but also in timings. When one part of the country is under floods the other part suffers from drought and famine. With all the knowledge of engineering technology, it is not possible now to take excess of flood water from one part of the country to the famine-affected area. From the present day knowledge of Geohydrology it is seen that vast underground fresh water has been already located in the heart of the great Indian desert of Rajasthan, in the Narmada valley, coastal area of Gujarat and Orissa. In other parts of our country exploration work for finding the underground water reservoirs are either in progress or under contemplation. This exploration work is time consuming and requires good lot of foreign exchange, foreign machinaries and experts. As we are in need of quick results, and short of foreign exchange and experts, instead of going in for the deep underground fresh water reservoirs we can get benefitted by the water got from flow aquifers which are available throughout the length and breadth of our country at shallow depths. Scientifically these flow aquifers can be traced by the 'Radio-isotope tracer technique'. Even this is tied up with foreign exchange and technical personnels.

2. In these hard days of 'want' not only in the field of increasing agricultural produce but also for drinking purposes why shall not we adopt the method which our forefathers were adopting in locating the wells. Great number of old wells are found to be perennial and the yield from these wells are not much affected by the vagaries of monsoon. Wells in some villages are found to supply water even when the entire area has been subjected to drought conditions for continuous years. But for these wells many people should have died due to want of drinking water but no report of this type has ever been received. During drought years due to want of water to replenish the ground water losses, the water table should have gone down and these wells also should have dried up. But this has not taken place. Does this not indicate that apart from the ground water table there is some other source of water supply in the sub-soil? This source is the meteor flow aquifer. Our forefathers were wise enough to trace out these flow aquifer and provided the wells on them. How were they able to do it in the absence of 'Radio-sotope tracer technique'? An investigation of this indicates that this could be done by some people who had a natural instint in finding the aquifer. This natural power in some is the divine power which in modern terms is called "DOWSING".

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3. The art of dowsing (Water Divining) has been practised not only in India but also throughout the world from time immemorial. Mr. W. H. Trinder in his book—"Dowsing", on page No. 106 writes as follows:

"THERE IS, HOWEVER, AN EARLIER RECORD OF IT, THOUGH IT IS UNFORTUNATELY MISLAID, IF NOT DESTROYED. A FRIEND OF MINE WHO CAN READ ARABIC WAS SEARCHING AMONGST SOME OLD BOOKS, WHICH WERE THEN IN THE POSSESSION OF COLONEL TILLARD, WHO DIED IN CAIRO ABOUT 1919, AND CAME ACROSS AN ARABIC MANUSCRIPT DEALING, ALTHOUGH IT WAS WRITTEN LATER, WITH A PERIOD BEFORE MOHAMMED. IT MENTIONED THAT WHEN THE QUEEN OF SHEBA CAME TO VISIT SOLOMON SHE HAD, AMONGST HER TRAIN, DIVINERS WHO DEVINED FOR GOLD AND WATER."

3.1. Though this art is in practice from the time of King Solomon no detail seems to be available in any of the Indian ancient books. But according to Sir William Barrett and Theodore Besterman who are the joint authors of the books, *The Divining Rod*, the practice of dowsing has been put to use first in the mining district of Germany probably in the Harz mountains for finding mineral ores in 16th century. In England it is supposed to have been introduced in the later part of 16th century by German miners who were taken to that country to work the CORNISH mines. In France the rod was put to use for finding water and criminals in the 17th century. But records are there to show that dowsing had been used by miners in the year 1430 A.D. In the bibliography appended to the abovementioned book names of 593 written works upto 1923 have been published. But in India there seems to be no written evidence for proving the use of dowsing method for finding the hidden objects under the grounds though the results of dowsing is available in the form of many wells that have been dug on perennial flow aquifers many centuries back.

4. In theory the faculty of dowsing has not been proved scientifically though the scientific work on the subject has been started in the year 1641, by Uesint Athanasius Kircher and is still continued by many societies in England, America, France, Germany, Switzerland, Italy, Ireland, Urguay and Rajasthan University in India. As in the case of Alchemy the pursuit of which opened the doorway of finding the basis for the present day chemistry world so also is the scientific approach to the problem of dowsing has helped the dowser in practically finding the methods by which with greater certainty he is able to tell the exact materials such as water, coal, oil, sulpher, iron, tin, lead, etc., that are hidden under the earth. The present day dowser is not only able to tell the exact material but also the approximate quantity and the exact depth at which the same is available. It will not be out of place here if I mention some of the successful dowsers of the past and present in other countries whose works have been appreciated by the local Governments.

4.1. *Famous French Dowsers.*—(1) Jacquises Aymar 17th century. He was mostly used by the State for finding thieves and murderers (2) Barthamby Bleton—18th century. There are many written documents giving details of his success as a dowser from the age of 7 to his death. This has appeared in the monthly review for 1782. "These successes lead the Queen of France to employ Bleton and the springs that had been found in consequence of his indications have fertilised and embellished several districts, among which Trianon is a striking scarple, as that delightful seat has acquired new charms by Bleton's discoveries". (3) The Abbe Paramelle—19th century. Author of many books on finding of water. The verdict on him by poor people was "whether he be a sorcerer or a messenger of god we know not; this we know, that whereas we were perishing for want of water, now by his help we have an abundance".

4.2. Famous English Dowsers (1) William Scot Lawrance, (2) John Mullins, (3) William Stone, (4) Benjamine Tompkim, (5) Leicester Gataker, (6) Miss Clarissamiles, (7) Mr. Fergus

Carstairs Rogers, (8) Thomas Willis of Glouchester, (9) Charles Sims of Pillon, (10) Thomas Hares and John Blake, (11) Richard Anthony of Yelling, (12) John Stears of Hessle, (13) Henry Smart of Evercreech, (14) H. W. Golding of Braintree, (15) H. W. Mullins of Bath, (16) Thomas Heighway of Liandrinded wells, (17) S. T. Child of Ipswich Suffolk, (18) Walter Wyburn, (19) Mr. Kemp of Taunton, (20) The Boy Lockyer, (21) Colonel Hugh Rose and (22) The Boy Guy Fenley of Texas.

4.2.2. All the persons whose names have been mentioned were very famous and there are many standing monuments in the form of wells sunk in their times.

4.2.3. Many pages have to be filled up if the names of the present day dowsers are to be given. However, a few of them who are internationally fame, are mentioned below:

4.2.4. (1) W. H. Trinder, (2) Miss Enelynn Penrose, (3) Abbe Mermet, (4) H. Tomlinson, M.B., Ch. B.M.R.C.S. L.R.C.P., (5) V. D. Wethened, B.SC., (6) A. T. Westlake, B.E., M.B.B.S. Chir, M.R.C.S.L.L.R.C.P., (7) Henry De France, (8) Mr. Ruth Borchard, Ph.D., (9) Colonel K. W. Merryless, (10) Mr. H. G. Gross, (11) K. R. K. Murthi and (12) Martin J. Parkinson, M.D.Ph.D.M.I.S.N.P.

5. All the above information had to be given just to bring home to learned readers the facts about dowsing and to clear the doubts and to counteract the contempt some people are having for the dowsers because of the many costly failures which are generally met by many due to wrong advices given by some of the dowsers in our country who have not studied about dowsing and have not calibrated themselves though they are fortunate in having the dowsing faculty in them by nature.

6.1. Some of the State Governments had employed the water diviners to help them in giving locations for digging new wells. Most of the locations given by the diviners were found containing no water. Even today the diviners are not successful to 100 per cent. If the faculty of dowsing is a perfect one why should then one fail in many places and be successful only in a few places in our country whereas in other countries they are 100 per cent successful. That is because the fruit of study and research has not reached the dowsers of our country. As already reported elsewhere there are many societies in other countries which are helping the dowsers of their country. The following are the two societies the membership of which is open to persons of all countries:—

6.2. (i) The British Society of Dowsers, High Street Eydon, Rugby, Warinickshire, England and (ii) The American Society of Dowsers Inc. Galen O. Hutchisow RFD 3, Box 61, Brandon, Verment 05733, U.S.A.

