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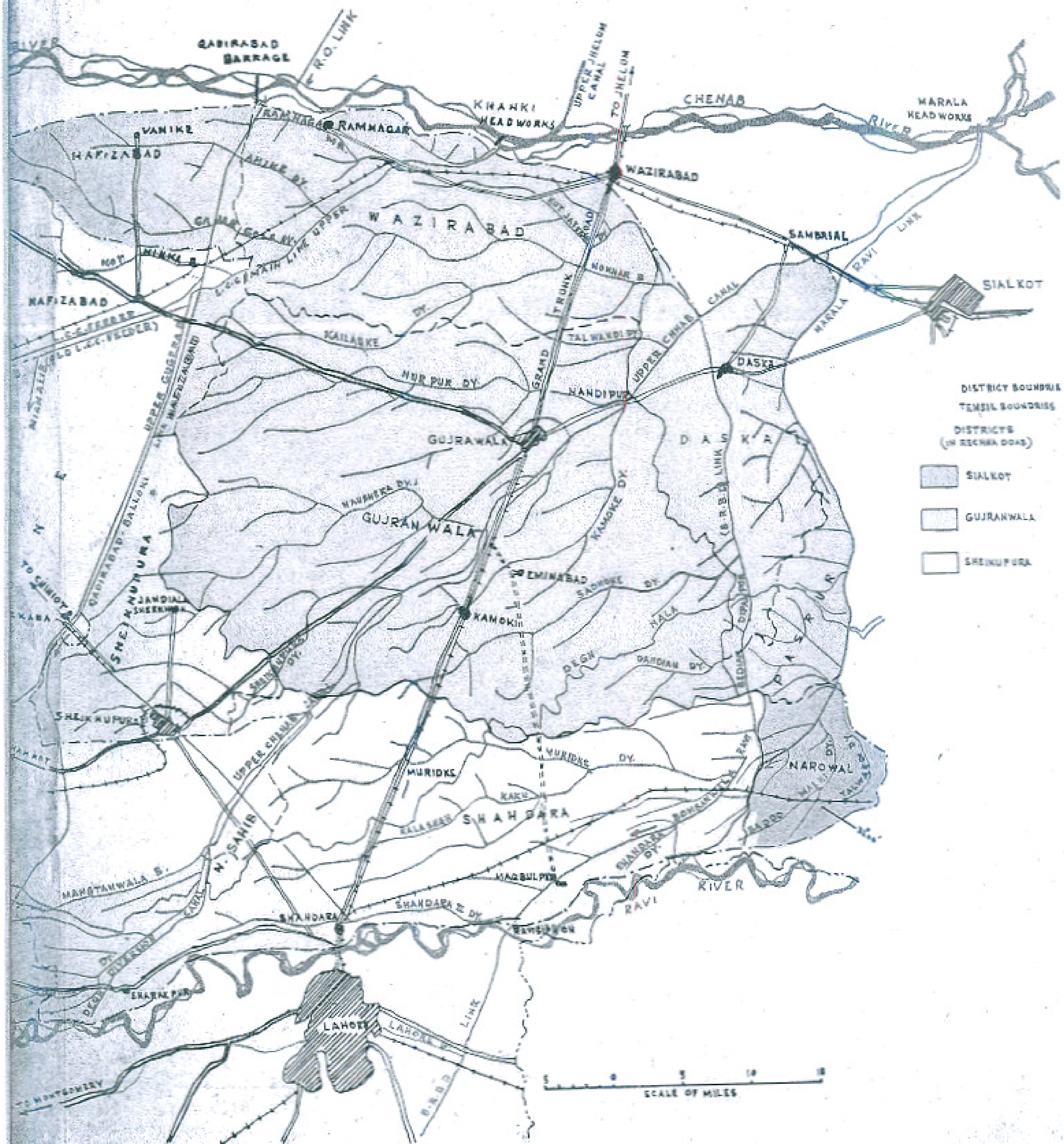

UPPER RECHNA DOAB PROJECT AREA

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Electrical Plant and Equipment of all Kinds

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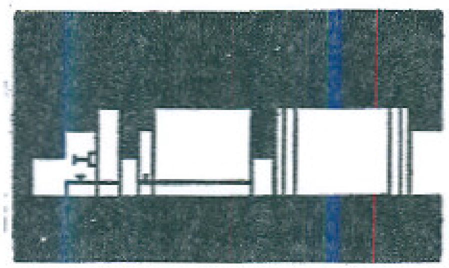

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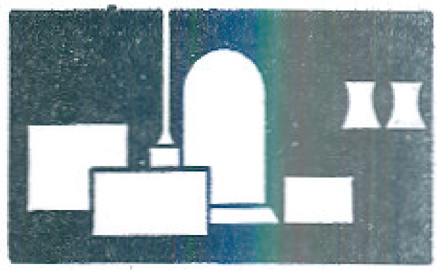

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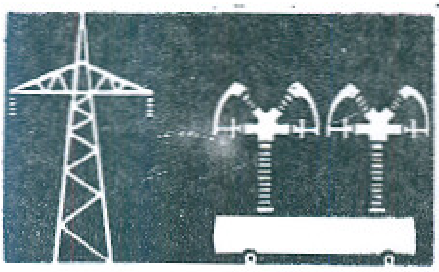

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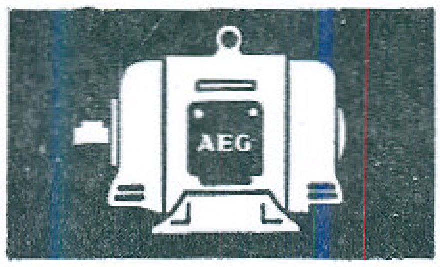

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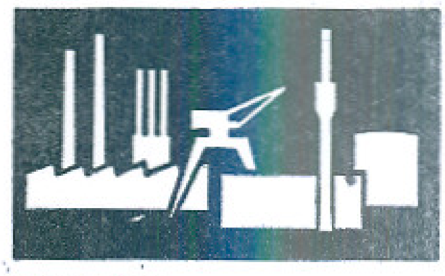

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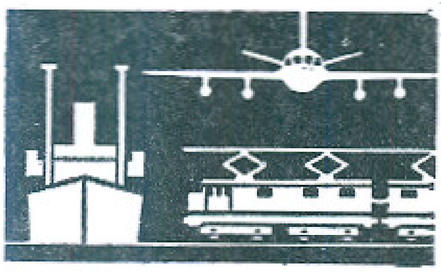

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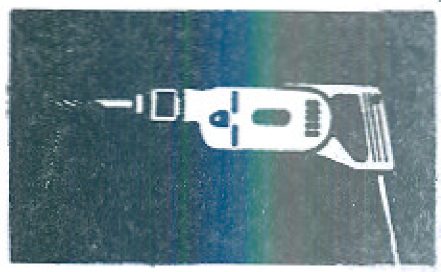
Marine Engineering
Airfield Equipment



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Vol. X June 1965 No. 2

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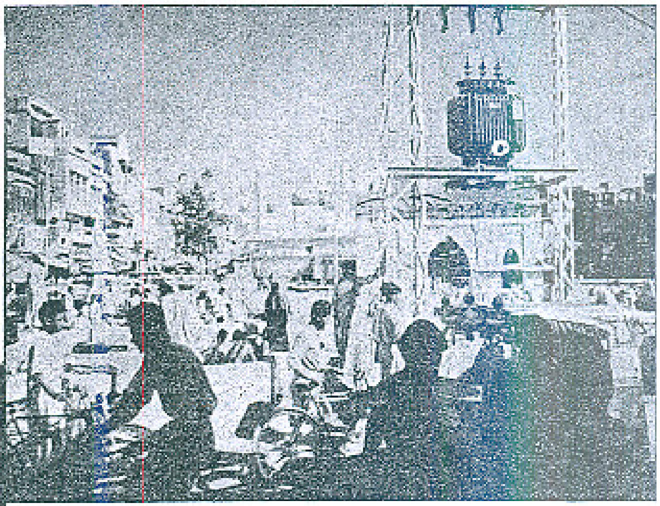
...to the large

power transformers...



supplying

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Capitals of

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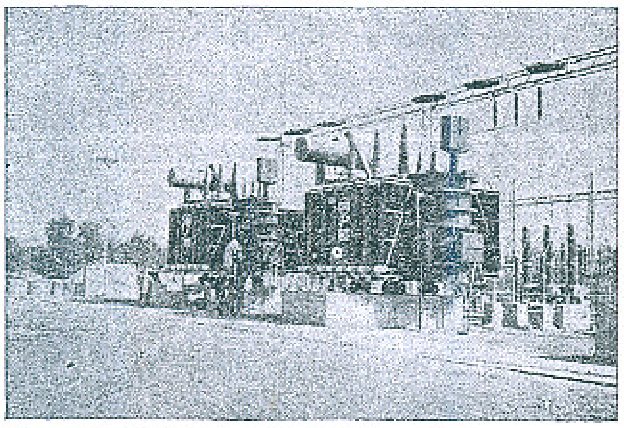
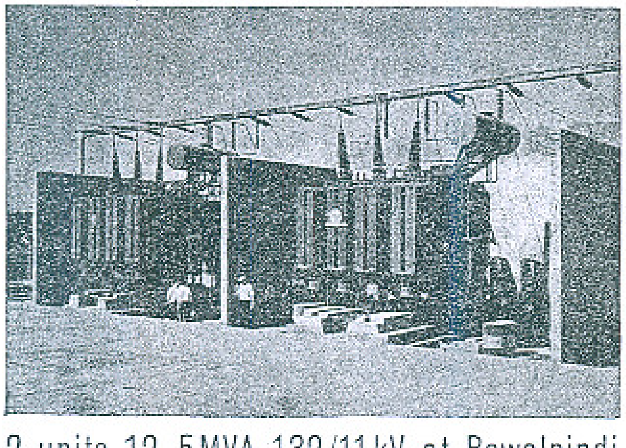
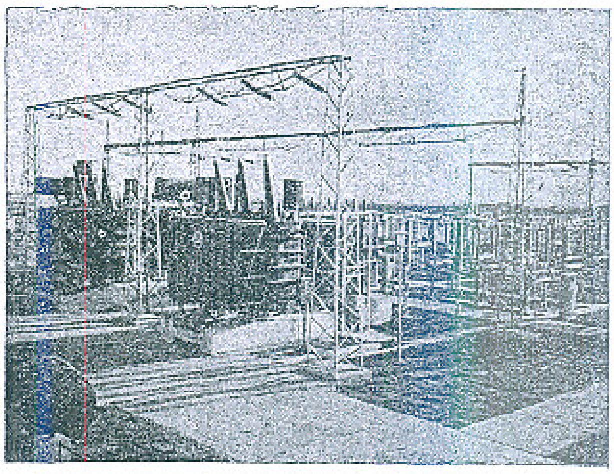


3 units 32MVA 132/71kV at Lahore



2 units 12.5MVA 132/11kV at Rawalpindi



2 units 16/5/11MVA 132/36/12kV at Islamabad

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Need of a Periodical on Tubewells

In its report for the year 1963, the Irrigation Research Institute drew attention to the increasing number of tubewell installations in the former Punjab and Bahawalpur State. Thereupon several organizations in the country took up surveys of their number, cost, rate of installation etc. Mr. Ghulam Mohammad (*vide Pakistan Development Review*) conducted a survey of private tube-well development in our coutry during 1964-65. This was followed by a reconnaissance survey of private tube-wells, conducted by Harza Engineering Co International, on the suggestion of Wapda's Chairman. The latest contribution to the subject is by Mr. Ghulam Yasin of the Board of Economic Enquiry (Punjab), Lahore, who has discussed the Economics of tubewell irrigation.

The farmers started taking interest in tubewells in 1950, when the rate of installation was only 44 tubewells per year. Five years later, in 1955, the rate rose to 300 per year. In the next five years, it rose to 1000 per year while in 1964, about 6500 tubewells were installed. It has been estimated that in the Punjab and Bahawalpur Region, about 25,000 private tubewells will be in operation by the end of the current year.

The secret of this phenomenal increase in the number of tubewell installations is low cost and return of the capital. A tubewell yielding $\frac{1}{2}$ to 2 cusecs can be installed for Rs 3000 to Rs. 8,000/- if electric power is available. In case the tubewell has to be run on diesel power, the cost is higher: Rs. 5,000/- to Rs. 12, 000/-.

As a matter of fact, the present cost of tubewell installation and construction is lower than it was 40 years ago when a Government tubewell, pumping 2 cusecs, could be installed for Rs. 6,000/- to Rs. 10,000/- Indeed, the present cost is even lower than that of installing a persian-wheel, maintaining a pair of bullocks to work it during a part of the day to obtain a yield 1/10th to 1/20th of that obtained from a tubewell. The low cost of the installation and operation, and the large yield of water has been a great attraction for the progressive farmers of the former Punjab and Bahawalpur, as the full capital is returned in the short period of two or three years. Although water thus obtained is more expensive than canal water, yet the deficit is made up by increased produce. At present some doubts are being expressed about the durability of this cheap design of tubewell but tubewell installation in the last fifteen years has convinced the farmers of its economic soundness.

The Indus Plain is saturated alluvium generally containing sand. Drilling at any site and adopting some means to keep the formation in position is a source of water. The development of coir-string strainer has paved the way towards cheap installation. In every city of the former Punjab, big and small, there are now dozens of local drillers and manufacturers of pipes and strainers. Tubewell manufacture has become a cottage industry, but there are no standards, no common specifications, pipes and strainers are generally made by persons least acquainted with the hydraulics of wells. Luckily, the water-yielding property of the formation and the coir string strainers made in any form, so long it keeps the formation in position, has helped the progress of tubewell installation. The need for uniformity of design and construction is indeed very great. There is a vast variation in the design of even Government tubewells. Wapda has not tried coir string strainer as yet. It is patronising foreign imported mild steel, fibre glass impregnated with epoxy resin, etc. The Irrigation Branch is slowly taking to the use of coir-string. Similarly, the Agricultural Department has also no standards. They install whatever type of material is acquired by the owners. Uniformity of design, standardization of specifications and dissemination of basic information about ground water hydrology and tubewell hydraulics can certainly improve the national efforts. Perhaps a quarterly periodical devoted to ground water and its exploitation is a need of the day.

Tubewells are bound to stay in this country of vast flat plains with little natural drainage. Slowly, the Sind farmers are also realising the advantages of tube-wells and in spite of their thin aquifer, are thinking of installing multiple wells. There are vast areas beside the rivers, regions of active floods, which were left out in the development of the irrigation system. These regions have no perennial irrigation. They get annual flushing and deposition of fresh sediment. They have good quality ground water, and natural drainage as a result of the rising and falling of the rivers. These regions have a great potential for the use of tubewells to exploit the good quality ground water. Thus tubewells are sure to come to these regions also. There are innumerable advantages in using the ground water of the Indus Plains. These should be exploited to the fullest extent, and success will be attained when backed by scientific guidance. There is thus a strong case for disseminating tubewell information for the benefit of our progressive farmers. With encouragement from the departments interested in the exploitation of ground water, an educative and informative journal can be published for the reasons stated above; this should be done without delay. The department concerned should undertake the venture forthwith.

The Use of Trigonometric Series in the Solution of Statically Indeterminate Beam Problems

By IFTIKHAR MUFTI

There are several structural problems which are statically indeterminate. A beam fixed at ends and carrying loads in the lateral direction is such an example.

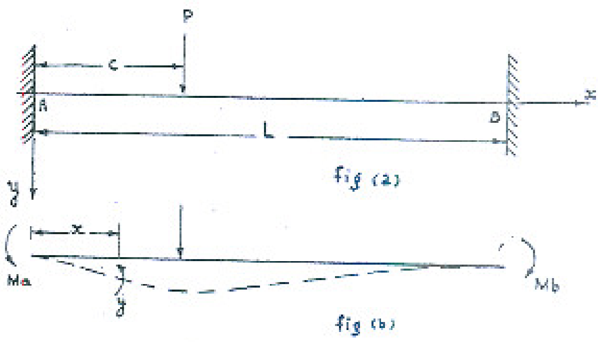
In this article Mr. Iftikhar Mufti has attempted an analysis of such cases by the use of Infinite Trigonometric series. The formulae developed by him have been used to solve many difficult problems quickly and easily. Tables are given in the text which facilitate analysis of complicated cases.