6.3. The above societies are publishing quarterly journals which contain a good lot of useful information. If all the dowsers of our country go through these journals and calibrate themselves then there will not be any complaint of failures and they can do yoman service for the benefit of the human race with the special gift of God. How exactly this can be put to practical use in solving our irrigation problem is explained hereunder:

7. From my tours in South India I have found that the entire country is having a net work of underground flow lines. They are spaced at almost 100 metres (327 ft.) apart. The depth at which they flow vary from place to place and in the same place from one location to the other. I have found the flow lines at 30 meters (98 ft.) to 4 meters (13 ft.) depth and majority of them are at about 14 to 15 meters (45 ft.—50 ft.). The quantity varies from 9,092 litres (2,000 gallons) per hour to 27,276 litres (6,000 gallons) per hour from these aquifers. The same will irrigate about ·86 ha. (2·133 acres) to 2·58 ha. (6·399 acres) per 8 hours with the duty at 72. Since the depth is not much, open wells can be sunk over these flow aquifers which will not involve any tie up with either foreign exchange or machinery and men of knowledge of technical know how. Local manual labour and material

which are available in plenty in our country side will be more than sufficient to have these wells dug and constructed.

8. Many of the wells that have been sunk recently are found drying. I have seen in some blocks that wells have been provided with steining walls and pullies and complete in every respect but they do not contain single drop of water. This sort of colosal waste of money, labour and time could have been very easily saved if a proper water diviner had been consulted. Even in these days of scientific advancement the method of finding anything that is under the ground is only by hit and miss method. Why not the same thing be done but in the place where a dowser points out ?

9. Now, I must tell about the successes and failures of dowsing method. As stated elsewhere some of the State Governments and private persons have been duped by the so-called water diviners. Hence, it becomes necessary now to write something about the field dowsing proper and the opinion of some authors on these. Sir William Barrett in his book "The Divining Rod", writes in page 57 that, " Throughout this book examples of cases have been quoted in which a dowser has succeeded after a Geologist or Engineer has failed." In an article Mr. Ruth Borehard, Ph.D. under caption " Towards Psycho Physiology of extra sensory perception in Dowsing" in the journal of the British Society of Dowsers Vol. XVIII No. 123 March 1964 says, " this paper accepts Michael Ashs dictum (It is the dowser himself that we seek to study. All research hitherto has brought us back to him as the unknown). I shall take it as scientifically established that field dowsing has proved itself successful".

10. Out of the two aspects of dowsing, i.e., the theoritical and practical, the theory portion remains unsolved , though developed concepts and methods are atleast 7,000 years old and the field dowsing has been very well established.

11. As against the underground deep reservoirs where the water is still, the meteor flow is in the form of channels ranging in width from about 3 centimetres (one inch) to 30 metres (98 ft.) (so far detected by me) at varying depths. When a dowser crosses these lines on the surface of ground, if either, both hands are in direct contact or are connected by some other object he gets a reaction which indicates the presence of water. It is only from this reaction that the dowser is able to find out the location. This has been in practice since a long time. By the adoption of this method many a failure has been taken place. Hence to find a fool-proof method adopting which a 100 per cent success can be guaranteed, some eminent dowsers spent a good lot of their time and money and conducted research and finally succeeded in their effort. What was that which was duping the dowsers is explained hereunder.

11.1. Every flow patron has five strong dowsing zones (reflected lines) of varying widths, in addition to many weaker and narrower ones, but it is only under one of these that flow aquifer is to be found. Figure No. I shows a section of ground in which the top line AFDHEGB is the ground surface and the point ' C ' is the underground stream. The rays from the water which the dowser picksup with the rod are drawn meeting the ground surface at FDHEG. It is seen from the diagram that the rays extend fanwise underground. But on reaching surface they become vertical. These rays extend to such an height as 2,000 ft. Thus a dowser will have reaction in five places namely FDHE and G. If he is not posted with this knowledge he will say that there is water at all the five places whereas actually it will be available only at one place that is at ' H '. Many dowsers are unable to sort out the real water line at ' H ' from the other dowsing reactions at FDE and G. This, I will explain with a plan.

11.2.1. Let K.L.M.N. be the plan of a field. Let us assume A.B. and C.D. to be real lines of flow aquifer.

11.2.2. If a dowser who does not know how to distinguish the real flow aquifer from the reflected lines is taken into the field for fixing

a well location, there is the possibility of his or her fixing 25 points, since there are five lines which ca be detected by the dowser for each of the flow lines. At all these places he will say that there is water and the effect of two wells can be got from one well since two lines cross at these points. But actually it is only at one place, i.e., at W, the effect of two wells can be got in one. At eight other places, i.e., at W 1 to W 8 the effect of one line can be got. At the other 16 places W 9 to W 24 no water can be struck. Thus the percentage of success works to 36 which is generally the case with most of the water diviners. Thus it can be seen that it is not the gift of God alone that counts to the success of a dowser but also the latest knowledge on dowsing which go to make a dowser 100 per cent successful.

12. If the service of all the educated dowsers are pooled, a systematic survey of the country can be very easily done for locating the useful flow aquifers which when opened out will easily irrigate all the land that are fit for cultivation and there will not be any need for going in for the deep underground reservoir which are costly and time consuming.