INTRODUCTION

The paper describes the use of Infinite Trigonometric Series for determining the deflection curve of a beam with fixed ends and carrying loads in the lateral direction. The mathematical expression derived has an advantage that a single relation holds for the entire length of the span. The boundary conditions in such a beam, provide for no deflection at the fixed ends. Using a half range infinite sine series for this purpose, the equation for the elastic curve has been determined. This helped to find the indeterminate constants by introducing suitable boundary conditions. With this brief introduction of the method the theoretical treatment is worked out.

Mathematical Analysis

AB is a beam of length "L Ft" partially fixed at the ends and carrying a concentrated load of P lbs at a distance "C" from the origin along the x-axis, the origin is assumed at A (*see* Fig. a). With ends of the beam



partially fixed, certain moments would be developed at the ends, rotating the left end of the beam in the anti-clock-wise and the right end in the clockwise direction. Let the magnitude of these moments be M_a and M_b respectively. The elastic curve of the beam under the action of these moments and the concentrated load P would be as shown dotted in Fig. (b).

The bending moment M at any section, distant x from the left end will be given by the following two equations:

$$M=-\frac{P(L-C)}{L}x+M_a\frac{(L-x)}{L}+M_b\cdot\frac{x}{L} \qquad (0<x\leqq c)$$

$$M=-\frac{Pc}{L}(L-x)+M_a\frac{(L-x)}{L}+M_b\cdot\frac{x}{L} \qquad (c<x\leqq L)$$

This bending moment can be expressed in terms of a single half-range infinite Sine-series of the form

$$M=b_1\sin\frac{\pi x}{L}+b_2\sin\frac{2\pi x}{L}+b_3\sin\frac{3\pi x}{L}+\ldots b_n\sin\frac{n\pi x}{L}+\ldots\ldots$$

where

$$b_n=\frac{2}{L}\Big[\int_0^c\Big\{-P\frac{(L-C)}{L}x+M_a\frac{(L-x)}{L}+M_b\cdot\frac{x}{L}\Big\}\sin\frac{n\pi x}{L}\,dx.$$

$$+\int_c^L\Big\{-Pc\frac{(L-x)}{L}+M_a\frac{(L-x)}{L}+M_b\frac{x}{L}\Big\}\sin\frac{n\pi x}{L}\,dx\Big]$$

$$=\frac{2}{L}\Big[-P\frac{(L-C)}{L}\int_0^c x\sin\frac{n\pi x}{L}dx+\frac{M_a}{L}\int_0^c(L-x)\sin\frac{n\pi x}{L}dx$$

$$+\frac{M_b}{L}\int_0^c x\sin\frac{n\pi x}{L}dx-\frac{P_c}{L}\int_c^L(L-x)\sin\frac{n\pi x}{L}dx$$

$$+\frac{M_a}{L}\int_c^L(L-x)\sin\frac{n\pi x}{L}dx+\frac{M_b}{L}\int_c^L x\sin\frac{n\pi x}{L}dx\Big]$$

$$=\frac{2}{L}\Big[-P\frac{(L-C)}{L}\Big\{-\frac{xL}{n\pi}\cos\frac{n\pi x}{L}+\Big(\frac{L}{n\pi}\Big)^2\sin\frac{n\pi x}{L}\Big\}_0^c$$

$$+\frac{M_a}{L}\Big\{-\frac{L}{n\pi}(L-x)\cos\frac{n\pi x}{L}-\Big(\frac{L}{n\pi}\Big)^2\sin\frac{n\pi x}{L}\Big\}_0^c$$

$$+\frac{M_b}{L}\Big\{-\frac{xL}{n\pi}\cos\frac{n\pi x}{L}+\Big(\frac{L}{n\pi}\Big)^2\sin\frac{n\pi x}{L}\Big\}_0^c$$

$$-\frac{P_c}{L}\Big\{-\frac{(L-x)}{n\pi}\cos\frac{n\pi x}{L}-\Big(\frac{L}{n\pi}\Big)^2\sin\frac{n\pi x}{L}\Big\}_c^L$$

$$+\frac{M_a}{L}\Big\{-\frac{L}{n\pi}(L-x)\cos\frac{n\pi x}{L}-\Big(\frac{L}{n\pi}\Big)^2\sin\frac{n\pi x}{L}\Big\}_c^L$$

$$+\frac{M_b}{L}\Big\{-\frac{xL}{n\pi}\cos\frac{n\pi x}{L}+\Big(\frac{L}{n\pi}\Big)^2\sin\frac{n\pi x}{L}\Big\}_c^L\Big]$$

$$=\frac{2}{L}\Big[\frac{M_aL}{n\pi}-\frac{PL^2}{n^2\pi^2}\sin\frac{n\pi c}{L}-\frac{M_bL}{n\pi}\cos n\pi\Big]$$

$$=\frac{2}{n\pi}(M_a-M_b\cos n\pi)-\frac{2PL}{n^2\pi^2}\sin\frac{n\pi c}{L}$$

Hence

$$M=\sum_{n=1}^{\infty}\frac{2}{n\pi}\,(M_a-M_b\cos n\pi)\sin\frac{n\pi x}{L}-\sum_{n=1}^{\infty}\frac{2PL}{n^2\pi^2}\sin\frac{n\pi c}{L}\sin\frac{n\pi x}{L}$$

Which is an expression for the B. M. at any point within the interval $x=0$ to $x=L$.

From our knowledge about the deflection of laterally loaded symmetrical beams we know that

$$EI\frac{d^2y}{dx^2}=M \text{ (for the direction of coordinate axes as shown in the fig.)}$$

$$\text{Therefore } EI\frac{d^2y}{dx^2}=\sum_{n=1}^{\infty}\frac{2}{n\pi}\,(M_a-M_b\cos n\pi)\sin\frac{n\pi x}{L}-\sum_{n=1}^{\infty}\frac{2PL}{n^2\pi^2}\sin\frac{n\pi c}{L}\sin\frac{n\pi x}{L}$$

If we intergate this expression twice with respect to x we shall get an expression for the deflection of the beam at any section distant x from the left end.

$$\therefore\quad EIy=\sum_{n=1}^{\infty}\frac{2}{n\pi}(M_a-M_b\cos n\pi)\iint\sin\frac{n\pi x}{L}\,dx\,dx-\sum_{n=1}^{\infty}\frac{2PL}{n^2\pi^2}\sin\frac{n\pi c}{L}\iint\sin\frac{n\pi x}{L}\,dx\,dx$$

$$=\sum_{n=1}^{\infty}\frac{2L^2}{n^3\pi^3}\,(M_b\cos n\pi-M_a)\sin\frac{n\pi x}{L}+\sum_{n=1}^{\infty}\frac{2PL^3}{n^4\pi^4}\sin\frac{n\pi c}{L}\sin\frac{n\pi x}{L}\qquad\ldots.(a)$$

(constants of integration vanish by introducing boundary conditions *viz.* $y=0$ for $x=0$ and for $x=L$).

If we differentiate this expression with respect to x, we get an expression for the slope at any section.

$$\therefore\quad EIy'=\frac{2L}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{n^2}\,(M_b\cos n\pi-M_a)\cos\frac{n\pi x}{L}$$

$$+\frac{2L^2}{\pi^3}\sum_{n=1}^{\infty}\frac{P}{n^3}\sin\frac{n\pi c}{L}\cos\frac{n\pi x}{L}\qquad\ldots.(b)$$

At the ends where $x=0$ and $x=L$, the expressions for the slope will be found by inserting these values of x in (b) above

$$\therefore\quad EIy'_{x=0}=\frac{2L}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{n^2}\,(M_b\cos n\pi-M_a)+\frac{2L^2}{\pi^3}\sum_{n=1}^{\infty}\frac{P}{n^3}\sin\frac{n\pi c}{L}$$

$$=\frac{2L}{\pi^2}\Big[-(M_a+M_b)\left(\frac{1}{1^2}+\frac{1}{3^2}+\frac{1}{5^2}+\ldots\ldots\infty\right)$$

$$-(M_a-M_b)\left(\frac{1}{2^2}+\frac{1}{4^2}+\frac{1}{6^2}+\ldots\ldots\infty\right)\Big]$$

$$+\frac{2PL^2}{\pi^3}\sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi c}{L}$$

$$=\frac{2L}{\pi^2}\Big[-(M_a+M_b)\left(\frac{1}{1^2}+\frac{1}{3^2}+\frac{1}{5^2}+\ldots\ldots\infty\right)$$

$$-\frac{1}{2^2}\,(M_a-M_b)\left(1+\frac{1}{2^2}+\frac{1}{3^2}+\ldots\ldots\infty\right)\Big]$$

$$+\frac{2PL^2}{\pi^3}\sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi c}{L}$$

The sums of the infinite series

$$\left(\frac{1}{1^2}+\frac{1}{3^2}+\frac{1}{5^2}+\ldots\ldots\infty\right) \text{ and } \left(\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+\ldots\ldots\infty\right)^* \text{ are } \frac{\pi^2}{8} \text{ and } \frac{\pi^2}{6}$$

respectively

$$\therefore \quad EIy'_{x=0}=\frac{2L}{\pi^2}\left[-(M_a+M_b)\frac{\pi^2}{8}-\frac{1}{2^2}(M_a-M_b)\frac{\pi^2}{6}\right]+\frac{2PL^2}{\pi^3}\sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi c}{L}$$

$$=\boxed{-\frac{L}{6}(2M_a+M_b)+\frac{2L^2}{\pi^3}\sum_{n=1}^{\infty}\frac{P}{n^3}\sin\frac{n\pi c}{L}} \quad \ldots.(c)$$

and similarly

$$EIy'_{x=L} \quad =\boxed{\frac{L}{6}(M_a+2M_b)+\frac{2L^2}{\pi^3}\sum_{n=1}^{\infty}\frac{P}{n^3}\sin\frac{n\pi c}{L}\cos n\pi} \quad \ldots.(d)$$

For a beam completely fixed at the ends, the slopes at both the ends are zero and therefore equating both (*c*) and (*d*) with zero, we can find out the values of the unknown end moments M_a and M_b for any position of the load P. If the concentrated loads are more than one in number and are placed at different points along the length of the beam, the slopes produced at the ends by the application of these loads individually shall be added together algebraically to get the total slope. For example if P_1, P_2, P_3 are the loads acting at distances C_1, C_2 and C_3 etc., from the left end support, then the expression for the slopes at the ends would be as below:

$$EIy'_{x=0}=-\frac{L}{6}(2M_a+M_b)+\frac{2L^2}{\pi^3}\left[P_1\sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi c_1}{L}+P_2\sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi c_2}{L}+\ldots\ldots\right] \quad \ldots.(e)$$

and

$$EIy'_{x=L}=\frac{L}{6}(M_a+2M_b)+\frac{2L^2}{\pi^3}\left[P_1\sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi c_1}{L}\cos n\pi+P_2\sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi c_2}{L}\cos n\pi+\ldots\ldots\right] \quad \ldots.(f)$$

The values of the series within the sigmas can at once be read out from the tables A & B where for certain values of C/L, the values of these series have been calculated. The use of these tables would be clear from the examples to be given later. In this way we save the labour of finding out the area of the B. M. diagram and the position of its C. G. as is needed while applying the moment area method. In a simply supported beam, M_a and M_b are both zero and we get the familiar expressions for the end slopes as

$$y'_{x=0}=\frac{2PL^2}{\pi^3 EI}\sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi c}{L}$$

and

$$y'_{x=L}=\frac{2PL^2}{\pi^3 EI}\sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi c}{L}\cos n\pi.$$

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*Knopp, "Infinite series" pages 237 and 238.

Beam with ends fixed and carrying a uniformly distributed load

Suppose that the beam carries a uniformly distributed load of intensity q lbs/ft over a length of the span from $x=a$ to $x=b$. The weight of a small element of length 'dc' at a distance $x=c$ from A is 'qdc'. Replacing P by qdc in equation (b) and integrating with respect to "c" from $x=a$ to $x=b$ we have

$$EIy' = \frac{2L}{\pi^2}\sum_{n=1}^{\infty}\frac{M_b\cos n\pi - M_a}{n^2}\cos\frac{n\pi x}{L} + \frac{2qL^2}{\pi^3}\sum_{n=1}^{\infty}\frac{1}{n^3}\cos\frac{n\pi x}{L}\int_a^b \sin\frac{n\pi c}{L}\,dc \quad \ldots.(g)$$

from which we can deduce the expressions for end slopes and hence those of the unknown end moments. If the load is distributed along the entire length we get

$$EIy' = \frac{2L}{\pi^2}\sum_{n=1}^{\infty}\frac{M_b\cos n\pi - M_a}{n^2}\cos\frac{n\pi x}{L} + \frac{2qL^2}{\pi^3}\sum_{n=1}^{\infty}\frac{1}{n^3}\cos\frac{n\pi x}{L}\int_0^L \sin\frac{n\pi c}{L}\,dc$$

as the expression for slope at any section distant x from A.

$$\text{Since } \int_0^L \sin\frac{n\pi c}{L}\,dc = -\frac{L}{n\pi}\cos\frac{n\pi c}{L}\Big]_0^L = \frac{L}{n\pi}(1-\cos n\pi) = \begin{cases} 0 & (n \text{ even}) \\ \frac{2L}{n\pi} & (n \text{ odd}) \end{cases}$$

We have the expression for the slope at any section

$$EIy' = \frac{2L}{\pi^2}\sum_{n=1}^{\infty}\frac{M_b\cos n\pi - M_a}{n^2}\cos\frac{n\pi x}{L} + \frac{4qL^3}{\pi^4}\sum_{n=1,3,5..}^{\infty}\frac{1}{n^4}\cos\frac{n\pi x}{L} \quad \ldots.(h)$$

The deflection curve would be obtained by integrating this expression with respect to x. Therefore,

$$EIy = \frac{2L^2}{\pi^3}\sum_{n=1}^{\infty}\frac{M_b\cos n\pi - M_a}{n^3}\sin\frac{n\pi x}{L} + \frac{4qL^4}{\pi^5}\sum_{n=1,3,5..}^{\infty}\frac{1}{n^5}\sin\frac{n\pi x}{L} \quad \ldots.(j)$$

Since in most of our problems we shall be concerned with the end slopes we deduce the expressions for y' corresponding to $x=0$ and $x=L$

$$\therefore\; EIy'_{x=0} = -\frac{L}{6}(2M_a+M_b) + \frac{4qL^3}{\pi^4}\left(\frac{1}{1^4}+\frac{1}{3^4}+\frac{1}{5^4}\ldots\ldots\infty\right)$$

$$= -\frac{L}{6}(2M_a+M_b) + \frac{4qL^3}{\pi^4}\times\frac{\pi^4}{96}$$

$$= \boxed{-\frac{L}{6}(2M_a+M_b) + \frac{qL^3}{24}} \quad \ldots.(k)$$

and similarly,

$$E\,Iy'_{x=L} = \boxed{\frac{L}{6}(M_a+2M_b) - \frac{qL^3}{24}} \quad \ldots.(l)$$

The equations (a) to (l) are perfectly general and can be used both for the determinate as well as indeterminate problems. In determinate problems where the beams are resting on supports, the end moments M_a and M_b shall be zero.

Problem 1.—Determination of Indeterminate constants in case of a Beam with ends built-in and having a concentrated load

In this case, we shall make use of equations (*c*) and (*d*). Since the ends are fixed the end slopes shall be zero and therefore to determine M_a and M_b both of these expressions would be put $=0$. For a particular case let us assume L=12 ft, C=3 ft. and P=10 lbs, and and let it be required to find out M_a and M_b. We have from equation (*c*)

$$\frac{12}{6}(2M_a+M_b)=\frac{2\times10\times144}{\pi^3}\sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi}{4}$$

or
$$2M_a+M_b=\frac{1440}{\pi^3}\left(\frac{1}{1^3}\cdot\frac{1}{\sqrt{2}}+\frac{1}{2^3}+\frac{1}{3^3}\cdot\frac{1}{\sqrt{2}}+\ldots\ldots\right)^*$$

$$=\frac{1440}{\pi^3}(0.71+0.125+0.02168+\ldots\ldots)$$

$$=\frac{1440}{\pi^3}\times0.85829=39.8 \qquad \ldots.(i)$$

From equation (*d*) we get

$$\frac{12}{6}(M_a+2M_b)=-\frac{2\times10\times144}{\pi^3}(-0.71+0.125-0.02618+\ldots\ldots)$$

or
$$M_a+2M_b=\frac{1440\times0.60829}{\pi^3}=28.3 \qquad \ldots.(ii)$$

Equations (*i*) and (*ii*) give $M_a=17.1$ lbs ft, and $M_b=5.6$ lbs ft. Let us now suppose P be at the mid span *i.e.* C=L/2 Therefore from equation (*c*) we get

$$2M_a+M_b=\frac{6}{L}\times\frac{2PL^2}{\pi^3}\left(1-\frac{1}{3^3}+\frac{1}{5^3}-\ldots\ldots\infty\right)^*$$

$$=\frac{6}{L}\times\frac{2PL^2}{\pi^3}\times\frac{\pi^3}{32}$$

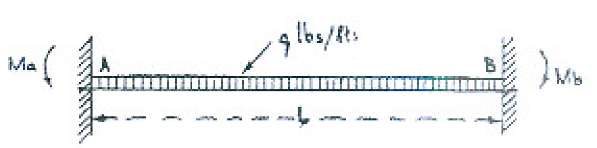
$$=\frac{3PL}{8} \qquad \ldots.(i)'$$

and equation (*d*) gives $\qquad M_a+2M_b=\frac{3PL}{8} \qquad \ldots.(ii)''$

(*i*)′ and (*ii*)″ give $\qquad M_a=M_b=\frac{PL}{8}$

Problem 2.—Beam with ends built in and carrying a uniformly distributed load.

To find out the end moments in this case we make use of equation (*h*). For $x=0$ we have



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*We can omit the remaining terms.

**Sum of the series in brackets is $\frac{\pi^3}{32}$ Knopp. "Infinite series" page 240.

$$EIy'_{x=0}=\frac{2L}{\pi^2}\sum_{n=1}^{\infty}\frac{M_b\cos n\pi-M_a}{n^2}+\frac{4ql^3}{\pi^4}\sum_{n=1,3,5\ldots}^{\infty}\frac{1}{n^4}$$

$$=-\frac{L}{6}(2M_a+M_b)+\frac{4ql^3}{\pi^4}\left(\frac{1}{1^4}+\frac{1}{3^4}+\frac{1}{5^4}+\ldots\ldots\infty\right)^*$$

$$=-\frac{L}{6}(2M_a+M_b)+\frac{4ql^3}{\pi^4}+\frac{\pi^4}{96}$$

Equating this with zero we get

$$2M_a+M_b=\frac{ql^2}{4} \qquad \ldots.(i)$$

Similarly for $x=L$ we have

$$M_a+2M_b=\frac{ql^2}{4} \qquad \ldots.(ii)$$

From (i) and (ii) we get $M_a=M_b=\frac{ql^2}{12}$

Problem 3.—Determination of the end moment M_b for the beam shown

In this case we apply equation (d). M_a is zero and therefore for the end B

$$\frac{L}{6}(2M_b)+\frac{2PL^2}{\pi^3}\sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi c}{L}\cos n\pi=0$$

or

$$M_b.\frac{L}{3}=-\frac{2PL^2}{\pi^3}\sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi c}{L}\cos n\pi$$

and hence

$$M_b=-\frac{6PL}{\pi^3}\sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi c}{L}\cos n\pi.$$

when $c=L/2$ we get

$$M_b=-\frac{6PL}{\pi^3}\sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi}{2}\cos n\pi$$

$$=-\frac{6PL}{\pi^3}\left[\frac{1}{1^3}(-1)+\frac{1}{3^3}+\frac{1}{5^3}(-1)+\ldots\ldots\infty\right]$$

$$=\frac{6PL}{\pi^3}\left[\frac{1}{1^3}-\frac{1}{3^3}+\frac{1}{5^3}\ldots\ldots\ldots\infty\right]^{**}$$

$$=\frac{3PL}{16}^{***}$$

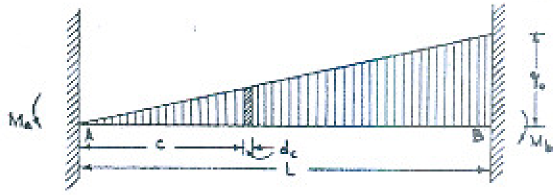
---

*Sum of series in brackets is $\frac{\pi^4}{96}$. Advanced Math. for Engineers by Reddick and Miller.

**Sum of series in brackets is $=\frac{\pi^3}{32}$ Knopp. "Infinite series" page 240.

***See also Timoshenko's strength of Materials Vol. I page 180.

Problem 4.—Beam with ends fixed and carrying a non-uniformly distributed load.



The method is easily applicable for beams carrying load distributed non-uniformly. We examine the simple case of a beam loaded as shown.

In this case we make use of equation (*c*) and (*d*) with the load P replaced by the weight of a small element *dc* (in this case $\frac{q_o c}{L}$ *dc*) and integrate over the entire length

$$\therefore \quad EIy'_{x=0} = -\frac{L}{6}(2M_a+M_b) + \frac{2L^2}{\pi^3}\sum_{n=1}^{\infty}\frac{q_o}{Ln^3}\int_0^L c \sin\frac{n\pi c}{L}\,dc$$

$$= -\frac{L}{6}(2M_a+M_b) - \frac{2L^2}{\pi^4}\sum_{n=1}^{\infty}\frac{q_0 L}{n^4}\cos n\pi$$

$$= -\frac{L}{6}(2M_a+M_b) + \frac{2q_0L^3}{\pi^4}\left(\frac{1}{1^4}-\frac{1}{2^4}+\frac{1}{3^4}+\ldots\ldots\infty\right)^*$$

$$= -\frac{L}{6}(2M_a+M_b) + \frac{2q_0L^3}{\pi^4}\times\frac{7\pi^4}{720}$$

$$= -\frac{L}{6}(2M_a+M_b) + \frac{7q_0L^3}{360}$$

equating this with zero (since the ends are fixed) we get

$$2M_a+M_b=\frac{7}{60}q_0L^2 \qquad \ldots.(i)$$

Similarly from the condition $y'_{x=L}=0$ we have

$$M_a+2M_b=\frac{2}{15}q_0L^2 \qquad \ldots.(ii)$$

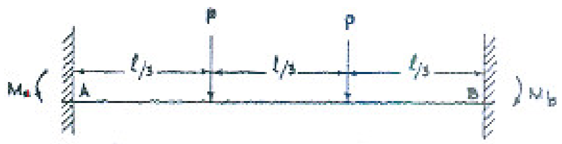
from (*i*) and (*ii*) we get $M_a=\frac{q_0L^2}{30}$ and $M_b=\frac{q_0L^2}{20}$ **

The tables A and B give approximate values of

$$\sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi c}{L} \text{ and } \sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi c}{L}\cos n\pi$$

for certain values of c/L. The use of these tables in conjunction with the equations (*c*) (*d*), (*e*) etc., enables us to find out the values of the unknown moments with utmost convenience. The examples given below would make the use of these tables quite clear.

Problem.—Find out M_a and M_b for the beam loaded as shown:



Solution.—From symmetry we see that

$M_a=M_b$

From equation (*c*) we have

*Sum of series in brackets is $\frac{7\pi^4}{720}$. Knopp, "Infinite Series" page 239.

**See also Timoshenko's Strength of Materials, Vol. I, page 188.

$$\frac{l}{6}(2M_a+M_b)=\frac{2Pl^2}{\pi^3}\left(\sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi c_1}{l}+\sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi c_2}{l}\right)$$

Since $M_a=M_b$ we have

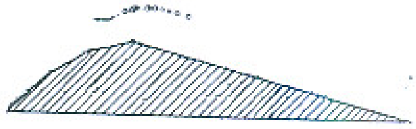
$$M_a=\frac{4Pl}{\pi^3}\left(\sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi c_1}{l}+\sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi c_2}{l}\right)$$

From table A, the sums of the two infinite series in the bracket are 0.96077 and 0.77129 respectively.

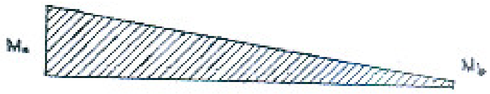
(These are the values of $\sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi c}{l}$ for $\frac{c}{l}=\frac{1}{3}$ and $\frac{2}{3}$ respectively.

Therefore $M_a=\frac{4Pl}{\pi^3}(0.96077+0.77129)=0.2222\ Pl=\frac{2}{9}\ Pl$

Example:—To find out the end moments for the beam with fixed ends and loaded as shown :



B. M DIAGRAM DUE TO LOADS



B. M DIAGRAM DUE TO END MOMENTS

Solution.—If this problem is solved by the moment area method, it would present quite many difficulties in firstly finding out the areas of the bending moment diagrams and secondly in locating the centres of gravity of these diagrams (shown in the figure) in order to find out the end reactions of the conjugate beams. The use of the equations (*e*) and (*f*) in conjunction with the tables A and B would reduce the labour very much, as would be seen below. Since the end slopes are zero:

Therefore: $$EIy'_{x=0}=-\frac{10}{6}(2M_a+M_b)+\frac{2\times100}{\pi^3}[2\times0.42725+3\times0.75106+4\times0.930176]=0$$

or $$2M_a+M_b=\frac{120\times6.82832}{\pi^3}=26.4 \qquad \dots(i)$$

Also $$EIy'_{x=L}=\frac{10}{6}(M_a+2M_b)+\frac{2\times100}{\pi^3}[2\times-0.25059+3\times-0.49494+4\times-0.71076]=0$$

or $$M_a+2M_b=\frac{120\times4.82904}{\pi^3}=18.7 \qquad \dots(ii)$$

Equations (*i*) and (*ii*) give

$M_a=11.34$ ft. lbs. and $M_b=3.72$ ft. lbs.

CONTINUOUS BEAMS

The method can be used to a great advantage in case of continuous beams whatever the type of loading may be. To explain it, we consider two adjacent spans l_n and l_{n+1} of a continuous beam carrying concentrated loads P_n and P_{n+1} at distance C_n and C_{n+1} from the left end support of each span. Considering that the spans after deflection form a continuous curve, we would realize that the slope at the right end of the nth span must be equal to the slope at the left end of the $(n+1)$th span. Therefore from equations (c) and (d) we have

$$\frac{l_n}{6}(M_{n-1}+2M_n)+\frac{2P_nl_n^2}{\pi^3}\sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi c_n}{l_n}\cos n\pi$$

$$=-\frac{l_{n+1}}{6}(2M_n+M_{n+1})+\frac{2P_{n+1}\cdot l^2_{n+1}}{\pi^3}\sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi c_{n+1}}{l_{n+1}}$$

or $$l_n\cdot M_{n-1}+2M_n(l_n+l_{n+1})+l_{n+1}\cdot M_{n+1}$$

$$=\frac{12}{\pi^3}\left[P_{n+1}\,l^2_{n+1}\sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi c_{n+1}}{l_{n+1}}-P_nl^2_n\sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi c_n}{l_n}\cos n\pi\right] \quad \ldots(m)$$

which is a three moment equation. Similar equations can be framed for the other spans as well and solved simultaneously to obtain the values of the unknown moments. The values of $\sum_{n=1}^{\infty}\frac{1}{n_3}\sin\frac{n\pi C_{n+1}}{l_{n+1}}$ and $\sum_{n=1}^{\infty}\frac{1}{n^3}\sin\frac{n\pi C_n}{l_n}\cos n\pi$ can be directly obtained from the Tables A and B.

Example.—Determine the bending moments at the supports for the continuous beam as shown.

Solution.—Here we have $M_o=M_4=0$

Equation (m) in conjunction with Tables (A) and (B) gives the following simultaneous equations.

$$4\times0+2M_1(4+6)+6M_2=\frac{12}{\pi^3}[4\times36\times0.96077-0)$$

or $$20M_1+6M_2=52.0 \quad \ldots(i)$$

$$6M_1+2M_2(6+4)+4M_3=\frac{12}{\pi^3}[8\times16\times0.96296+4\times36\times-0.77129]$$

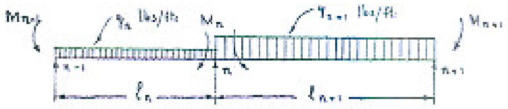
or $$6M_1+20M_2+4M_3=90.3 \quad \ldots(ii)$$

$$4M_2+2M_3\times10=\frac{12}{\pi^3}\times8\times16\times0.96296$$

or $$4M_2+20M_3=47.8 \quad \ldots(iii)$$

Equations (*i*), (*ii*) and (*iii*) give $M_1 = 1.54$ ft tons. $M_2 = 3.75$ ft tons and $M_3 = 1.64$ ft tons.

In case the adjoining spans carry uniformly distributed loads of different intensities say q_n and q_{n+1} lb/ft, then equations (*k*) and (*l*) would be used with the same condition that the slope on the left end of the $(n+1)$ span is equal to the slope on the right end of the *n*th span



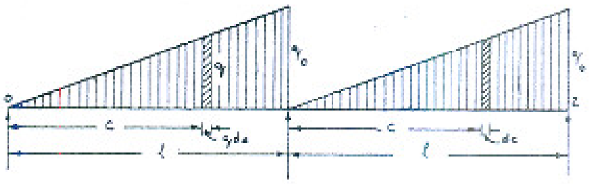
therefore

$$\frac{l_n}{6}(M_{n-1}+2M_n)-\frac{q_n \cdot l^3{}_n}{24} = -\frac{l_{n+1}}{6}(2M_n+M_{n+1})+\frac{q_{n+1} \cdot l^3{}_{n+1}}{24}$$

or

$$l_n M_{n-1}+2M_n(l_n+l_{n+1})+M_{n+1} \cdot l_{n+1} = \frac{q_n \cdot l^3{}_n}{4}+\frac{q_{n+1} \cdot l^3{}_{n+1}}{4}$$

If some spans carry distributed loads and some concentrated loads then equations (*c*), (*d*), (*k*) and (*l*) would all be used with proper care considering that under all circumstances the slope on the right end of the *n*th span must be equal to the slope on the left end of the $(n+1)$th span.



In the end we consider a continuous beam having two equal spans each of length *l* "ft.," and carrying a non-uniformly distributed load on each span. If the beam is simply supported at the ends, M_0 and M_2 would each be zero. Equation (*m*) will be used in this case with slight modifications that P_n and P_{n+1} would be replaced by the weights of small elements of length *dc* (in this case $\frac{q_0 c}{l}\,dc$ for both the spans) and integrated over the entire length of each span.