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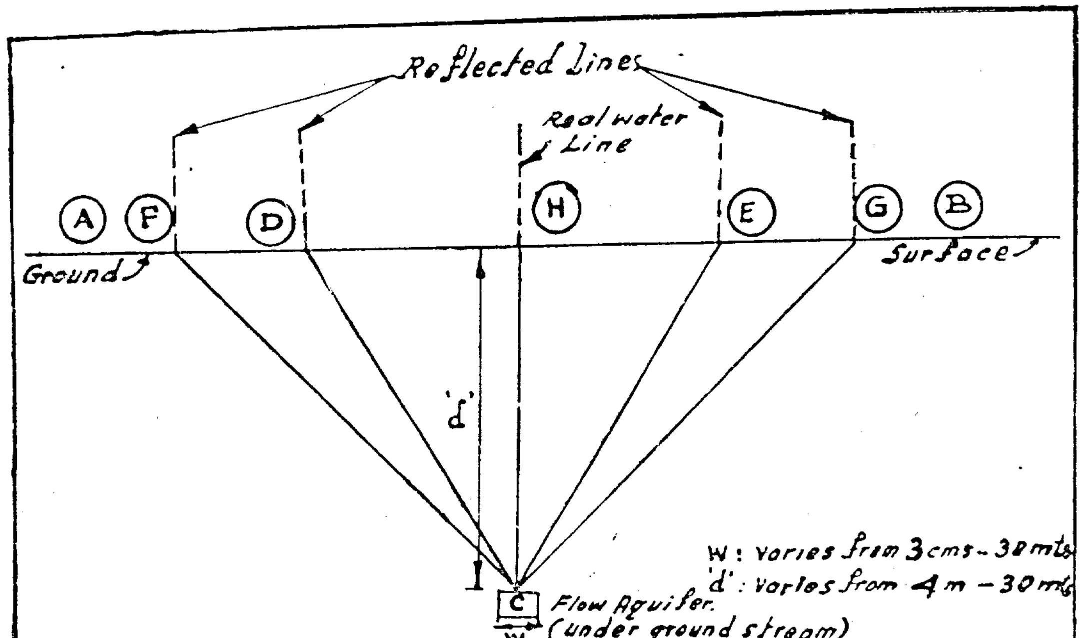
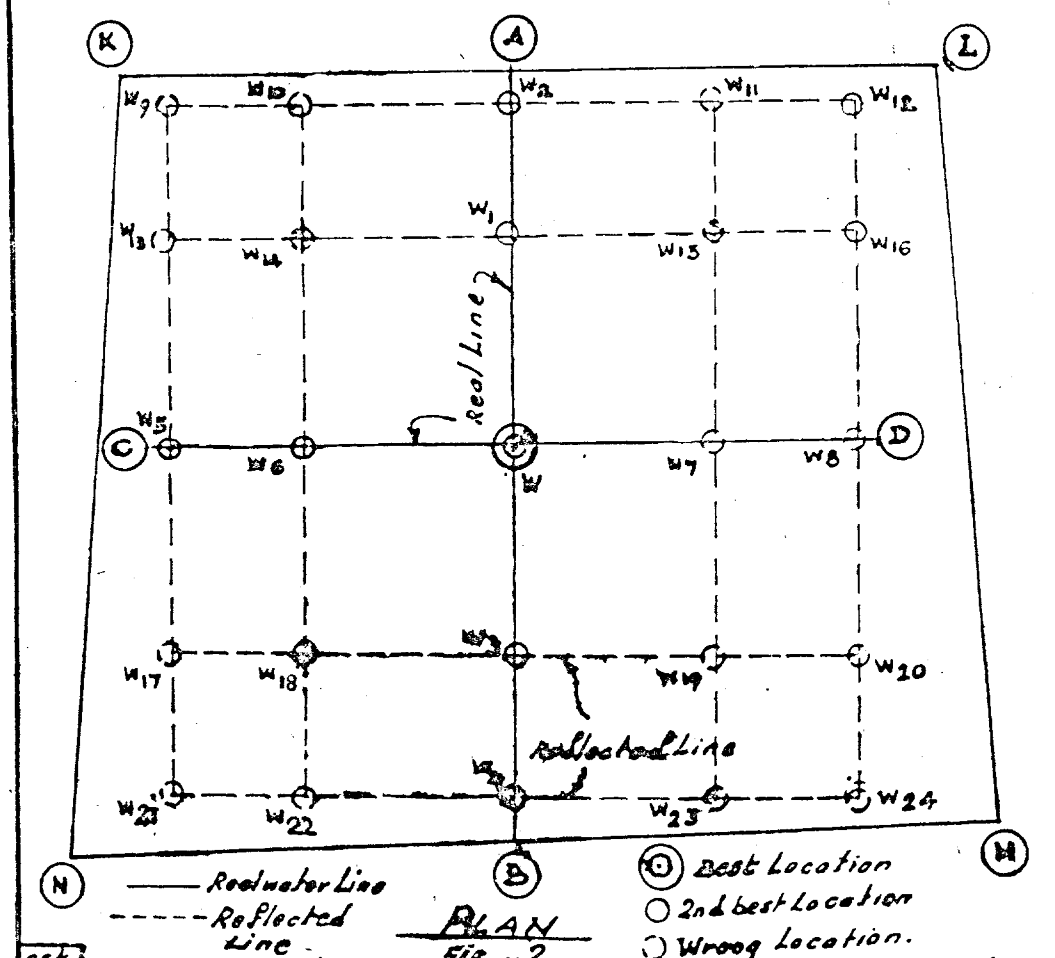


FIG 1
SECTION



PLAN
Fig...2.

HYDRAULICS AND IRRIGATION FORMULAE IN METRIC UNITS.

BY

CODES DIVISION, TAMIL NADU P.W.D.

In response to pouring requests from all quarters, we are happy to publish the formulæ in metric units once again after carrying out certain corrections. Since only limited number of copies of the New Irrigation Era are printed, it is regretted that no spare copy can be had from the editor.

—EDITOR.

INTRODUCTION

Cumec : Cubic meter per sec.

1 Hectare : 2.471 Acres

1 Cusec : 0.028 Cumec

1 Hectare : 10,000 Sq. meters
or 0.01 Sq. Km.

1 Hectare/Cumec : 0.06997 acre/Cusec

1 Hectare : 8.108 acre feet

1 Cumec flowing per day
: 0.0864 million Cu. mt.
: 8.64 Hectare mt.

1 M.Cu. mt. : 11.574 Cumecs flowing per day.

Formulae used in Irrigation Engineering and Hydraulics.

SERIAL NUMBER AND DESCRIPTION.	FORMULAE IN F.P.S. UNITS	FORMULAE IN METRIC UNITS (EXACT EQUIVALENT)	REMARKS
①	②	③	④
1. Duty	1 Cubic foot a Sec. per 100 acres	1 Cubic mt. a Sec. per 1430 hectares	
2. Formula Connecting duty, base and av. depth over area.	$d = \frac{24B}{\Delta}$ d = duty in acres/cusec B = base in days and Δ = Ave. depth in inches	$d = \frac{864B}{\Delta}$ d = duty in hectare/cumec B = base in days and Δ = ave. depth in Cms.	
3. Intensity of Rainfall. Prof. Talbolt's formula	..	For ordinary down pour $i = \frac{2667}{t+15}$ ordinary max. For medium conditions $i = \frac{4572}{t+30}$ once in 15 years. For extreme cases $i = \frac{9144}{t+30}$ 2 or 3 times in a Century	

①	②	③	④
		i : intensity of rainfall in m.m/hour during the particular period under Consideration. t : duration of rain fall in minutes which has the above intensity	
4. Run-off. Lacey's formula	..	$R = \frac{P}{1+\frac{3048F}{PS}}$ R = Monsoon run-off in mm P = Monsoon rainfall in mm S = Catchment area factor F = Monsoon duration factor VALUES OF S & F ARE AS UNDER	
5. Inglis formula.	..	FOR GHAT CATCHMENTS – $R = 0.85P - 304.8$ FOR NON GHAT CATCHMENTS $R = \frac{(P-177.8)P}{2540}$ P = rainfall in mm R = Run-off in mm	

Values of S for Lacey's formula:

	VALUES OF S
Flat cultivated & black cotton soil	0.25
Flat partly cultivated in various soils	0.60
Average	1.00
Hills & places with cultivation	1.70
Very hilly & steep with hardly any cultivation	3.45

CLASS OF MONSOON	VALUE OF F
Very short	0.50
Std. length	1.00
Very long	1.50

(1)	(2)	(3)	(4)
6. Khosla's formula.	..	$R = P - 4.811\,T$ R = Run off in mm P = Annual rainfall in mm T = Mean temp in °C	
7. Flood discharges- Dicken's formula	$Q = CM^{3/4}$ Q: Maxm. discharge in Cusecs. M = Catchment area in Sq miles C: Const. depending on the nature of area	$Q = CM^{3/4}$ Q: Maxm. discharge in Cumecs. M = Catchment area in Sq. Km. C = Const. depending on the nature of area(a) C = 11.45 for areas of annual R.F of 610 mm to 1270 mm.	
8. Ryves formula	$Q = CM^{2/3}$ M = Catchment area in Sq. miles Q = Maxm. discharge in Cusecs.	$Q = CM^{2/3}$ M = Catchment area in Sq. Km Q = Maxm. discharge in Cumecs. C = Constant depending upon the nature of area (Normally the value of C will vary from 6.76 to 40.60)	
9. Formula of Krensnik.	$Q_{max} = \frac{21800\sqrt{A}}{0.31+\sqrt{A}}$ Q_{max} = Maxm. run off in cusecs A = drainage area in Sq. miles	$Q_{max} = \frac{\alpha\, 32\sqrt{A}}{0.5+\sqrt{A}}$ Q_{max} = Maxm. run off in Cumecs A = drainage area in Km^2	

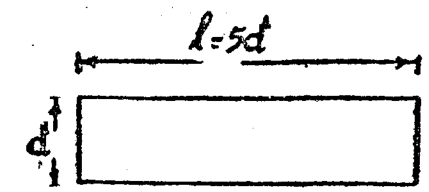
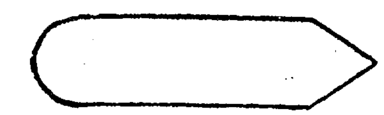
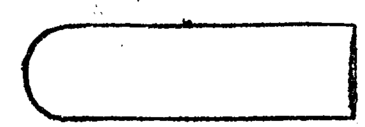
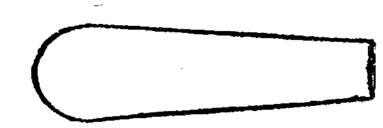
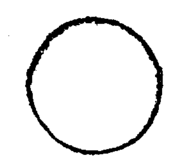
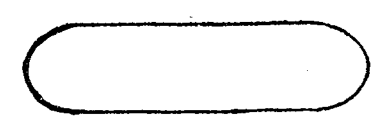
α (for both): Coeff. having a value of about 0.02 for flat Valley lands & 0.1 to 0.2 for the slopes.