Therefore $\quad l \times 0 + 2M_1 \times 2l + l \times 0$

$$= \frac{12}{\pi^3}\left[q_0 l \sum_{n=1}^{\infty} \frac{1}{n^3} \int_0^l c \sin \frac{n\pi c}{l}\,dc - q_0 l \sum_{n=1}^{\infty} \frac{\cos n\pi}{n^3} \int_0^l c \sin \frac{n\pi c}{l}\,dc \right]$$

$$= \frac{12}{\pi^3}\left[-\frac{q_0 l^3}{\pi} \sum_{n=1}^{\infty} \frac{1}{n^4} \cos n\pi + \frac{q_0 l^3}{\pi} \sum_{n=1}^{\infty} \frac{1}{n^4} \cos^2 n\pi \right]$$

$$= -\frac{12 q_0 l^3}{\pi^4}\left[\left(-\frac{1}{1^4}+\frac{1}{2^4}-\frac{1}{3^4}+\ldots\ldots\infty\right) - \left(\frac{1}{1^4}+\frac{1}{2^4}+\frac{1}{3^4}+\ldots\ldots\infty\right)\right]$$

$$= \frac{12 q_0 l^3}{\pi^4} \times 2 \times \frac{15}{16} \times \frac{\pi^4}{90} = \frac{q_0 l^3}{4}$$

Therefore $\quad M_1 = \frac{q_0 l^2}{16}$

Table "A"

C/L	$\sum_{n=1}^{\infty} \frac{1}{n^3}\sin\frac{n\pi c}{L}$	C/L	$\sum_{n=1}^{\infty} \frac{1}{n^3}\sin\frac{n\pi c}{L}$	C/L	$\sum_{n=1}^{\infty} \frac{1}{n^3}\sin\frac{n\pi c}{L}$	C/L	$\sum_{n=1}^{\infty} \frac{1}{n^3}\sin\frac{n\pi c}{L}$
1/10	0.42725	1/9	0.46984	1/8	0.52091	1/7	0.58295
2/10	0.75106	2/9	0.80331	2/8	0.85829	2/7	0.91298
3/10	0.93016	3/9	0.96077	3/8	0.98248	3/7	0.98798
4/10	0.98790	4/9	0.98544	4/8	0.96296	4/7	0.90394
5/10	0.96296	5/9	0.92351	5/8	0.83694	5/7	0.68282
6/10	0.87068	6/9	0.77129	6/8	0.60829	6/7	0.35703
7/10	0.71076	7/9	0.54623	7/8	0.31289		
8/10	0.49494	8/9	0.27836				
9/10	0.25059						

C/L	$\sum_{n=1}^{\infty} \frac{1}{n^3}\sin\frac{n\pi c}{L}$	C/L	$\sum_{n=1}^{\infty} \frac{1}{n^3}\sin\frac{n\pi c}{L}$	C/L	$\sum_{n=1}^{\infty} \frac{1}{n^3}\sin\frac{n\pi c}{L}$	C/L	$\sum_{n=1}^{\infty} \frac{1}{n^3}\sin\frac{n\pi c}{L}$	C/L	$\sum_{n=1}^{\infty} \frac{1}{n^3}\sin\frac{n\pi c}{L}$
1/6	0.65882	1/5	0.75106	1/4	0.85829	1/3	0.96077	1/2	0.96296
2/6	0.96077	2/5	0.98790	2/4	0.96296	2/3	0.77129		
3/6	0.96296	3/5	0.87068	3/4	0.60830				
4/6	0.77129	4/5	0.49494						
5/6	0.41526								

Table "B"

C/L	$8\sum_{n=1}\frac{1}{n^3}\sin\frac{n\pi c}{L}\cos n\pi$	C/L	$8\sum_{n=1}\frac{1}{n^3}\sin\frac{n\pi c}{L}\cos n\pi$	C/L	$8\sum_{n=1}\frac{1}{n^3}\sin\frac{n\pi c}{L}\cos n\pi$	C/L	$8\sum_{n=1}\frac{1}{n^3}\sin\frac{n\pi c}{L}\cos n\pi$
1/10	—0.25059	1/9	—0.27736	1/8	—0.31289	1/7	—0.36703
2/10	—0.49494	2/9	—0.54643	2/8	—0.60829	2/7	—0.68282
3/10	—0.71076	3/9	—0.77129	3/8	—0.83694	3/7	—0.90394
4/10	—0.87068	4/9	—0.92002	4/8	—0.96296	4/7	—0.98798
5/10	—0.96296	5/9	—0.98195	5/8	—0.98248	5/7	—0.92298
6/10	—0.98790	6/9	—0.96077	6/8	—0.85829	6/7	—0.58295
7/10	—0.93016	7/9	—0.80331	7/8	—0.52091		
8/10	—0.75106	8/9	—0.46984				
9/10	—0.42725						

C/L	$8\sum_{n=1}\frac{1}{n^3}\sin\frac{n\pi c}{L}\cos n\pi$	C/L	$8\sum_{n=1}\frac{1}{n^3}\sin\frac{n\pi c}{L}\cos n\pi$	C/L	$8\sum_{n=1}\frac{1}{n^3}\sin\frac{n\pi c}{L}\cos n\pi$	C/L	$8\sum_{n=1}\frac{1}{n^3}\sin\frac{n\pi c}{L}\cos n\pi$	C/L	$8\sum_{n=1}\frac{1}{n^3}\sin\frac{n\pi c}{L}\cos n\pi$
1/6	—0.41526	1/5	—0.49494	1/4	—0.60829	1/3	—0.77129	1/2	—0.96296
2/6	—0.77129	2/5	—0.87068	2/4	—0.96296	2/3	—0.96077		
3/6	—0.96296	3/5	—0.98790	3/4	—0.85830				
4/6	—0.96077	4/5	—0.75106						
5/6	—0.65882								

Development of Water Supply Schemes
IN WEST PAKISTAN AND MODERN TRENDS IN THE DESIGN

By NAZIR AHMAD JIABAJEE*

With the passage of time, water supply schemes in the Indus Basin have slowly developed upon the use of the natural resources.

Advancement of the country socio-economically and with the development of scientific knowledge and research many new design problems have appeared.

In this article is discussed the improvement in the Water Supply Schemes based upon the demand and development of society, both for rural and urban towns.

Necessity of Drinking Water

Water is a dire necessity, life cannot be sustained without it. It is now the responsibility of the Local Bodies under the Constitution of Pakistan to arrange for good drinking water at the door of every consumer.

In West Pakistan, there are some areas where the women folk have to cover several miles to get water. They start under the glow of the stars, walk miles and return by the early dawn with water requirements of the family. Even then in some cases the quality of water brought is not wholesome and it paves the way to water-borne diseases. Such are the areas of Mianwali, Jhelum, D. I. Khan, D. G. Khan, Kharan, Mekran, Cholistan etc.

Sources of Water

A. Main sources of ground-water are percolation wells. These are:

(*a*) Water-table type wells in which the water is found at certain level, very often below the surrounding natural surface. There is no pressure other than the atmospheric upon the water.

(*b*) The artisian well in which the water rises above the level at which it is encountered in the aquifer.

(*c*) The flowing well is an artisian well in which the pressure raises the water level above the level of the natural surface.

(*d*) Spring wells which appear as a natural under-ground drainage of the high level source. Ground-waters are important sources of water supply in Indus Basin. It

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usually requires very little treatment, and is thus a principal source for human consumption. There are centuries old wells still in existence in the country.

"Bowally" system was most common in the Moghal period. These are open wells with steps leading up to the spring level for consumers to draw their supply. On the Grand Trunk Road constructed from Peshawar to Calcutta by Sher Shah Suri these existed in large number. One such well still exists about 21 miles from Rawalpindi on the Karachi Peshawar National Highway, opposite to the monument of Sir George Nicholson.

Kareezes are under-ground arteries of water flowing as a result of percolation of water in the substratum. These exist mostly in a Baluchistan Area.

Springs exist in hill areas and flow downward.

Seepage from galleries in hill areas, from Nullahs and streams also serves as a source of supply.

Surface water from rainfall or canal is sometimes impounded in reservoirs, and used for consumption.

Development during British Period

On the annexation of the Punjab by the Britishers in 1857, piped water supplies were arranged for the cantonments in the Punjab, N.-W.F.P. and Baluchistan etc. Later on these facilities were extended to citizens.

Water supply schemes for Murree, Tret Camp, Lahore and Rawalpindi were executed by M. E. S. during 1861-1881.

Lahore Water Supply was got executed by the Muncipality through a private British firm.

The sources of water depended upon on springs, wells and galleries and the water was lifted by various contrivances and delivered to over-head tanks for distribution.

Murree Water Supply

Murree Water Supply was derived from 17 small springs near Doonga Gali at an altitude of 9000 feet, about 20 miles from Murree. The scheme was prepared, designed and built by Captain Moore, C. R. E. and completed in the latter part of the nineteenth century.

Spring water is collected in an intercepting chamber from where it flows to Murree at an altitude of 7000 ft. into three Tonley Tanks (1889), Punch Pando (1925) and Storage Tank (1944).

In 1934, star-shaped steel plated tanks 4×4 ft. were constructed to store 32,00,000 gallons of water at head-works in Doonga Gali. In 1944 a third storage masonry tank was designed and constructed by the author to store 20,00,000 gallons.

Tret Camp Water Supply

About 23 miles from Rawalpindi on road to Srinagar a military camp was established in 1896 for watering of mules and horses. Water was brought from the Sambli springs. By the time of World War (1944-45), the water supply pipe line got fully encrustrated and it was replaced by the author. Two underground masonry tanks were added for water storage.

Lahore Water Supply

Lahore Water Supply was built in 1887 by constructing galleries in the old bed of River near Badami Bagh. Water was pumped into Lange-Mandi Reservoir and distributed to city area for fire fighting, drain flushing and for drinking purposes.

Rawalpindi Water Supply

For a small population of 10,000 souls, Water Supply was arranged from vertical galleries sunk in the bed of Kurang river about 6 miles from Rawalpindi. It was brought to Bani Mai Vero 'Tank' in the city area, through Masonry Duct.

In 1925, Hailey Water Works was constructed. The supply was supplemented with two big diameter wells in the Water Works compound, having some artisian condition. A steel reservoir was constructed to store 250,000 gallons. Later on insanitary way of drawing stored water from tank was eliminated by a new scheme.

Tubewell Era

The year 1910 opened the tubewell era.

First tubewell was tried in Lahore in 1910. It was a great success. Tubewells are a marvellous improvement in water sources and met with great success in alluvial plains, due to the strata being re-charged from rivers, canals, rains and floods and perennial natural underground drainage lines. Exception was the salt range extending to Sargodha, Jhelum and Mianwali Districts where the ground water is brackish.

By the time we entered the tubewell stage economic conditions of people rose, and the allowance of water per capita had to be increased from 5 to 10 gallons.

urface Water Source

Where ground water source failed, recourse was had to canal water. It was used after sedimentation in storage tanks and filtering by passing water through slow sand filters. The water from the storage tanks is pumped into high evel tanks of two thirds daily capacity and then passed into filter-beds with filtration rate of 30-35 gallons per s. ft. of filter surface per day. The filtered water is collected into clear water reservoir and delivered into the distribution system.

Post-World War I Water Supply Schemes

Post-War Water Supply Schemes completed are as under:—

(*a*) *Open wells:* Campbellpur and Shahpur.

(*b*) *Galleries:* Rawalpindi, Sailkot, Khushab Taman, Thaiti Nasrati, Dagh Ismail Khel, Koi Nara, Hindu-Bagh, Loralai and Harnai.

(*c*) *Springs:* Thal Ilaqa, Daiwal, Kuror and Tailokar, Buni-khel Sanwans, Jabi, Dhokri, Choa Saidan Shah, Choa Katas, Vehoa, Choa Warcha, Choa Pani, Fort Sandeman, Barkhan, Ziarat, Pashin, Chaman and Kalat.

(*d*) *Canal Source:* Lyallpur, Jaranwala, Tandlianwala, Sargodha, Toba-Tek-Singh, Gojra and Sangla Hill.

(*e*) *Seepage Wells:* D. G. Khan, P.D. Khan, Bannu and Qilah Saif Ullah.

(*f*) *Tubewells:* Multan, Musa Khel, Khanewal and Bhalwal.

(*g*) *Dams or impounded reservoirs:* Quetta, Warcha.

Developments of Water Supplies after 1935

In 1937 the rate of Lahore Water Supply was raised to 30 gallons per head. In fact introduction of Sewerage Scheme fixed the rate of consumption at 30 gallons for cities and 10 gallons in colony towns and rural areas. This phase improved the Water Supply Schemes of Rawalpindi, Sargodha, Lyallpur and Hyderabad.

Major developments took place in 1935-1940 due to the extensions of canal system in Nili Bar and Ganji Bar, and other colony towns. Water supplies were arranged for new towns at Montgomery, Okara, Burewala, Arifwala, Mian Channu, Kamalia, Pirmahal and Mandi Bahaud-din.

Activities during the Second World War 1939-1945

During the early days of war for fire fighting activities, the capacity of distribution pipe-line was increased along with the number of fire hydrants and static water tanks.

Priority of construction was Rawalpindi, Lahore, Multan, Campbellpur, Jhelum, Gujrat, Lalamusa, Wazirabad, Murree, Mianwali, Muzaffargarh, Dera Ghazi Khan, Sargodha, Lyallpur etc.

Landing grounds which were equipped with potable water supply schemes included:

Wah, Dab, Murid, Akwal, Kamra, Basal, Fateh Jang and Gujrat.

At the tail end of the War in 1944-1945 leave camps were made for recessing soldiers for 25 days in the Murree Hills and Gullies. Thus extensions to distribution was done at Khanspur, Ghora Dakha, Barian Topa (Upper and Lower) Gharial, Murree Headquarters, Sunny Bank etc.

Independence of Sub-Continent in 1947

Partition of the sub-continent in 1947 brought in large influx of refugees from India. Pakistan Government had to establish Satellite Towns or camps on the outskirts of the cities and the large towns. These were developed on modern lines of water supply and drainage system. Supply of water was fixed at 5 gallons per head per day in the camp and 30 gallons in Satellite Town with adequate number of fire hydrants.

Proper sewerage was provided for the disposal of sullage water from these areas.

Hand pumps were provided along the routes of the caravan that entered into Pakistan from Indian territory.

The Camps were established at Harbanspura, Walton Camps, Chinese Barracks, Kasur, Shahdara etc. Enough water supply was arranged at five gallons per refugee per day and bore-hole latrines were installed.

Post-Independence Period

The work of water supply of urban and rural areas remained suspended from 1947-57. In 1957 a new organization called the Social Welfare Works Department was entrusted with the development of Water Supply and Drainage of the urban and rural areas on modern lines. This Department was reorganised in 1961 as Public Health Engineering Department. This organization decided to raise the per capita consumption and terminal pressures. The following policy was adopted :—

	gallons per capita
(*i*) Population 5000-10000 with no drainage ..	10
(*ii*) Population with 5000-10000 with existence of drainage ..	15
(*iii*) Population 10000-25000 ..	20
(*iv*) Population 25000-100000 ..	30
(*v*) Population over one lac. 30 to 40 gallons per head per day.	

Terminal pressure was fixed at 30 ft. at the farthest ends in rural areas and 40 ft. in urban areas.

In case of canal water source such as Lyallpur rapid gravity filters were introduced and a scheme was prepared for 1.5 lac gallon over-head storage tank.

In the cities and towns where the ground water is brackish shallow seepage tubewells are also installed on the bank of canals and in the compound of water-works to tap the seepage from the canal and the sedimentation tanks.

Seepage tubewells cannot be regarded a reliable source, as and when the discharge from these type of tubewells exceeds the rate of seepage from the canal especially during the closure period. In case of shallow tubewells, 80 feet in depth is considered where it is possible to locate the strainer. In seepage tubewells this principle is ignored and the location of strainer is made from the depth from where the water is struck. About half a cusecs of discharge is yielded by 50 ft. long 10" diameter strainer located within 100 ft. depth from surface.

The first trend in all areas is that without giving any consideration to topography, hydrostatic conditions to tap natural resources we should adopt the cheapest source of water by tubewells.

Free water wells are not at all a reliable source, as in such cases the seepage is very limited and spring levels encountered are deep.

In certain sites situated at the foot of the hills such as Tajozai, Distt. D. I. Khan; Chindhru, Distt. Mianwali; Chitta-Watta, Distt. Mianwali; Sethi, Distt. Jhelum, surface water percolates from fissures into the lower stratum, causing deep underground. Here open wells of big diameters due to more surface area yield more water although their depth of strata penetrated is small. Galleries sunk in the water-bearing strata can also yield water but these are difficult to construct.

In cases where natural drainage lines are near the surface, well galleries are designed to tap the underground flow across the Nullahs and get it percolated into a sump situated on one side of the Nullah at a suitable place, protected from floods. Depth of galleries is kept according to the depth of underground flow during driest season and the depth of the existence of impervious strata contracted to take maximum advantage of the condition at site. These work quite satisfactorily in upper reaches of hill streams, while in lower reaches these get choked in no time due to high turbidity of water passing over these, depositing clay in thick layers over the loose infiltering media, thus reducing the percolation rate. Gallery source involves sufficient lengths of carriage mains to gravitate water to the town and villages. In some cases water is to be lifted in a high level tank to let it gravitate to the sites where it is to be distributed.

Similarly if the source is a spring we have to provide gravity mains of considerable lengths, 10-15 miles in some cases increasing even to 30-40 miles. This increases the cost of the scheme and its maintenance. Such cases exist in Dera Ghazi Khan District.