(1)	(2)	(3)	(4)
10. Craig's formula	..	$Q = 25.4\,PVB \log_e \frac{4.97L^2}{B}$ P = a coeff. 0.12 to 0.18 V = Mean Vel. of flood flow in M/sec. at site. B = Ave. width of strip in Km L = Length of strip in Km	Area should be divided into a no. of strips before application
11. Inglis formula.	For fan shaped catchment $Q = 123.2\sqrt{A}$	For normal single catchment. $Q = 123.2\sqrt{A} - 2.62(A - 259)$ For Small & large catchment $Q = \frac{123.2\,A}{\sqrt{A+10.36}}$ Q = flood discharge in Cumec A = Catchment area in Km^2	
12 Ali Nawaz Jung's formula.	..	$Q = C\left\{\frac{A}{2.59}\right\}\left(0.993 - \frac{1}{14}\log_e A\right)$ Q = flood discharge in Cumec. A = Catchment area in Km^2 C = Coeff. 48.1 to 59.5	
13. Hydrabad formula for Tungabadhra	..	$Q = 49.6\left\{\frac{A}{2.59}\right\}\left(0.988 - \frac{1}{14}\log_e A\right)$	
14. Madras formula for Tungabadhra	..	$Q = 56.64\left(\frac{A}{2.59}\right)$ Q = flood discharge in Cumec A = Catchment area in Km^2	
15. Evaporation & absorption loss by absorption between the head of distributory & at a pt. at a dist. l from the head.	$Loss = Al^{5/6}$ A = loss of head in ft. ascertained by experiment at the end of one mile. l = length in miles	$Loss = 0.672\,A\,l^{5/6}$ Loss & A are in mts. (A is the loss in mts at distance of 1.6 Km from the head. l = length in Kilo meter	

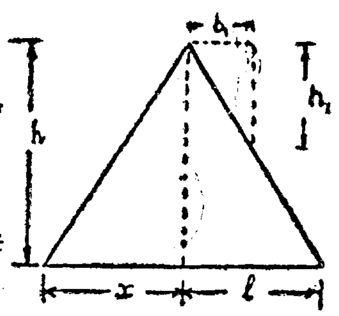
①	②	③	④
16. Wave height- Moliter's formula	$h_w = 0.17\sqrt{VF} + 2.5 - \sqrt[4]{F}$ h_w = Wave ht. in ft. V = Wind Vel. in miles/hour F = fetch or st. lenght of water subject to wind section in statute miles.	$h_w = 0.0322\sqrt{FV} + .763 - .271\sqrt[4]{F}$ h_w = Wave ht. in metre (Measured between trough and crest) V = Wind vel. in Km per hr. F = fetch in statue Km.	
17. Stevenson's formula for wave ht.	$H = 1.5\sqrt{F} + 2.5 - \sqrt[4]{F}$ H = Wave ht. in feet F = fetch in statute miles	$H = 0.38\sqrt{F} + .76 - .271\sqrt[4]{F}$ H = Wave ht in metre F = fetch in statute Km.	
18. Formula based on observation of wave ht. in Belle Foruche Reservoirs in U.S.A where the fetch is 5 miles (8.047 Km)	$H = 0.075(V-8.5)$ H = ht. of wave in ft V = Vel. of wind in miles/hour.	$H = 0.014(V-13.7)$ H = Ht. of wave in mt. V = Vel. of wind in Km/hour	
19. Pressure on Dam due to waves	..	$P_w = 2002\, h_w^2$ P_w = wave pressure in Kg/m width of dam h_w = ht. of waves in m.	
20. Earthquake forces of water	..	Wester guards eqn. for coeff. K for the earth quake force of water on dam when parabolic variation of pressure is assumed. $K = 816 \Big/ \sqrt{1 - 0.72\left(\frac{H}{305t}\right)^2}$ where k is the coeff. from formula $P_h = k c \sqrt{hH}$ P_h = pressure at a depth h in Kg/m^2 c = ratio of earthquake acceleration to the acceleration due to gravity. h = depth at which the pressure is P_h in m H = ht. of dam in mt. t = earthquake period in seconds varying from 0.8 to 1.20 sec	
21. Resonance for Concrete dam	..	Westerguards eqn. for period of vibration of a Conc. dam. $t = \frac{h^2}{611 \times l}$ t = period of vibration in sec. h = ht. of dam in mts. l = length of base in mts.	
22. Dams- Radius of Crest over flow dams. Rehbock's law.		Minm. radius 'r' of the crest necessary to prevent the set from separating from the weir at the crest is $r = \frac{1}{36}\left\{(20+3H_{max}-6d) + \sqrt{(20+3H_{max}-6d)^2 + 72dH_{max}}\right\}$ Adherence to this rule, however results in an excessively large section.	
23. Stilling pool or water cushion for prevention of scour below fall; Leliavosky's formula.		$P = \sqrt{\frac{q}{5H^{1.5}}}$ where q = discharge in Cumecs per mt. width of dam.	

①	②	③	④
		q = discharge in Cumecs per width of dam. H = drop between sill level and basin bed level in mt. P = Height of end sill expressed in terms of H $\varepsilon = 0.084$, $\alpha = 0.5$ to 0.8 $\beta = 0.05$ $P = 0.15$ $\delta = 0.75$	
24. Conjucate or Sequent depths of Hydraulic Jump	..	$d_2 = \sqrt{\frac{2q^2}{g d_1} + \frac{d_1^2}{4}} - \frac{d_1}{2}$ q = discharge per m. width in m^3/sec. d_1 = depth before jump in mt g = acceleration due to gravity in m/sec^2.	
25. Shooting flow through Chutes.	..	$V = 55 R^{0.52} \sin^{0.40}\alpha$ V = Vel. of flow in m/sec R = hydraulic radius in m $= \frac{A}{P}$ P - Wetted perimeter α = Angle of flume with horigontal	
26. Loss of Head at Trashrack	..	$h_t = 36.1 \left(\frac{TV}{D}\right)^{2} \sin\alpha \sec 15/8\beta$ h_t = loss of head in Cm T = Thickness of Trashrack bars in Cm. V = Velocity of water down-stream of trashrack in m/sec. α = Angle of inclination of trashrack bars with the horigontal.	