Modern Trends

In West Pakistan we have not so far achieved the international standard of purity. This needs resources. The improvements needed are:

1. Water purification and treatment on modern de-Aerators, for water treatment by adding or removing air or gases.
2. Chemical feeders for removing harmful chemicals.
3. Pressure filters to increase the capacity of filtering media.

4. Gravity filters to affect economy in:

(*i*) The precipitators for sedimentation of suspended materials.

(*ii*) Separators for removal of precipitates and coagulents.

(*iii*) Cont ol cubicals for feeding of chemicals.

(*iv*) Demineralization for rendering brackish water fit for human consumption.

Use of R.C.C. Pipe Against C.I. Pipe

Cast iron pipes need foreign exchange. We can use R.C.C. pipes by giving more break pressure tanks in the feeder line to keep the pressure within range of these pipes. Collar joints in R.C.C. pipes can take 10-15 lbs pressure per square inch and the number of B.P. tanks is excessive. This increases the initial cost of the scheme as compared with the C.I. pipes in which this life factor is totally ignored. Greater loss of heads is due to roughness in R.C.C. pipes and the flatter gradients as these have to be laid according to the range of pressure these can bear. At inlets and outlets in case of hard water there is excessive incrustation. As saving of foreign currency is the main object, the efficiency of C.I. pipes over R.C.C. pipe is thus ignored.

Water Supply in Hill Areas

To use metallic pipes with high heads is costly. Our resources offer R.C.C. pipes. Even prestressed pipes have not met with success. It is uncommon to use local cement asbes'os pipes. At present we are getting foreign-made pipes of this kind till such time that we arrange our own industry for their manufacture. Some Belgian-made Asbestos cement pipes are in use. Similarly P.V.C. pipes have been arranged by UNICEF but the solution to our demand is to have our own industry to build this material locally.

The joints with lead should be replaced by rubber flexible joints or expandite Cement Asbestos chaulked joints and in case of steel pipes welded joints will be a solution to cost problem.

Scientific Coordination

Modern trend in water supply engineering is based upon scientific investigations and the data collected by sister organizations on water development, such as WAPDA and WASID. Irrigation Research Institute Lahore, Agriculture University (Lyallpur) can be utilized. Research carried out by WHO and other countries can be carefully studied, to adapt them to our own conditions.

(*a*) *Points for consideration in planned water-supply schemes:* The present rate of growth of population in West Pakistan is 25 per cent per ten years. But in towns being rapidly industrialized the growth of popula'ion is 40 per cent per ten years. In agricultural rehabilitation, industrialization and urbanization in the barrage areas in Sind, the increase in population is reckoned as 50% in 10 years.

(*b*) *Quantity of water per capita:* Rate of water on per capita bases has to be increased in next 20 years. The following will be the expected rate per capita:

(*i*) Hospitals, 200 gallons per indoor patient per day. For outdoor, 5 gallons per patient per day. Mandi towns 30 gallons per day.

Cities of population abovs 400,000, abou 60 gallons.

Rural areas of water supply, 5-10 gallons per day.

(*ii*) Other anticipated facilities needing more water of which have to be kept in view are:

(*i*) Electric washing machines, plate washers etc.

(*ii*) Extra industrial water.

(*iii*) Water required for atomic reactors.

(*iv*) Health education in rural areas for necessary demand of water for proper health facilities.

(*v*) Fire-fighting requirement in timber markets, hay stacks, rubber goods, tyers or inflammable material etc.

(*c*) *Useful measures to be adopted in the future:*

(*i*) International quality standard for water to be maintained in towns and cities and hill resorts.

(*ii*) Preserve ground storage by construction of dams and avoid run-off to sea.

(*iii*) Provide afforestation to avoid denudation and conserve soil for absorption of water.

(*iv*) Metering to stop waste of water.

(*v*) Advance exploitation of resources for planning periods and their conservation.

(*d*) *Utility of New Research Methods:*

(*i*) Utility of Solar energy for de-salinization of water where brackish or sea water is the only source. This may consist even of domestic solar stills.

(*ii*) Possibilities of using high dry blast compressed air for boring in water-less areas.

(*iii*) Utility of electric resistivity in postulating proposals.

(*e*) *Industries related to drinking water development:* Anticipated demand based on census of water supply pipes, fitting and machinery for heavy industry of the next two decades.

(*f*) *Economic Trends:* Foreign consultants to be discouraged in routine water supply problems.

Further Development

As a developing nation we have to keep in touch with the most modern researches and experiences of other countries and develop fast within our resources and whatever foreign component which the Government provides for arranging materials from foreign manufacturers.

Help of foreign benevolent agencies has been carrying us forward but the materials so arranged are more costly than that which could be manufactured in West Pakistan. However, this requires heavy machinery and plenty of capital investment and as such foresight has to be used in economic design of Water Supply Schemes.

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Upper Rechna Doab Reclamation & Salinity Control Project

—W. P. WAPDA

Tipton & Kalmbach Consultants to West Pakistan WAPDA have issued their fourth Project Report dealing with the salinity control and reclamation of the Upper Indus Plains. The project is for 2.05 Million Acres of the northern part of the Rechna Doab comprising of a part of Sialkot, Gujranwala and Sheikhupura Districts. The proposals are to install 3273 tubewells pumping 13103 cusecs of water. The capital cost of the project is estimated at Rs. 454 million which will include Rs. 224 million of foreign exchange. The annual maintenance cost after the completion of the project will be Rs. 36 million. Brief details of the Hydrology, Soil and Irrigation of the region is given in this note which is extracted from the project report in question.

Introduction

Salinity control and reclamation project No. 4 is another of a series of projects in the Northern Zone designed to reclaim deteriorated lands, control subsurface drainage, and provide full supplemental irrigation water requirements by exploitation and management of ground water supplies. Project No. 1, serving over one million acres in Central Rechna Doab, was completed in 1962. Project No. 2 which will serve over two million acres in Chaj Doab, is now under construction while two sub-projects encompassing about three hundred thousand acres are already in operation. Project No. 3 comprising over two million acres in Lower Thal Doab is scheduled to go into construction in 1965.

The area of W. Pakistan is about 310,000 square miles. About half of the province is mountainous terrain—the Himalayan Mountains in the north and the various ranges and hills along the western border which extends from the Hindu Kush to the Mekran Range on the Arabian Sea. The other half of the province is the alluvial plain of the Indus River and its tributaries. According to the 1961 census, the population of west Pakistan is about 43 million of which 75 per cent live in the plains. The population is increasing at the rate of 2.5 to 3 per cent per year, sufficient to double the population every 25 to 30 years.

The Indus Plains are essentially flat and featureless with a slight slope averaging about one foot per mile toward the Arabian

Sea. Natural internal drainage is poorly developed and no perennial streams rise in the plains. Intermittent drainage channels, callled "nallahs", carry storm runoff to the rivers during the summer monsoon, but they are dry throughout most of the remainder of the year.

Precipitation over the Indus Plains generally is less than 20 in. annually except along the edge of the Himalayan foothills where it ranges from 20 to 35 inches. In the central portion of the plains the annual precipitation is less than 10 inches and in many areas it is less than five inches. Essentially all of the runoff of the Indus watershed is derived from snowmelt and precipitation in the Himalayas.

The oldest method of irrigation in the Indus Plains is flood irrigation, locally known as "sailab" which is restricted to the active flood plains. After the flood-waters recede, the wetted areas are planted in grains, principally wheat. This is the most primitive form of irrigation in the Indus Basin, dating back thousands of years, but it still makes an important contribution to the agricultural economy. The soil remains salt-free and relatively fertile because of the periodic flooding of these riverain areas.

Canal irrigation began centuries ago with the development of inundation canals which draw water from rivers during periods of high stage for distribution to upland areas bordering the flood plains.

By 1962 all of the major canal systems had been converted to weir control. Average annual diversions from the Indus River system through the existing complex of canals are about 80 maf, which are used to irrigate about 24 million acres. The Northern Zone accounts for 48 maf. of the diversions to irrigate 16 million acres, the largest essentially contiguous area of irrigation devopment in the world.

Culturable Area of the Scheme

The area in this project also includes the foothill lands of Sialkot District. It includes the most famous rice producing areas of Gujranwala and Sheikhupura Districts.

The total area included in the project is 2.05 m. ac. of which the culturable land is 1.80 m. ac. The area under commands of canals (U.C.C., M.R. Link & L.C.C.) is 1.65. m. ac and the area presently under perennial supplies is 33% of the total and is equal to 0.6 m. ac. The area irrigated by Persian-wheel is 0.4 m. ac. and that under irrigation by private tubewells (numbering till Jan., 1965 about 6500) is 0.39 m. ac. Some areas have recently been brought under tubewell irrigation and these amounts to 0.034 m. ac. Dry farming (Barani) is also practised on an area of 0.28 m. ac.

During Kharif about 0.7 m. ac. are harvested and in Rabi about 0.9 m. ac. are used giving a cropping intensity of 92%.

Irrigated Areas under Command of Various Canals

The Upper Chenab Canal which flows through the area commands culturable area equal to 1.45 m. ac. Part of this area included in the project is 1.37 m. ac.

Area commanded by U.C.C. under perennial irrigation is equal to 0.535 m. ac. and under non-perennial irrigation is 0.832 m. ac. The rest of the area of this scheme under the command of L.C.C. and M.R. Link is non-perennial. The L.C.C. system irrigates 0.116 m. ac. M.R. Link irrigation is limited to 0.105 m. ac. The total non-perennial area under irrigation is 1.053

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Fig. 1 (a)

m. ac. The total area under perennial canal supplies is 0.600 m. ac.

Irrigation Water Supplies from Canals

The Upper Chenab Canal has its authorised full supply (AFS) for Rechna Doab equal to 5340 cusecs in Kharif and 1840 cusecs in Rabi. It, however, delivers 5100 cusecs in Kharif and 1600 cusecs in Rabi to the project areas.

Its break-up is

(i) AFS of Nokhar Branch equal to ..	717	cusecs.
(ii) AFS of B.R.B.D. Link equal to ..	1940	cusecs.
Water delivered by U.C.C. Main Line Lower is ..	2683	cusecs.
Total discharge delivered during Kharif by U.C.C. is thus ..	5340	cusecs.
Water delivered to the project area during Kharif from L.C.C. Canal system is ..	723	cusecs.
An area of 0.105 m. ac. will receive Kharif supplies from M.R. Link, it may deliver approximately ..	650	cusecs.
Thus total AFS discharge during Kharif from all the canals flowing in the area is ..	6700	cusecs.
Rabi supplies as delivered by U.C.C. equals ..	1600	cusecs.
Use of supply factor equal to 0.79 reduces the Kharif supply of ..	5500	cusecs.
	(2020, 000	A. Ft.)
Using a factor of 0.6 for Rabi, reduces the discharge to ..	960	cusecs.
	(345, 000	A. Ft.)

The Land and the Soils

The project covers the fertile lands of Sialkot. It spreads to Gujranwala and Sheikhupura Districts.

The land can broadly be classified into three main groups of soil series. Fine textured belonging to Nokhar, Chuharkana and partly to Buchiana series. This type constitutes 52% of the total area being 1.066 m. ac. Medium textured soil of Buchiana series constitutes another 23% or 0.697 m. ac. Only 14% of the land i.e. 0.287 m. ac. is coarse textured belonging to Jhang and Farida series.

The approximate gross acreage of the three land use groups in the project area is given below :—

Land Use Group	Soil Series Groups	*Distribution* Acres	%
Fine textured Soils.	Nokhar, Chuharkana & fine surface textured Buchiana.	1,066,000	52
Medium textured soils.	Buchiana.	697,000	34
Coarse textured soil.	Jhang & Farida.	287,000	14

Fine textured soil is ideal for production of fine variety of rice crops. Out of 0.722 m. ac. cultivated during Kharif, rice is sown on 0.483 m. ac. or nearly 27 per cent of the area. The rest of Kharif crops constitute 13 per cent making up presently 40 per cent crop intensity during Kharif.

The land is good for crop, so that during winter it occupies 34.4 per cent of the area equal to 0.617 m. ac., the other crops constitute the rest of 17.3 per cent to make winter crop intensity of 51.7 per cent. The total annual crop intensity being 92 per cent.

Soil Salinity

The project area has not generally a serious problem of surface salts. About 60 per cent (1.290 m. ac.) of the land possesses

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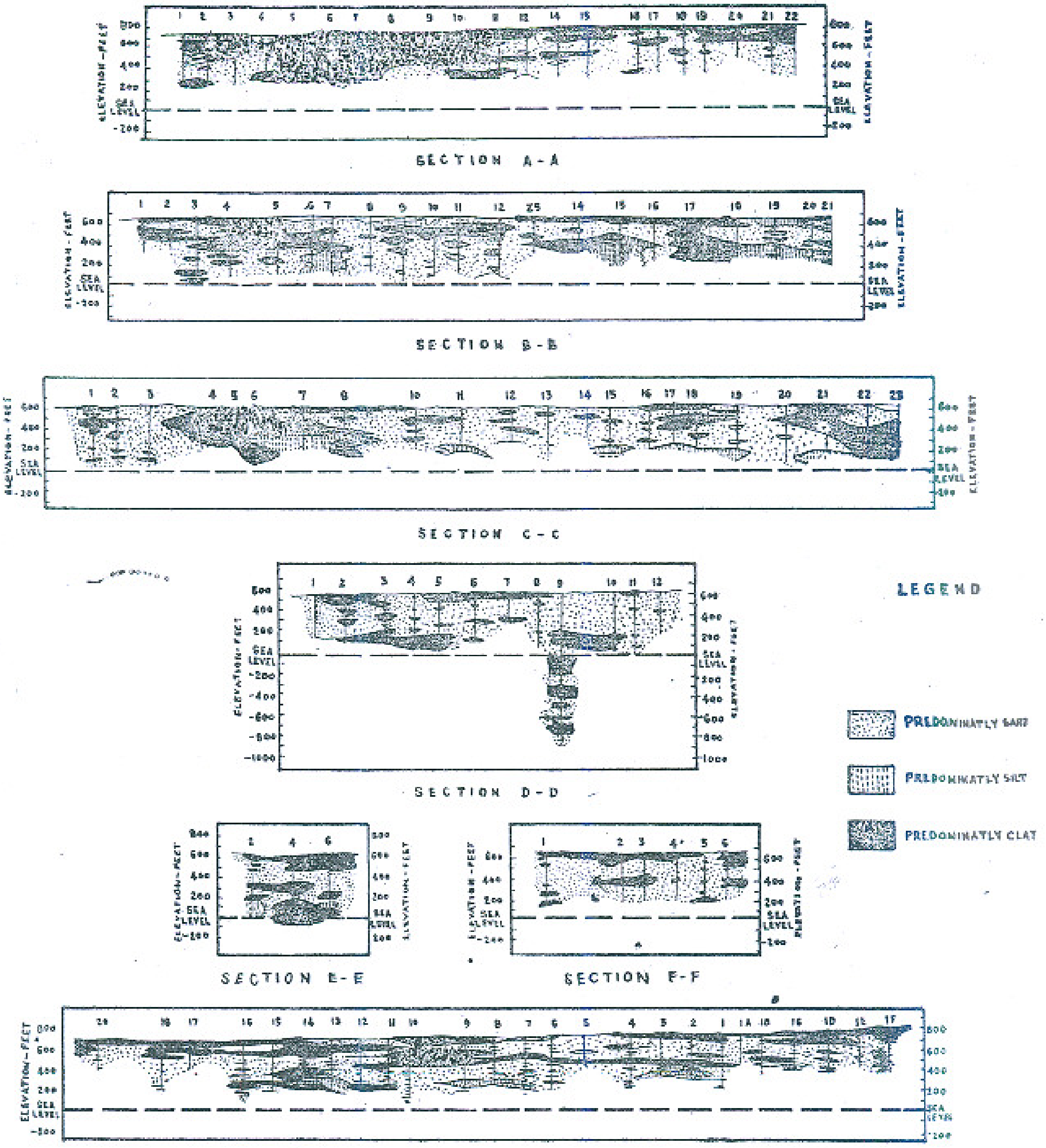

Fig. 1 (*b*) Geological Sections in Upper Rechna Doab normal percentage of salts less than 0.2 per cent.

Lands with salts between 0.2 to 0.5 per cent and more than 0.5 per cent constitute 22 per cent (0.485 m.ac.) and 17 per cent (0.375 m.ac.) respectively. These high salt soils are found in Mongtanwala, Sheikhupura, close to Muridke and Eminabad and on some land on the down stream portion of Bombanwala Ravi Link Canal.

The classification of soil into normal, saline, non-saline alkaline, saline alkaline are as under:—

		percent of total
Normal	..	43
Saline	..	1.0
Non-saline alkaline	..	31.0
Saline alkaline	..	25.0

It may be noted that in this region alkaline soils are spread on nearly 56 per cent of the area and yet produce excellent crops.

According to the analysis of the project report, only 10 per cent of the land will need chemical amendment for reclamation, 40 per cent will need simple leaching and the rest 50 per cent does not need reclamation at all.

Ground Water and the Alluvial Formation

The average slope of the land is 2 ft. per mile. Just upstream of M.R. Link, the slope is still steeper and this area is interspersed with hill streams like Deg, Aik, Bheed, etc.

In foothill areas pediment soil predominated and some time it exists to a considerable depth. In the project area very thick clay zones, in some cases more than 200 ft. thick, exist close to Pasrur and Narowal Tehsil and the area adjoining these and served by Raya Branch now B. R. B. D. Link Canal (See Fig. 1 (*a*, *b*). The rest of the formation, however, contains predominantly sand of coarse grade upstream of M. R. Link and coarse, medium to fine in the main project area. This area has more saline ground water as shown in Fig. 2.

The storage coefficient as determined by WASID is fairly low, average being 10-13% only. At places it is as low as 2 to 7 per cent. It may be due to the presence of thick clay or silty formations.

The permeability coefficient is, however, fairly high varying from 0.001 to 0.005 ft. per second. Detail is given in Table below :—

Lateral Permeabilities and Specific Yields

Test No.	Lateral Permeability (cusecs per sq. ft.)	Specific Yield
R-1	.0020	..
R-6	.0031	.01
R-16	.0048	.12
R-17	.0044	.11
R-18	.0011	.14
R-19	.0038	.09
R-20	.0040	.15
R-29	.0038	.09
R-43	.0052	10
R-44	.0020	.02
R-46	.0028*	.02
R-47	.0032	.07
R-48	.0026	.03
R-49	.0019	.03
R-50	.0041	.13
R-51	.0018	.10
R-58	.0027**	.12
R-59	.0012	.11

*Vertical permeability =0.00005
**Vertical permeability =0.00003

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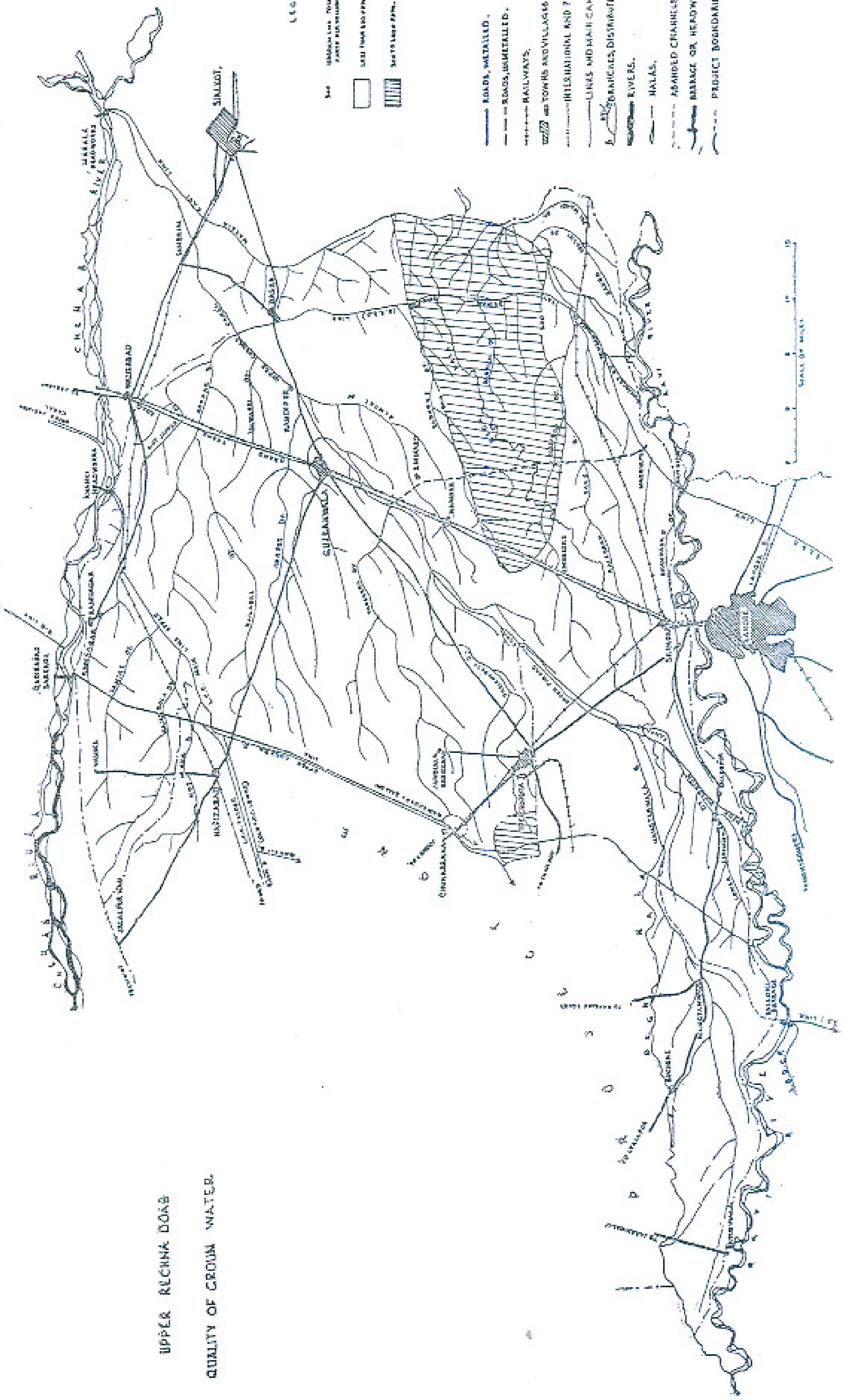


UPPER RECHNA DOAB
QUALITY OF GROUND WATER.

FIG: 2.

The ground water quality is excellent with salts generally less than 500 ppm. up to a depth of more than 500 ft. Only that area which has no aquifer and possesses predominantly thick clay formation as mentioned above, has saline water with salts varying from 500 to 2,000 ppm. (Pasrur and Narowal Region). Fig. 2 in the text.

Position of Ground Water Level

The ground water in a large tract of the project area in the districts of Sialkot and Gujranwala has always remained within reach of its exploitation by open wells. Before the imposition of irrigation system the ground water from the Ravi up to Shahdara and the present M. R. Link extending to Eminabad up to the Pasrur Tehsil existed at a depth less than 20 ft. The same was the case in the area adjoining the Chenab. The depth of ground water in Gujranwala Distt. was up to 40 ft. and close to Sheikhupura it was still deeper (See Fig. 3).

Imposition of the canal system caused a general rise of ground water at the usual rate of a foot per year. The ground water along U.C.C. and close to it, however, rose much quicker, average 2.0 to 2.5 ft. per year.

The present position (before scarp No. 1) is, that in Sheikhupura District, the ground water is within 5 ft. and in a big area of Gujranwala, it is within 10 ft. The water table in the area of Sialkot District, around Pasrur, Daska and Muridke up to Shahdara lies within 10 to 20 ft. (See Fig. 4).

The ground water in this area now lies within exploitable depth by centrifugal pumps.

Surface Water Resources

The district of Sialkot receives annual precipitation of 30 inches per year of which 80 per cent occurs during the monsoon summer months. The rainfall intensity decreases towards Gujranwala and Sheikhupura.

The upper areas of the project near Pasrur in the South and Daska in the North, the Deg, Aik, Bheed, etc., bring heavy floods and often overflow in the areas around these. The water of these Nullahs is used to a large extent for irrigation of the lands.

RECLAMATION POLICIES AND PROJECT DESIGN CRITERIA

The Project Proposals

After considering all aspects of the area, the proposals for control of salinity and reclamation, as put forth by WAPDA, are to install in the whole area tubewells of varying capacities.

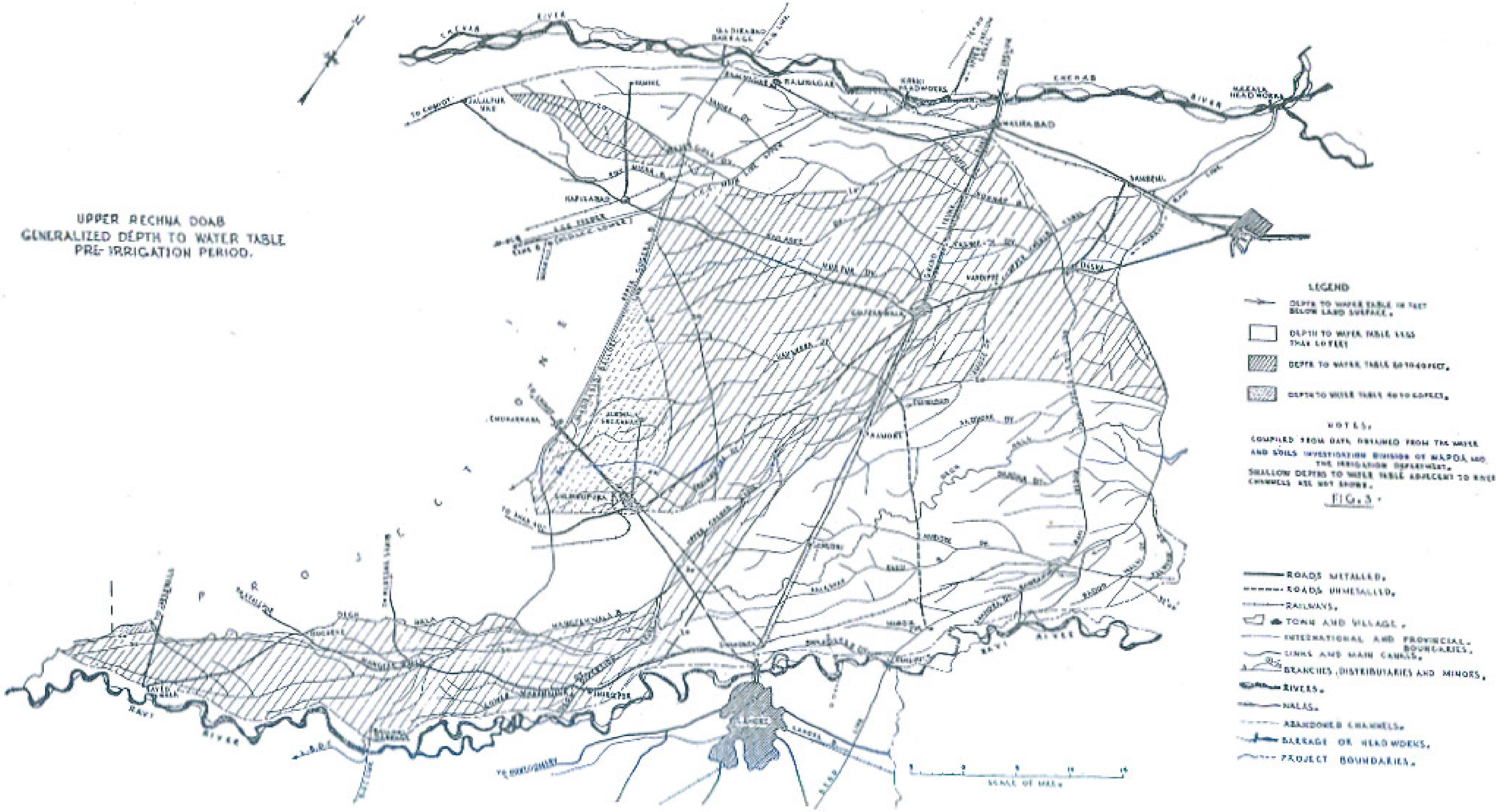
The area is divided into six commands. For each command, the gross area, the culturable area, the irrigation requirements, the surface water supplies available, from canals and the requirements from ground water, is worked out and on this basis the number of tubewells of varying capacity have been determined.

In Table No. 1, the information for all the six commands is given.

The total requirements for commanded and uncommanded area are shown separately in Table No. 2. The total number of tubewells proposed to be installed, as per table 2, is 3273 of which 2 cusecs capacity tubewells are only 312, 3 cusecs capacity are 670, four capacity wells are 986 and 5 cusecs capacity tubewells are 1305.

The ground water utilization from tubewells has been kept at about 43% of the

UPPER RECHNA DOAB
GENERALIZED DEPTH TO WATER TABLE
PRE-IRRIGATION PERIOD.



TABLE

Data of Tube well proposed to

All values in A. ft. and

Command		Cross area	Cultur-able area	Ann. Irr. require-ment	Ann. canal delivery	Ann. T/W delivery	Designed T/W duty
Marala Ravi Link	..	176820	161620	496600	177500	319100	132
BRBD Link	..	450050	727440	1345460	425050	920410	151
Nokhar Br. U.C.C.	..	216100	200740	618090	175890	442200	144
U.C.C. main line	..	619640	583480	1796140	489700	1306440	157
Mangtanwala U.C.C.	..	164170	154730	554540	118450	436090	124
U.C.C. main line upper	..	147700	129198	372210	155320	216890	159
Total	..	1774480	1657208	5183040	1541910	3641130	867

TABLE

Summary of the Project Scarp No. 4

Command		Cross area	Cultur-able area	Ann. Irr. require-ment	Ann. canal delivery	Ann. T/W delivery	Designed T/W duty
Commanded area	..	1776450	1657180	5183040	1541910	364130	148
Uncommanded area	..	273550	142820	464970	—	464970	77
Total	..	205000	1800000	5648010	1541910	4106100	138

TABLE
posed to
ft. and

Designed T/W duty
132
151
144
157
124
159
867

TABLE
p No. 4

Designed T/W duty
148
77
138

1

be installed in Scarp No. 4

at water courses

No. of tubewell cusecs capacity				Total	Installed cap. 1 cusec	A. ft.	Ann. % utiliza-tion
2	3	4	5				
56	122	156	26	360	1232	892170	36
57	126	200	306	689	2822	2043580	45
20	58	103	153	334	1391	1007300	44
121	248	147	354	970	3744	2711270	48
12	53	112	123	300	1246	902290	48
31	148	47	84	210	814	589470	37
297	655	865	1046	2863	11249	8146080	

2

Tubewells to be installed in the area

No. of tubewell cusecs capacity				Total	Installed cap. 1 cusec	A. ft.	Ann. % of utiliza-tion
2	3	4	5				
297	655	865	1046	2863	11249	8146080	45
15	15	121	239	410	1854	1342590	35
312	670	986	1305	3273	13103	9888470	43

actual pumpage capacity. The full capacity of pumps is 13,103 cusecs *i.e.* 9.49 maf. and actual utilization is 4.106 maf. excluding the canal supplies of 1.54 maf.

Design of Tubewells

Tubewells will be installed with reverse rotary system, drilled to a depth of 200 to 400 ft. with bore diameter varying from 22 to 24 inches.

The pump house, casing, will be 14 to 16 inches in diameter, with $\frac{3}{4}$ inch wall thickness and 60 to 100 ft. deep. The bowels of the turbine pump will be located at a suitable depth in the housing pipe.

The screen will consist of epoxy bonded fibre glass, 9 inches and 10 inches in diameter. The length of screen will range from 120 to 200 ft. depending upon the capacity. The screen will be slotted. The number of slots per foot will be 180 and their dimensions will be 3/32 inches × $1\frac{3}{4}$ inches. There will be 4 rows of 45 slots each grouped in three, equally spaced. The outer diameter of the screen will be $10\frac{3}{4}$ inches and the open area will be 7.8%.

Similarly for $8\frac{3}{4}$ inches outer diameter screen, the number of slots will be 144 each $3/32 \times 1\frac{3}{4}$ inches, in 4 rows of 36 slots grouped in threes. This will give an open area of about 7.6%. The top of the pump bowel will be set at 10 ft. below the anticipated future or ultimate pumping level.