①	②	③	④
		D = Spacing of trash rack bars c/c in Cm β = Angle of the approaching current makes with the centre line of sluices Another formula used is $h_t = C \sin\alpha \; 11.1 V_o^2 W / 2dg$ α = Angle of inclination of trash rack bars with the horigontal V_o = Velocity of water u/s of trash bars in m/sec. g = acceleration due to gravity in m/sec^2 W = Maxm. width of bars in Cm. d = Space between the bars in Cm. C = Coeff. which has the values as given below	

BAR SECTION	C	BAR SECTION	C
	2.42		1.03
	1.83		0.92
	1.79		0.76
	1.67		

(1)	(2)	(3)	(4)
22 Available Hydropower ..		Theoritical output, maxm. attainable $= (\rho/75)QH$ (P_t). P_t = Theoritical output in metric h.p ρ = Unit wt of water in Kg/m³ Q = Flow through turbine in m³/sec H = head available in m Effective output (in metric horse power) $P_e = eP_t = e(\rho/75).Q.H$ e = efficiency For estimate the efficiency is assumed as 75 per Cent $P_e = 10QH$ – metric h.p 1 metric hp equals 0.7355 KW Available hydropower in KW = 7.355 QH	
28. DAM: Top width of earth dam.	$B = 8(H+5\cdot6)^{1/2}$ B = Top width in ft H = Maxm ht of dam above ground in ft	$B = 3.6(H+1.5)^{1/2}$ B = Top width in mt H = Maxm. ht of dam above ground in mt	
29. The widening of base to a masonry dam on the U/S side (to prevent tensile stresses on the d/s side when reservoir is empty)	$x = \frac{b_1h_1(b-2b_1)}{bh+2b_1h_1}$ x, b, h, b_1 & h_1 are in feet.	$x = \frac{b_1h_1(b-2b_1)}{bh+2b_1h_1}$ x, b, h, b_1 & h_1 are in meters	



(1)	(2)	(3)	(4)
30. For a weir with water cushion	$D = C\sqrt{H^3d}$ D = depth of water cushion in feet H = height of drop in feet. C = 0.75 for Compact stone = 1.25 for hard brick d = depth of water over crest in feet	$D = 3.28C\sqrt{H^3d}$ D = depth of water cushion in mtr. H = height of drop in mtr. C = 0.75 for Compact Stone = 1.25 for hard brick d = depth of water over crest in feet	
31. Width of floor of cushion.	$W = 6\sqrt{d}$ to $8\sqrt{d}$ d = depth of water over crest in feet W = Width in feet.	$W = 3.31\sqrt{d}$ to $4.42\sqrt{d}$ d = depth of water over crest in mtr W = Width in mtr.	
32. Thickness of floor.	$\frac{1}{5}(H+D)$ to $\frac{1}{4}(H+D)$ H = Height of Crest above d/s floor in feet. D = Head of water over crest in ft	$\frac{1}{5}(H+D)$ to $\frac{1}{4}(H+D)$ H = Height of crest above d/s floor in meter. D = Head of water over crest in mtr.	
33. River Weirs– Overturning moment on a weir when there is no overflow & water is at crest level or at shutter level as the case may be	$M = \frac{(H+S)^3W}{6}$ M = Moment in ft. Lbs H = Ht. of weir in ft. S = Ht. of shutter in ft. W = Wt. of one cft of water in lbs.	$M = \frac{(H+S)^3W}{6}$ M = Moment in Kg.mtr H = Ht. of weir in mtr. S = Ht. of shutter in mtr W = Wt. of one m³ of water in Kg.	
34. When water passes over the weir.	$M = \frac{H^2}{6}(H+3d)W$ d = depth of water over crest in feet.	$M = \frac{H^2}{6}(H+3d)W$ d = depth of water over crest in mtr.	

1	2	3	4
35. When there is clear overfall	$M = 1/6\,(H^3 + 3dH^2 - D^3)\,W$ D = tail water depth in feet. H & d are as above W = density of water in Lbs/cft.	$M = 1/6\,(H^3 + 3dH^2 - D^3)\,W$ D = tail water depth in meter H & d are as above W = density of water in kg/m^3	
36. Crest width of weir	$a = \sqrt{H} + \sqrt{d}$ & $\nless \frac{3d}{2\rho}$ a, H & d are in feet H = height of body wall d = depth of water over weir crest ρ = Sp. gr. of the material of the wall	$a = \frac{\sqrt{H}}{1.811} + \frac{\sqrt{d}}{1.811}$ $= \frac{\sqrt{H} + \sqrt{d}}{1.811}$ and not less than $3d/2\rho$ a, H and d are in mts H = height of body wall d = depth of water over weir crest ρ = Sp. gr. of the material of the wall.	
37. Bottom width of weir	$b = \frac{(H+d)}{\sqrt{\rho}}$ b = bottom width in ft H & d are as above ρ = Sp. gr. of the material of the wall	$b = \frac{H+d}{\sqrt{\rho}}$ b = bottom width in mtr. H & d are as above ρ = Sp. gr of the material of the wall.	
38. Depth of Scour	$R = 0.9\left(\frac{q^2}{f}\right)^{1/3}$ R = depth of scour in ft q = discharge in Cusecs/ft. run f = Lacey's silt factor	$R = 1.35\left(\frac{q^2}{f}\right)^{1/3}$ R = depth of scour in mtr. q = discharge in cumecs/mtr. run f = Lacey's silt factor	
39. Apron-Length of Solid apron.	$L_1 = 4C\frac{\sqrt{H_s}}{13}$ L_1 = Length in feet C = Bligh's Creep Coeff	$L_1 = 1.2C\frac{\sqrt{H_s}}{3.96}$ L_1 = Length in mtr C = Bligh's Creep Coeff.	

- To Be Continued -

NEWS FROM ABROAD

RUSSIANS FIRE OFF AN INSTANT ROCKFILL DAM.

Dam Building is Booming in the Soviet Union.

With 2,000 tons of meticulously placed explosives, Soviet Engineers this spring created an instant dam across the Vakhsh River in Tadzhikistan near the Afghan border. Picking a narrow, steep sided canyon, engineers loaded a side wall with explosives and blasted 2·6 million cu. yd. of rock into the river. After the dust had finally settled, the Russians had created a pile of rock 180 ft. high and about as long in the 32 ft. deep river.

The dam has no foundation trench, no impervious core and no facing to prevent water from seeping through or under it. But it doesn't leak.

To convert the pile of rock into a dam, Soviet Engineers used a technique similar to the one they used in building the upstream cofferdam at Aswan High Dam in Egypt. There, they barged in rock and dumped it into the river, then sluiced the rock with a sand and water slurry carried in through pipes lowered into the river near the rock pile. The sand washed into the rocks and filled the voids making the dam impervious (ENR 5/21/64 p. 55).

At Vakhsh, Russian workmen bulldozed clay with a high calcium content into the river upstream of the artificial rockslide. The river washed the clay into the upstream face of the embankment, creating an impervious seal. Engineers say the Vakhsh is a dirty river, and they expect the normal heavy deposits of silt to strengthen the dam against seepage.

Ivan Nikolayev, deputy design chief in the Ministry of Melioration and Water Enterprises, says that the instant dam technique saved about 30 million on the 180 million project.

TRUSTING THE TRUST—A unique Russian agency, the Explosion Trust in the Ministry of Assembly and Special Construction Projects, planned the blasting down to the most minute detail. According to Chief Engineer Fedor A. Avdeyev, "These were not ordinary explosions. The main problem was to achieve proper compression of the rock and proper compostion of both the large and the small pieces".

To get the desired results, Explosion Trust engineers designed an elaborate application of chemical blasting agents similar to ANFO, which they call AS granulite. Some charges were placed deep in the canyon wall above the dam site. Others were strung along the long, shallow tunnels running parallel to the canyon wall.

The big shot was rigged so the shallow tunnel charges fired first, about six seconds ahead of the main blast. Because they were small and near the surface, the charges produced small stones that fell into the river to form a foundation blanket. Deeper charges produced the bulk of the dam. The last and largest charges to fire gouged out huge chunks of rock that fell on the dam as a sort of riprap cover. The total blast consisted of 133 charges, 13 large and 120 small. Avdeyev says that the explosions were planned so well that seepage through the dam was "very small" even before the clay washed in to fill the voids.

Besides producing the exact size stone in the exact sequence needed to make a dam, the explosions had to be precise to avoid damage to a tunnel and a spillway about 500 ft. away. "Usually explosions of this kind involve a half mile danger zone. But we had many sensitive objects well within that range, so we made the sensitive zone only 1,000 ft. There was no serious damage to anything, just the minor things we expected," says Avdeyev.

The spillway Avdeyev mentions is to the left of the dam. It is a four-gate concrete chute spillway connected to the river by a concrete-lined diversion canal, built in the dry 33 ft. above the river.

The 164 ft. deep reservoir impounds 75,750 acre ft. of water that will be used for irrigation in the fairly arid region.

ONE COOKIE CUTTER.—Two tunnels are carrying Vakhsh water from the reservoir to two dry river beds, one north and one south of the Vakhsh project. The main tunnel, which took six years to build, is 4·5 miles long and 17·4 ft. in diameter. The non-pressure tunnel is lined with reinforced concrete and can handle 2,470 cfs. (It's more than coincidence that the diameter is exactly the same as that of the Moscow subway). The Moscow Metro Trust, which builds many of Russia's tunnels under contract, used the same equipment employed for sub-way tunnels on the Vakhsh job.

The other tunnels is 3 miles long and 10·1 ft. in diameter and carries 530 cfs.

In addition to irrigation, the instant dam will also provide water for a 500,000 Kw. power-house scheduled for completion in the early 1970's.

According to Nikolayev, the Russians are satisfied with their instant dam technique. "The results are good. We are quite sure all problems have been solved" he said.

Extract from May 30, 1968—Engineering News-Record (pages 24–25) 330 W. 42nd street, Newyork. N.Y. 10036.

ENGINEERS, TECHNOLOGISTS AND SCIENTISTS IN THE NATIONAL ECONOMY.

HRH The Duke of Edinburgh, at Salford University, 16 June, 1967.

'Science holds the keys to future development but a high level of pure scientific research can only be sustained by successful and profitable industry. We need all kinds of people, lawyers, doctors, civil servants and teachers, but above all we need the whole range of specialists who can make our industry profitable and competitive throughout the world. This cannot be done by technical knowledge alone, it requires real people with an intelligent concern for human civilisation. Technology is more than a vocation it is both a challenge as well as an opportunity to people who are capable of original thought, who have the fire of ambition in their bellies, and who can learn to use their judgment'.

The Institution of Civil Engineers, August 68', Proceedings.

MODERN CONCEPTS IN IRRIGATION OF CROPS

BY

* THIRU R. SANKARA IYER, B.SC. (ENGG.)

1. Synopsis.

Irrigation crops in India is being done by farmers on an arbitrary basis, depending upon their experience. Practical irrigation on scientific lines, based on the soil-moisture regime concept, has not yet become prevalent in our country. As a result, there is a heavy loss of water in irrigating our fields due to irregular and excessive application of water, not to speak of the consequent reduction in yield of crops. This article explains the recent scientific advancements in scheduling of irrigation of crops, which should profitably be followed in future years to improve our water-use efficiency.

2. Aim of irrigation.

2.1. The aim of irrigation is to supply the necessary moisture to the root zone of the soil for the healthy growth of the plant. The soil moisture enters the plant through the root system, and is used up mostly for transpiration from the leaves. Water is also used up for unavoidable evaporation from the soil surface. These two are together called the evapo-transpiration or consumptive use of the crop, and represent the portion of the irrigation water beneficially utilised by the plants. A significant amount of water applied in the field is lost by surface drainage, deep percolation below the root zone and leaching requirements to wash off salts formed by weathering and other chemical processes in the soil.

2.2. Almost all crops with the exception of paddy, do not tolerate stagnation of water, or saturation of soil. Paddy alone falls into a different category, requiring submergence of the field for a major period of its growth. Other crops require not only adequate moisture, but also a good circulation of air in the root zone depth of the soil, for root respiration and bacterial activity. The scientific regulation of the irrigation of such crops according to the soil moisture regime concept is explained in the succeeding paragraphs.

3. The soil moisture regime concept.

3.1. The maximum amount of water, that a soil can hold by capillary attraction is called its field capacity. It is determined from a soil sample, two days after a copious irrigation, when the gravitational water would have drained off, and is expressed as a percentage of the oven-dry weight of soil. At field capacity, the soil pores are partly filled with water, and partly occupied by air. The percentage of moisture in the soil at which permanent wilting occurs in plants, is called the wilting point. The difference in moisture content of the soil between the field capacity and permanent wilting is termed the available moisture. For convenience, this is also expressed in terms of inches (or cms) depth of water per foot (or metre) depth of soil. Data in respect of typical soils are furnished in Table I.

3.2. In extracting the soil water, the plant roots have to apply a certain amount of force, called soil moisture tension. At field capacity, this tension is about 1/10 to 1/3 atmospheres, the higher figure corresponding to clay soils, and at wilting point, about 15 atmospheres. However, the soil moisture tension rises to only about 1 atmosphere till 50 per cent to 75 per cent of the available moisture is removed. Beyond this, the intake of moisture by the roots becomes slow at higher tensions, and the growth of plants is adversely affected. Irrigation should be resorted to at this juncture, as its object is to eliminate the limitation to crop production, from lack of moisture. If more frequent irrigations at higher levels of moisture are given, there will be excessive wastage of water and increase of labour costs. Hence irrigation should be

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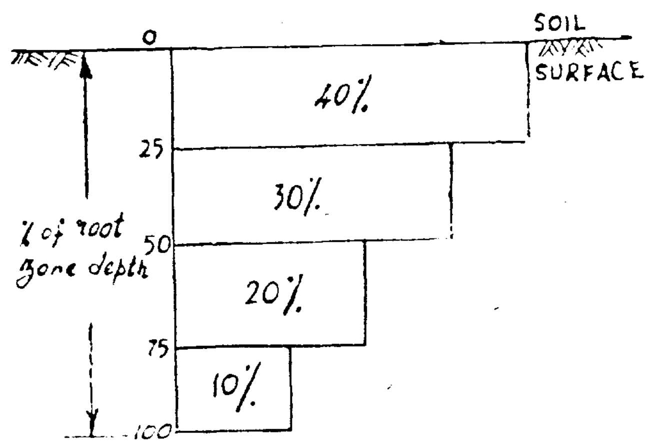
practised at the longest possible interval without detriment to crops. However, the most desirable moisture level for optimum plant growth has not been determined for all crops. Experiments at the Indian Agricultural Research Institute, New Delhi, have shown that, for the best results, Indian wheat, fodder sorghum and tomatoes, grown in sandy loam soil should be irrigated when the available moisture level in the soil reaches 50 per cent, 75 per cent and 70 per cent respectively.

3.3. The extraction of soil moisture is also not uniform throughout the root depth. The average extraction pattern for soil moisture in many plants is shown in the figure below.



Extraction Pattern for Soil Moisture from Root Zone.

The top half of the root zone may be taken to supply 2/3 of the water requirements of the plant and the bottom half 1/3. As a general principle, irrigation may be resorted to when the moisture level in the top half of the root zone drops to 50 per cent of the available moisture in the soil, unless the optimum moisture level for the particular crop has otherwise been determined by research for similar soil conditions.

4. What to know in field irrigation.

Three factors have to be known in the irrigation of crops. (1) How much to irrigate: i.e., the quantity of water to be applied over the field to raise the soil moisture level in the root zone to field capacity:

(2) When to irrigate: i.e., the irrigation interval between two waterings;

(3) How to irrigate: i.e., the method most suitable for efficient irrigation of the field, considering its size and slope, nature of the soil and the crop, size of the irrigation stream, etc.

The first two aspects only are dealt with in this paper, as the third is a vast subject for detailed study.