The blank casing will be of the same material. The coupling will also be of fibre-glass with threads on the screen or the casing pipe. As for other details about the designed head, H. P. of motor, average depth of bore, etc., the detail is given in Table 3.

The screen will be shrouded to prevent the fine sand to move in. The shrouding material will be well rounded siliceous particles.

It is estimated that irrigation tubewell will have a life of about 40 years and the pump, motors and motor controls will be replaced once during that period.

Tubewell will be located at the head of the water course so that tubewell water will be mixed with canal supplies wherever it will have doubtful quality. The approximate spacing of tubewell will be 3000 ft. and in some cases even closer.

Cost of Tubewell

In this report unit cost of tubewell components is not given but total cost of various items is put forth. The total cost of the project is Rs. 27.97 crores of which the dollars component will be $27.7 m, and Rupees component equal to 147.84 m. thus nearly 50 percent cost will be in dollars. Amortization of the Project in 35 years and at $4\frac{3}{4}$ per cent interest is worked out equal to Rs. 19.965 mill. The period of construction of the project is four years during which interest will be paid continuously. The total expenditure works out equal to Rs. 276 m.

During the next five years the project will continue to be developed and during the period the interest will amount to Rs. 59.47m.

It is supposed that amortization will start from the 11th years and will be completed in the next 35 years. For this period every year payment of principal and interest will be Rs. 20.0 m., which will include Rs. 7.7m., of foreign exchange.

Cost of Electricity

The operation of 3273 tubewells will need 164.000 H.P of electricity. Large number of tubewells are already in existence and siliceous

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village electrification will also be kept in view during the scheme. The detailed estimate of power needed is given in the project report. Tubewell will need 169.56 MVA and considering 69.80 MVA as load of existing tubewells and 33.95 MVA for village electrification, the estimate of requirement of power is put at 290.22 MVA, the cost of which works out at Rs. 175.6m. which includes dollars worth 19.87 m. and local currency equal to Rs. 81.04 m.

The Foreign Exchange Component is again about 50%. Amortization of loan in 40 years at $4\frac{3}{4}$ interest is considered and it will result in annual payment of Rs. 9.89 m. to be met from the sale of electricity.

Total Cost of the Project

The total cost of the project is estimated at Rs. 454.0 m. of which 49% will be in Foreign Exchange.

Maintenance Cost of the Project

After the full development of the project it is estimated that the operation, maintenance and amortization will amount to Rs. 65.0 m. per year.

Cost Benefit Ratio

It is estimated that the present harvested acres equal to 221 will increase to 472 and their return will increase from Rs. 353.0 m. to Rs. 1,195.1 m. It is thus estimated that the benefit/cost ratio will be 5.2, 1.

TABLE 3

Variable Characteristics and Dimensions of Wapda Proposed Tubewells

Tubewell capacity cusecs	2.0		3.0		4.0		5.0	
Pump-Head-ft. ..	50	65	55	70	60	75	70	85
Column pipe dia. in. ..	8	8	8	8	10	10	10	10
Column pipe length-ft. ..	50	65	55	70	60	75	70	85
Bowel dia. in. ..	12	12	12	12	15	15	15	15
Motor horse-power ..	20	20	30	40	40	50	60	75
Approximate length of casing, ft. ..	—	—	—	—	—	—	—	—
Pump housing casing, 16" ..	—	—	—	80	100	90	—	110
Pump housing casing, 14" ..	70	90	80	90	—	—	—	—
Slotted tubewell casing, 10" ..	—	—	60	60	100	100	140	140
Blank tubewell casing, $10\frac{3}{4}$ ..	—	—	11	11	18	18	25	25
Slotted tubewell casing, 8% ..	100	100	60	60	60	60	60	60
Blank tubewell casing, 8% ..	18	18	10	10	10	10	10	10
Approximate average depth of tube-well, ft.	190	210	225	235	270	290	325	345

Private Tubewells

According to the project estimate, by Jan. 1965 about 6600 tubewells had been installed in the area. Their capacity is about 1.5 cusecs. Incentive to install a tubewell is a result of high gains from the rice and sugar cane crops. It is estimated to be Rs. 170 to 175 per ac. from both these crops. About 80% of the tubewells belong to farmers owning 20 to 100 ac. and only 20% have been installed as a commercial venture.

In an area of about 0.4 mac. tubewells have been installed on a large scale. This step has increased the acreage of rice, sugar cane and wheat crops considerably. The largest installation of tubewells has been in the rice producing area where originally only 15% of the land was canal irrigated and 70% was uncommanded.

In the coarser soil with less possibility of rice production, only 25% of the area is commanded by tubewells.

The lowest intensity of tubewell installation is in the area unsuitable for rice production, and affected by salts. Those areas, in proxity to Government tubewell schemes have also not been developed.

According to the estimate of Tipton and Kalmbach, the maximum number of private tubewells needed for the full development of the area will be about 40,000.

According to cost estimate for private tubewells, as given in the project report, assuming life of strainer and bore equal to 3 years, life of engine, pump, and black pipe at 15 years with 7% annual interest, cost per acre foot has been worked equal to Rs. 19.83 and Rs. 9.66 for Diesel and Electric operated wells respectively.

According to the report:—

1. The objective of the WAPDA programme cannot be accomplished under private development.

Full development will be delayed for 40 years or more because elements of marginal utility will interfere with timely installation of sufficient number of private tubewells to serve only the best lands.

2. Under private wells programme reallocation of existing canal supplies cannot be made. The report has suggested to transfer 0.728 maf. of water to Lower Rechna when tubewells are installed in this area. It will include the full supply of Rabi equal to 0.6 maf.

3. Private owners will not develop marginal utility lands needing reclamation and initial expenditure.

4. Unless additional power facilities are provided, private tubewell development will not prosper. For 30 thousand tubewells, the initial capital cost of electrification is estimated by the consultants at Rs. 470.0 m. This is again a conservative estimate. It will include £65.20 m. of Foreign Exchange and Rs. 160.251 m. local currency. The foreign exchange now being estimated at about 66% of the total cost.

This measure will render obsolete some 5000 diesel engine presently in use.

5. The full exploitation of the ground water reservoir to support inter-regional transfer of surface water cannot thus be achieved under private development. "The consequences are intolerable".

6. Electrification of private tubewells is a costly proposition to be undertaken on a sufficient scale to benefit a significant proportion of villages in the project area.

7. Equitable distribution of natural resources is only possible under public exploitation. As private owners sell the water at 1/3th share of the crops, rich will become richer and the poor become relatively poorer.

8. The economical evaluation shows a benefit/cost ratio of about 4.5 to 1, some, what less than benefit/cost ratio by public exploitation (5.2 to 1).

9. The development of down stream areas will be handicapped as diversion from the fragmented project will total less than 300,000 ac. ft. per year compared to 728,000 a. ft. per year from the complete project.

Full development of Lower Rechna Doab cannot be planned without a firm commitment for re-allocation of canal supplies.

10. No concentration of private tubewells will return benefits equivalent to those gained from an efficient public programme.

11. Many of the existing private wells will be withdrawn from regular service as the public wells commence operating.

12. Farmers who have experienced the benefits of even the crude form of technology exemplified by inefficient, short-lived wells will not be contented with the status quo.

Development of Roads in West Pakistan

By ZIAUDDIN*

Transportation equalises opportunities and products. It contributes two kinds of utilities— Place Utility and Time Utility. These are economic terms which simply mean having goods where they are wanted and when they are wanted. Consumption of raw materials, where found is negligible. Transportation of raw material, at the desired time, to the points of processing and consumption, brings both kinds of utilities into play.

Cento countries now knit under RCD are closely linked for general economic development. Roads and communications linking them although originally planned for Military Defence, will have far more influence on economic and cultural well-being of these countries. The importance of communication link for economic improvement is discussed in this article by Mr. Zia-ud-Din.

Communication Key to Development

The essential functions of communications in regard to goods, equally apply to the manifold functions and relations of the people. The economy of a country, its social order, its culture and all other aspects of life, feel the impact of transportation. The reader of this article might well be amazed at how closely interrelated are transportation and his personal necessities, duties and comforts. The cost of almost everything he buys is determined in part by the cost and availability of transportation facilities.

In the recent past, countries and areas, hitherto isolated, have become closely associated. Goals of individual nations have assumed regional bias. Working together for their common good, has become fundamental to the economic and social progress of nations, as much as the necessity for military defence. This is evident from the formation of CENTO and such other organisations. CENTO's original purpose was military defence, but it has now increasingly concerned itself with economic development in general. It has been primarily felt in CENTO, that communications form the key to all problems of development. Agricultural development loses its real significance unless products can quickly and safely be moved within country and across borders. New industries thrive only in areas where transportation of goods to potential trade areas is convenient and quick. Natural

* S. E. Construction Circle B & R, Multan.

resources lay fallow unless means of removing them to the consumption centres are available. It is realisation of this fundamental fact that has enlarged the scope of communication facilities in the CENTO countries and one of the chief aims of the Organisation is the establishment of highway LINKS between Turkey, Iran and Pakistan which are now under construction.

R.C.D. Stresses early Completion

Emphasis on the growth of a wellknit transportation system is one of the cardinal principles of R.C.D. countries. The Committee on Roads and Railways in its meeting on 2/4 December, 1964 at Karachi in the R.C.D. Session also "stressed the need" of completion of these road links by 1968. When these links are completed, the R.C.D. countries will be potential market for the industrial and agricultural products of each other. To compete successfully, each country needs to have a safe, fast and comfortable internal transportation system with flexibility and functional economy. By flexibility is meant the ability of vehicle to go anywhere a fair road way is available ; even across fields and open country where going is not rough. In this respect highway network is more far-reaching than Railway or any other mode of communication. A truck, loaded at factory door, can go directly to the door of consignee with no intermediate handling. Specially useful is the truck's ability to tread its way through the city streets or farmer's lands. Railways, no doubt, are still the backbone of the transportation system, if one thinks in terms of the total movement of goods, but it is generally conceded that motor vehicle can transport goods for shorter distances at lower cost than Railways ; and only for long distances for heavy products-in-bulk the railways have a cost advantage. In the movement of small consignments in less than cart-load lots the motor vehicles have a cost advantage even over long distances.

Functional Economy

It would be of advantage to the reader to explain to them "Functional economy" which means low vehicle operating cost. Industries must naturally move closer to the sources of raw material in order to avoid increased freight charges. Many lands would be unusable or unprofitable for agricultural purposes if cheap transportation did not enable the products to be taken to distant markets. In other words, there is a close relation between transportation cost and other costs of production of any goods. This can be illustrated by Figure I.

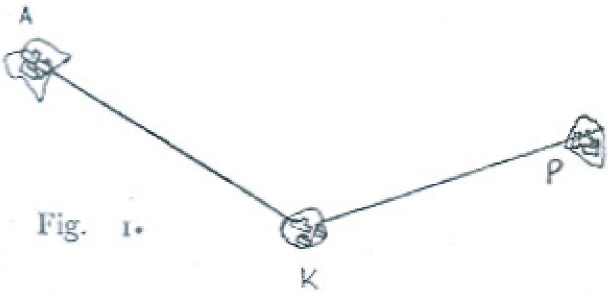


Fig. 1.

Suppose there are two countries A and P either of which can produce goods of certain kind which are sold in market K. Suppose further that the cost of producing the goods at A and at P is Rs. 10 per maund and Rs. 9 per maund, respectively, and the cost of transporting the goods from A and P to K is Rs. 8 per maund and 10 per maund, respectively. Although the goods can be produced at P for Rs. 9 per maund, P cannot compete (supply) market at K for its delivered price would be Rs. 9 + 10 = Rs. 19 per maund while A can capture the market K for its delivered price at Rs. 10 + 8 = Rs. 18 per maund. Now suppose each country A and P improves substantially its internal transportation system and the cost of transportation is reduced to Rs. 5 per maund in each each case. A could now sell the goods at K for Rs. 15 per maund but P can sell the goods at K for Rs. 14 per maund. As a result, P now supplies the market at K.

Should the internal transportation system —mainly the highway network—in any country in R.C.D. be not adequately flexible and far-reaching, and should its cost be so great as to offset the advantages which that country in R.C.D. or CENTO has in the production of its speciality, no exchange between that country and other allies will take place. Goods will not be placed in the hands of that country's own people also at competitive rates and thus the process of production will remain incomplete.

There is, therefore, growing recognization today that highway system in West Pakistan must be strengthened and modernized Road Essential for Agricultural Economy of Pakistan:—

Road transport appears to be eminently suited to the movement of goods in West Pakistan where Agricultural Economy is predominant and truck transportation is increasingly becoming an integral part of process and exchange of goods as shown by detail in Appendix 2. Appendix 2 is an attempt to measure the requirements of the system. Some progress has been made in our road conditions but we are going too slowly. For balanced development in tune with the growth of population and commercial vehicular traffic, and in order to occupy the top position amongst Muslim States in CENTO, RCD and ECAFE, West-wing of Pakistan should have 37,000 miles of metalled roads by year 1981. This mileage should comprise 2,000 miles 24 ft. wide hardcrust roads 2,000 miles 18 ft. hardcrust roads and the rest 12 ft. wide hardcrust roads. This projection of requirement for 16 years up to the year 1981 for new and reconditioning works would mean construction outlay of the order of Rs. 300 lacs per year. This is over double the yearly provision in Third Five Year Plan. Whereas the Central Government recognizes that a very large investment is necessary to create additional road facilities necessary for the economic growth of our country sketched in Appendix 3, the task involved is so enormous that it could be conceived only as a long-term programme extending over several plan periods. What are the prospects of meeting these requirements with the revenues in sight. At present the Central Government of Pakistan imposes and collects a charge of about Rs.1.59 per gallon of petrol of which about 30% is assigned to Central Road Fund—amounting to about Rs. 200 lacs annually. Of this 15% is retained for administration and maintenance of the Central Road Fund Organization and the rest is allocated to the two Provinces by the Central Finance Ministry on the basis of four-part formula *i.e.*, Province's Area, Population, Expenditure on roads and Petrol consumption—after approval of the Provincial Road projects by the Central Planning Commission. In West Pakistan, revenues for road purposes are derived from taxes on motor vehicles, motor transportation, tyres, and transfer of vehicles. These revenues amount to about Rs. 250 lacs annually, and are not placed in any specific road fund, but are placed in the General Revenues. There is, therefore, little likelihood that porgramme of the above magnitude could be implemented under the current arrangement of highway support. It will be impossible to overcome accumulated deficiencies in the foreseeable future unless the rate of capital investment is stepped up sharply. The limited financial resources force a need for new financial techniques.

Road toll for Development

In their search for means of financing urgently needed road improvements and extensions, countries like France, Italy, U.S.A., Japan, Mexico have turned to "road-toll" device. Today similar need, for huge sums to modernize the heavily travelled roads and inadequacy of present highway revenue to finance such expensive projects, is felt in West Pakistan. No one could deny that motorists are willing to pay more for roads if by so doing they can enjoy better and safer service and at the same time realize savings in time and in vehicular operating cost. They realize that toll is merely a financing device to get improved road quickly now, rather than tolerate inadequate and unsafe standards for an extended period while the route in question awaits its turn for improvement. With this factual background the modern road-toll system (as supplementary means to achieve target of 37,000 miles) seems to have reasonable prospects of success in West Pakistan specially in areas of high traffic density, long hauls of goods traffic, short stretches to facilitate tourism or to bypass urban congestions, if our present system of road scheming could be adjusted on the following lines:—

(*a*) Since the toll tax is specific and assured service, it appeals more acceptable if the toll road is designed and constructed to standards which will provide appreciably superior service to that currently afforded or in prospect on parallel free road. The user of the toll road expects to obtain substantial money-saving economics accruing from reduction in travel time, lower vehicle operating cost associated with uninterrupted vehicle movements.