5. How much to irrigate.

5.1. The net amount of water application may be calculated by one of the following methods: (1) As the difference in moisture content between the field capacity in the root zone and the starting moisture level at the time of irrigation; and (2) by Shockley's method.

Amount of water application in inches= (Available moisture that can be held in the uppes of the root zone)—1.

0·40.

5.2. No irrigation method, is, however, 100 per cent efficient, and losses of water invariably occur in the field, due to unequal distribution of water, deep percolation, runoff, etc. The efficiency of the irrigation depends on the layout of the fields, irrigation method adopted, type, of soil, etc.

The gross amount of water application= Net amount ÷ water application efficiency.

5·3. Illustration.

Consider the case of a crop with a root zone depth of 4 feet in loamy soil.

Available moisture=1.7 inches per foot depth. (as per Table I).

Assume water application efficiency=60 per cent.

Available moisture in the top half of root zone= 3·4 inches.

Moisture to be replaced at 50 per cent depletion level=1.7 inches.

corresponding depletion in lower half of root zone=0·85 inches.

∴ Net water application =2·55 inches.

∴ Gross water application=4·25 *inches.*

Available moisture in the upper ½ of root zone =1·7 inches.

The net water application by shockley's method.

$$=\frac{1\cdot 7}{0\cdot 40}-1=3\cdot 25 \text{ inches.}$$

Gross water application=5·5 inches.

The figures arrived at by the two methods vary slightly, there being a longer depletion of moisture before irrigation, as per the latter method, and the irrigation interval should be suitably fixed to suit this water application.

5.4. Knowing the gross water application say d inches, required, the area of the field A acres, and the available irrigation stream Q cusecs, the time of water application T hours, can be calculated from the formula.

QT=Ad

6. When to irrigate.

6.1. There are several methods of determining the time at which irrigation is due. The direct observation method of crop appearance is not adopted, as it is deceptive and dangerous, and plants would have already been damaged due to lack of moisture before irrigation. The other available methods by which the soil moisture is reckoned by direct or indirect means are given below:—

(1) By the use of soil moisture measuring instruments like tension meters or electrical resistence meters. The moisture is gauged by measurement of the soil moisture tension or the electrical resistivity of the soil. This method is not possible of adoption at present in our farms, as these instruments are costly and have to be imported.

(2) *By soil-sampling method.*—The moisture in the soil can be determined in the laboratory by gravimetric analysis of soil samples taken from the field. This is possible only in research stations, and is not suitable for adoption by farmers.

(3) U.S. Department of Agriculture has evolved a simple field moisture test, which can easily be practised by farmers and does not require sophisticated equipments. The soil samples should be taken at several locations in the field, from the depth where most of the plant roots are growing. A handful of the soil sample is taken and squeezed firmly and compared with the description for that kind of soil in the table for the feel test (Table II).

(4) *Climatological approach.*—There is large scope for extensive application of the climatological approach in irrigation of crops in India. There are two methods under this category.

(i) Moisture-accounting or water-balance method; and

(ii) Pan evaporation method.

These methods are elaborated in the paragraphs below:—

7. The moisture-accounting method.

7.1. The moisture-accounting method is a simple book-keeping procedure, taking the effective rainfall received on the field between irrigations, as water-gains and the consumptive use as water loss. This method pre-supposes the availability of research data on the daily consumptive use of the crop for the particular agrochimatic region. The principal climatological factors influencing the consumptive use rate are temperature, sunshine hours, relative humidity and wind velocity, of which the first two are the most significant. Procedures are available for correcting the average daily consumptive use rates for fluctuations in temperature and sunshine hours. The moisture-accounting method requires a daily measurement of rainfall every morning. From this, the effective rainfall which goes to augument the soil moisture to field capacity level should be estimated, making allowance for run off and deep percolation.

7.2. The moisture-accounting method is advantageous in that it requires no costly equipments and very little labour, but its accuracy depends on the accurate estimates of available moisture and consumptive use rates. Its use is illustrated in the following example. Figures of average consumptive use rates for some irrigated crops evolved in Madhya Pradesh are given in Table III.

7.3. Taking up again the illustration in para (5.3), assume that the crop is sown on September 1, with the soil moisture in the entire root zone at field capacity, and that the average daily consumptive use rates for the crop at the location are

September	..	0·10″
October ..	..	0·15″
November	..	0·15″
December	..	0·20″
January ..	..	0·22″
February	..	0·13″

The rainfall during the season is—

October 20—23rd	..	1·0″
November 6—8th	..	2·5″
November 18—20th		3·0″
December 22nd	..	1·0″

Moisture that can be depleted between two irrigations =2·55″.

The dates of irrigation are calculated in the following table:—

Serial number of the irrigation after sowing.	*Date.*	*Consumptive use after previous irrigation in inches.*	*Effective rainfall received since previous irrigation in inches.*	*Net depletion of soil moisture in inches.*	*Remarks.*
(1)	(2)	(3)	(4)	(5)	(6)
1	September 26 ..	25×0·10=2·50	..	2·50	..
2	October 15	5×0·10+14×0·15 = 2·60 ..	..	2·60	..
3	December 6	17×0·15+30×15+5×0·20 = 8·05.	1·0+2·5+2·05 =5·55.	2·50	See note (1) below.
4	December 19 ..	13 × 0·20 = 2·60	..	2·60	..
5	January 4	13 × 0·20 +3 ×0·22 =3·26.	0·80	2·46	See note (2) below.
6	January 16	12× 0·22 = 2·64	..	2·64	..
7	January 28 ..	12 × 0·22 = 2·64	..	2·64	..
8	February 14	4×0·22 + 13×0·13 = 2·57.	..	2·57	..

NOTE.—(1) The entire rainfall in the periods Oct, 20–23 and Nov. 6–8th is assumed to be absorbed by the soil, as the moisture will still be below field capacity. Out of the rainfall of 3·0″ between Nov. 18–20, only 2·05″, being the amount required to raise the soil moisture to field capacity on Nov. 20th is the effective rainfall.

NOTE.—(2) Out of the rainfall of 1·0″ on Dec. 22nd only 0·80″ being the amount required to raise the soil moisture to field capacity on that day is the effective rainfall.

NOTE.—(3) In the initial growth stage, the crop will actually require light irrigation at more frequent intervals than those shown in the table, as the root depth will be shallow, than the crop is young.

It is seen from the above table that the crop requires eight irrigations after sowing. The gross water application during each irrigation at 60 per cent efficiency, being 4·25″ the delta on the field required for the crop comes to 34″ after sowing.

8. *Pan evaporation method.*

8.1. The pan evaporation method is a very cheap, simple and reliable method for scheduling irrigation of crops. There is a close relationship between the rate of consumptive use by crops, and the rate of evaporation from a well-located evaporation pan. The correlation is obtained by multiplying the pan evaporation data by a crop factor (which usually varies from 0·4 to 1·2).

Evapo-transpiration = Pan evaporation × crop factor.

The crop factor depends on the plant characteristics, environment and geographical location, and it also varies with the stage of growth of the crop, its value being smaller when the plant is small.

Crop factor has to be established by research for different crops.

8.2. In this method, it is necessary to know only the amount of moisture to be replaced at each irrigation. Using the crop factor, the depth of water that must be evaporated from the pan to equal the amount to be replaced in the soil can be calculated. The crop has to be irrigated, when the level of water in the pan goes down by this depth from the starting level. Rainfall received during the period will also be accounted for in the pan, but corrections will be required if the water level rises above the starting level. The Standard Water Bureau evaporation Pan is too sophisticated on equipment for ordinary farmers. Petrol drums or other can evaporimeters can satisfactorily be used in the field, with research accuracy.

8.3. A further advancement in this direction is the design of wire-mesh screens of different sizes to suit different crops, so that when a particular screen is used to cover the evaporation pan, the consumptive use and the pan evaporation will be identical. The pan evaporation method is quite suitable for large scale adoption in Indian farms for proper scheduling of irrigation.

9. *Conclusion.*

The problem of water management in irrigated fields in India has not so far been given the attention it deserves. There is great scope for increasing the water use efficiency in irrigation in our country by adopting scientific techniques to gauge the soil moisture, as a result of which crop yields can be increased, and the water saved can be used for irrigating additional areas or growing additional crops. The hybrid varieties, being introduced for cultivation, require better control of soil moisture for ensuring maximum production. Extensive research has to be undertaken to study the optimum soil moisture regime for different crops and their consumptive use rates in different agro-climatic regions, so as to provide necessary data framing irrigation schedules for guidance of farmers.

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TABLE I.

Approximate soil moisture constants for typical soils.

Type of soil.	Field capacity. per centage.	Wilting point. percentage.	Available moisture. Per centage.	Inches per foot depth of soil.	Cms. per meter depth of soil.
(1)	(2)	(3)	(4)	(5)	(6)
Sand	8·1	4·8	3·3	0·6	5·3
Loam	20·0	11·3	8·7	1·7	13·9
Clay	32·3	17·0	15·3	2·9	24·5

TABLE II.

Guide for judging availability of soil moisture for crops.

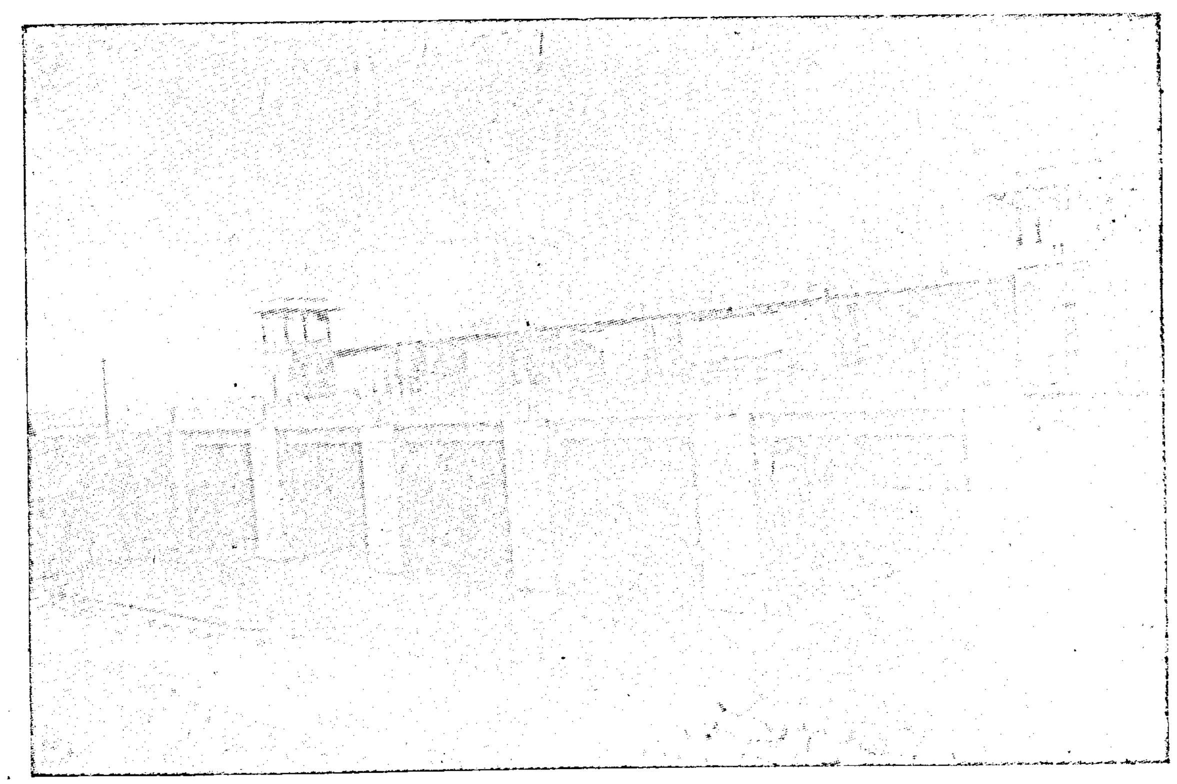
Available soil moisture. remaining.	Feel or appearance of soil. Coarse texture.	Moderately coarse texture.	Medium texture.	Fine and very fine texture.
(1)	(2)	(3)	(4)	(5)
0 to 25 per cent ..	Dry, loose, single—grained, flows through fingers.	Dry, loose, flows through fingers.	Powdery, dry, sometimes slightly crusted but easily broken down to powdery condition.	Hard, baked, cracked sometimes has loose crumbs on surface.
25 to 50 per cent ..	Appears to be dry, will not form a ball even with very firm pressure.	Appears to be dry will not form a ball.	Somewhat crumbly, but holds together under pressure.	Somewhat pliable will ball under pressure.
50 to 75 per cent ..	Appears to be dry, will not form a ball with moderate pressure.	Tends to ball under pressure, but seldom holds together.	Forms a ball, somewhat plastic, will sometimes stick slightly with pressure.	Forms a ball, ribbons and between thumb and fore-finger.
75 to 100 per cent (field capacity).	Tends to stick together slightly, sometimes forms a very weak ball under pressure.	Forms weak ball, breaks easily, will not stick.	Forms a ball, is very pliable, sticks steadily if relatively high in clay.	Easily ribbons out between fingers has sticky feeling.
At field capacity 100 per cent.	Upon squeezing, no free water appears on soil, but wet outline of ball is left on hand.			

TABLE III.

Consumptive use by major irrigated crops in Madhya Pradesh.

Crop.	Average daily use.	Mean monthly consumptive use.	Peak use per day at plant flowing stage.	Seasonal consumptive use.
(1)	(2)	(3)	(4)	(5)
	INCHES.	INCHES.	INCHES.	INCHES.
Wheat	0·13	4·0	0·25	17·0
Paddy	0·23	7·0	0·32	35·0
Sugar Cane	0·30	9·0	0·45	110·0
Cotton	0·20	6·0	0·28	30·0
Potatoes	0·13	4·0	0·22	19·0

GOMUKHI RESERVOIR



THIRUMOORTHI NAGAR REGULATOR

INVITATION TO READERS

Kind attention of the Engineers of the Madras Public Works Department and readers of the journal elsewhere is drawn to the meagre response to repeated requests for contribution of articles to the journal.

May we once again emphasise the two-fold objective of the journal, viz., to promote the interest of engineers and aiding their specialised work by placing before them the many problems of technical importance and ways and means of solving them, and secondly, opportunities being scarce for engineers to express their own experience in solving practical problems of design and execution, we wish to add that this journal has been the only medium of expression for those in the field. It is earnestly 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 the articles to the journal need not be rigorously confined to the subjects on irrigation alone. Articles which have a direct bearing on subjects given below are also welcome :—

(1) Technical aspects of foundation soils and foundation Engineering.

(2) Auxiliary works in the field of irrigation and other water-retaining structures and works.

(3) Practical solution to hydraulic problems in canals and distribution systems with reference to their maintenance.

(4) Problems of soil erosion and conservation and reclamation of land.

(5) Practical silt problems in rivers and reservoirs.

(6) Problems of sanitation and public health and possibilities of utilisation of sewage.

(7) Inland waterways and navigation, fishing schemes and protection of land against sea erosion, etc.

(8) Problems of drainage in deltaic tracts and entrance of rivers into the sea.

(9) Run-off studies in catchments and evaporation studies in reservoirs.

(10) All allied subjects.

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

PRINTED BY THE DIRECTOR OF STATIONERY AND PRINTING, MADRAS,
ON BEHALF OF THE GOVERNMENT OF TAMIL NADU 1969