(*b*) The toll road project should be schemed as self liquidating venture. When from the toll tax, sufficient revenue has

Appendix 2

West Pakistan General Growth

(The figures underlined are projected)

Year	Population (1,00,000)					Commercial Motor Vehicles (Thousand)				Mileage of metalled roads	
	Total	Urban	Rural	%Distribution Urban	%Distribution Rural	Year	Trucks	Buses	Total	Year	Mileage
1	2	3	4	5	6	7	8	9	10	11	12
1951	350.6	61.0	289.6	17	83	—	—	—	—	—	—
1956	379.6	75.9	303.7	20	80	—	—	—	—	1955	7980
1961	428.5	96.5	332.0	23	77	1959	17.35	8.78	26.13	1959	8690
1966	475.3	129.4	345.9	27	73	—	—	—	—	1961	8772
1971	531.0	173.6	357.4	33	67	1962	23.21	2.45	35.66	1962	9320
1976	599.0	245.5	353.5	41	59	—	—	—	—	1963	9820
1981	682.3	347.2	335.1	51	49	—	—	—	—		
						1965	27.0	14.0	41.0	1966	15100
										1971	23000
										1976	30100
										1981	37000
						1970	36.0	20.8	56.8		
						1976	44.5	23.3	67.8		
						1981	51.0	26.1	77.1		

Note.—The trend towards urbanization is clearly increasing under the impact of industrialisation and greater opportunities for cash income in the urban areas. Transport facilities must reach out into the rural areas so as to reduce the social or economic isolation of our village communities.

accumulated to pay principal and interest, the toll facility be turned over to the highway department to be included in the Provincial Highway system and operated free of toll. The toll tax must not be continued on such highway in order to apply the revenue to financing other schemes.

(*c*) Toll charges undoubtedly constitute a form of double taxation. That is, the user of toll road must not only pay the toll tax, but must at the same time pay the petrol tax, etc. etc., the proceeds of which will be spent on improvement of other roads. It appears that the only logical solution to the situation is that the Government should credit to the construction of toll roads a fair portion of tax earning. It is suggested that a substantial portion of the amount received yearly from Central Road Fund should go to the toll road schemes, otherwise the toll road users will claim why should the present users be required to pay the full amount necessary to finance a modernization or new construction programme of the toll road which is planned to serve the traffic needs of 30 years or so.

(*d*) The planning of the toll road be done in conjunction with the Provincial Road system as a whole. By that the Engineering Services and equipment available in the province will be used (saving in the cost of construction of toll road) and this will fit in with the programme to take up the toll road later on as integral part of the Provincial Road system.

(*e*) Consideration should be given to acquiring sufficiently wide strip of land at the time a new toll road is constructed to permit sale or lease of the land at added value resulting from the road improvement. This is a potential source of highway revenue. Such a policy would also permit control on adjacent land use to protect the travelled way from the encroachment of undesirable developments that create traffic congestion.

Appendix 3

General Growth of Pakistan

Items	Last year of Second Plan 1964-65	Last year of Third Plan 1969-70	Percentage increase in Col. (3) over Col. (2)
1	2	3	4
Population (Millions)	113	129	14
Gross National Product at factor cost (Million rupees)	44,000	57.000	30
Industrial Production (Million tons)	5.90	12.20	107
Agricultural Production (Million tons)	45.10	58.50	30
Mining Production (Million tons)	5.40	9.70	80

Conserving Solar Energy with Thur

By A. G. CHOWDHRY and
IFTIKHAR AHMAD

Our soils contain a lot of sodium sulphate. This is visible, particularly during winter season, as a white incrustation on the surface of soil. Locally it is called Thur.

Mr. A. G. Chowdhry and his associate have experimented to determine the heat conservation properties of the material and to use this heat for warming water and other purposes. This is an interesting use of the Thur which so far has been considered useless. Even a menace can have some uses.

Introduction

The sun is a great reservoir of energy. It radiates billions and trillions of kilowatts. This energy is in the form of heat and light. As it reaches the atmosphere, some of it is absorbed and the rest reaches the surface of the earth. Roughly the intensity of solar energy is about one kilowatt per square metre. It is possible to conserve this energy, and to use it for heating of rooms, for air conditioning, for refrigeration, for running even small engines. The sunlight can directly be used to produce power to run radio and even to store this energy. The great point in favour of the use of the solar energy is that it can be harnessed and used for practical purposes by cheap and simple apparatus. This aspect has been specially kept in mind while harnessing this power. A reflector of ordinary aluminium sheets can be made for Rs. 50/-. It will work quite satisfactorily. An aluminium reflector does not get rusty or dull, and can be used for several years. Brushing a reflector with clean rag will cause it shine again.

In this paper the authors have experimented with conserving of solar energy in sodium sulphate crystals and to reuse it afterwards. When sunlight falls on sodium sulphate crystals these melt. Roughly 50 calories are required to melt one gram of Thur (Sodium Sulphate) crystals. When this melted material is allowed to cool, it again solidifies reforming crystals yielding the conserved heat which can be put to any purpose.

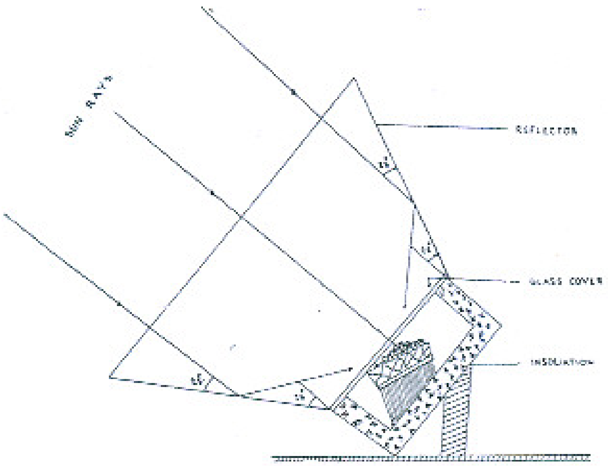
Apparatus used

The apparatus used for the experiments consisted of an insulated wooden box blackened inside and containing the sodium sulphate crystals in an enamelled or a glass vessel. The box was blackened inside and had a glass lid.

It was provided with four flat reflecting plates made of aluminium sheets to direct the sun rays into the box. The plates had hinges, so that their angle could be changed. The box was double walled.

The empty space of the same was filled with saw dust although any insulating material could be used.

The dimensions of the box and that of the reflectors were:—



	Box		Reflectors.
	Outer	Inner.	
Length cms.	52	32	62.5
Breadth ,,	40.5	23	40.0
Height ,,	32/22.5	19	—

Sodium sulphate from one to 5 lbs was used for experiments. The crystals of this salt contain about 10 molecules of water such as $Na_2\ SO_4.\ 10H_2O$. When these are heated the salt gets dissolved in its own water of crystallisation and liquefies. On cooling it again forms crystals. In the figure above is shown the box with reflectors.

The Experiments

A number of experiments were performed by using one to 5 pounds of Thur. The initial temperature of the salt was recorded and then it was exposed to the sun on a clear day from one to 4 hours. The rise in temperature was recorded. When the temperature of the salt rose to 60-70°C, it all got melted. It was noted that temperature inside the box in the month of February rose to 100°C within fifteen minutes.

In the month of June the temperature rose to 120°C whereas in August the maximum remained equal to 102°C.

After the salts got melted, the glass plate was removed and a vessel containing one lb. of water was placed on it. Within ten minutes the temperature of water rose by 10-20°C when the box was not insulated and by 10 to 30°C when it was insulated. The result of several experiments performed are given in tables 1 and 2.

Heat radiation by heated sodium sulphate crystals

Experiments were also conducted to study the heat radiation by the sodium sulphate salt. A vessel containing the salts was kept in the insulated box and the radiation took place from the top surface only. The result of these expepiments are given in table below:—

Salt Exp. one lb.

Max. Temp. raised	70	68	68	65
Heat dissipation time in minutes	Fall of temp. °C	Fall of temp. °C	Fall of temp. °C	Fall of temp. °C
0	68	66.7	67	65.0
15	—	—	64.5	62.5
30	61.7	60.5	61.5	60.0
45	—	—	59.5	58.0
60	56	56.0	58.0	57.0
75	—	—	56.5	56.7
90	51.5	52.0	54.7	—
105	—	—	52.7	—
120	47.5	49.0	—	51.0
140	—	—	50.6	—
150	43	46.0	—	48.25
170	—	—	48.5	—
180	40	44.0	—	46.0
200	—	—	46.5	—
210	—	42.0	—	—
230	—	—	44.9	—
240	—	40.7	—	—
250	—	40.0	—	—
260	—	—	43.4	—

Precautions in the Experiment

(1) Sunrays should fall normally on the glass plates but as the sun rotates, it is necessary to change the setting after every half an hour if the full efficiency is required. The tilt of the glass plates also need to be changed but an angle of 45° can work all round approximately.

(2) Insulation is absolutely necessary. Human hair can even be used for insulating the gap between the two walls. A dry saw-dust is easy to obtain. It was used in this apparatus.

(3) The enamelled or glass vessel containing the working material (Na_2SO_4), should also be insulated.

(4) While warming water, the bottom of kettle should touch the melted sodium sulphate. The uncovered surface of the melted sodium sulphate should be covered

Table 1.—Determination of Rise of Temperature and Final Temperature of One Lb. of Water after Exposing the Thur Crystals to Sun rays

1. Angle of reflector to sun ray 25°C.

2. Amount of water used, 1 lb.

(Without Insulation)

Serial No.	Condition of Weather	Mass of Sodium Sulphate Crystal taken (lbs.)	Time taken to melt this Mass (hour)	Temper ture to which melted Sodium Sulphate is raised (°C)	Time for which water is warmed (min.)	Initial temperature of water (°C)	Final Temperature (°C)	Rise of Temperature (°C)
1.	Partly Cloudy	$1\frac{10}{16}$	Two	66	10	36.5	47	10.5
2.	Clear	$1\frac{1}{2}$	$1\frac{50}{60}$	66	10	36.5	46.2	9.7
3.	Clear	2	$2\frac{20}{60}$	70	9	33	50	17
4.	Clear	2	$2\frac{27}{60}$	69	9	33.5	49	15
5.	Clear	3	$2\frac{45}{60}$	63	10	34	51	17
6.	Partly Clear	3	3	61	10	33	49	16
7.	Clear	4	$3\frac{15}{60}$	64	10	33	51	18.5
8.	Clear	5	$4\frac{8}{60}$	64	10	34	53.5	19.5

to reduce loss of heat. It is done by using a wooden board to cover the salt with a hole to pass the kettle.

(5) During the heating and melting of salt crystals, they should be stirred after every half an hour.

(6) Reflector should be polished and cleaned for good results.

(7) Sodium sulphate container should be placed too deep into the cavity of the box.

Crystallisation of sodium sulphate salts

When the experiment was conducted in winter or during hot summer days there was no difficulty of recrystallisation of salt on cooling. During August, it presented some difficulty due to high humidity.

The crystals were formed by cooling the solution of sodium sulphate using ice and some watar. The crystals were formed after 1½ hours of cooling. The process of crystal forming was quickened by adding a few crystals of the salt in the cooling solution.

Table 2—Determination of Final Temperature of Thur Crystals and the Rise of Temperature of 1 lb. of Water

1. Reflector at 25° to incident ray. 2. Size of front back reflectors 16 × 25 inches.

Serial No.	Condition of weather	Mass of Sodium Sulphate crystals taken	Time taken to melt this merely absorbing solar energy	Temperature to which Sodium Sulphate is raised	Time for which water is warmed	Initial temperature of water	Final temperature of water	Rise of temperature of water
				°C	mts.	°C	°C	°C
1.	Clear	1 Pound	1 hour and 35 minutes	69	10	27	46	19
2.	Clear	2 Pounds	2 hours and 20 minutes	66	10	27	49	22
3.	Clear	3 Pounds	3 hours and 25 minutes	67	10	27	51	24
4.	Clear	4 Pounds	4 hours and 5 minutes	65	10	27	52	25

NEWS & NOTES

INTERNATIONAL HYDROLOGICAL DECADE

In our previous issue we gave details of the programme of the International Hydrological Decades which is to be followed by Unesco with active cooperation of United Nations countries. Some of the recent resolutions adopted to further this programme are put forth in this volume. The Director-General has declared that an International Hydrological Decade for the period 1965 to 1974 is open as a world-wide enterprise of scientific co-operation among nations. A Co-ordinating Council of the International Hydrological Decade composed of twenty-one Member States of Unesco has been set up. It includes Pakistan. The first Session of the Council was held from 14th May to 3rd June 1965. The Member States are invited to take all appropriate measures to proceed with the implementation of the Programme for the training of Specialists and Technicians to strengthen Institutions of Research and allocate funds for the present programme and the long-term programmes. The Director-General has been authorised to collect, exchange and disseminate information concerning research on scientific hydrology and to assist in the training of hydrologists, research workers, technicians and laboratory personnel. The Symposia, one on hydrological research on representative and experimental basis and the second on the hydrology of fractured rocks are being held in this year. The former will be held in Budapest from 28 September to 5 October, and the latter will be held in Belgrade from 7 to 14 October.

In connection with this programme several short-term expert missions are being sent to Jordan, Senegal, Madagascar, Turkey and India. The International Association of Hydraulic Research will be held in Leningrad from 6 to 11 September 1965 and it will deal with some aspects of the problem. Some other countries of the world are also taking active interest in the matter.

* * *

ARID ZONE MEETINGS IN JODHPUR

Unesco has aided India to establish a Central A id Zone Research Institute. Last year from 23 to 30 November 1964 the

Institute was formerly opened when the 20th and the final Session of the Advisory Committee on Arid Zone Research was also held from 3 to 5 December. A symposium on problem of Indian Arid Zone was held in which 86 papers were presented. In Pakistan all our attempts even to obtain copies of the symposium have not borne fruit. In this volume we reproduce below some of the conclusions and recommendations as issued in the first bulletin of International Hydrological Decade.

After the symposium it was concluded that the basic problems of Arid Lands are :-

(*a*) atmospheric, soil-plant-water-energy relationship studies ;

(*b*) soil fertility as influenced by microbiological activity, uptake of nutrients from the soil and their rapid synthesis in the plants;

(*c*) saline water and its use in the production of crops and selection of species of legumes with rhizobium flora which will tolerate high temperature and salinity ;

(*d*) climatic adaptation of species of plants and domesticated animals ;

(*e*) investigations concerning the establishment of a drought-intensity index for plants and animals, covering a complex of such factors as atmospheric temperature, soil moisture, and quiescent state of wilting in plants.

It was stressed that with regard to water needs for Irrigation, Hydrological survey should be intensified to determine ground water, water-bearing rock formations and water quality. In the Arid Zone there are generally resources which can be exploitated. There are ample scope for the utilization of solar and wind energy for the desalination of brackish water and generation of electricity. Investigations on organic compounds to control evaporation from soil and water surfaces need greater investigations.

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JOURNALS OF HYDROLOGY AND OF HYDRAULIC RESEARCH

Hydrologist will be pleased to learn that recently two quarterly periodicals have started to appear. A journal of Hydrology published in Holland has started to appear. It is a result of the interest created by the United Nations Arid Zone Programme. This journal is publishing articles connected with Hydrological Science.

The contribution of the Internationals Association for Hydraulic Research for the promotion of the Science on Hydraulic needs no introduction. During the last 30 years of its existence, it has continued to become popular throughout the world. At present its membership stands at hundreds of practising hydraulic engineers. This organization has also started a journal of Hydraulic Research which will be welcomed by all connected with the promotion of Hydraulic Science.

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ENGINEERS' VISIT TO U.S.S.R.

Four Pakistani Engineers and Scientists visited U.S.S.R. in May 1963 and spent 18 days in the Soviet Union. The delegates included Dr. M. S. Qureshy, Mr. Sayyed Hamid, Brig. M. Z. Khan and Nur-ud-Din Ahmad. Dr. Qureshy has got printed his impressions of the tour in the form of a booklet "Control of Salinity and Ground Waters in the Agricultural Lands of U.S.S.R." which is separated into nine chapters.

These deal with Irrigation, Drainage and Reclamation in Uzbekistan, Azerbaijan and other areas. The method of Salinity and Ground Water Control in the collective form and the growth of cotton crops are discussed. Full chapters are devoted to afforestation and sheep breeding. The last chapter gives the conclusions and recommendations for control of salinity and ground water for agricultural production, afforestation and sheep-breeding.

* * *

SYMPOSIUM ON MASS CONCRETE

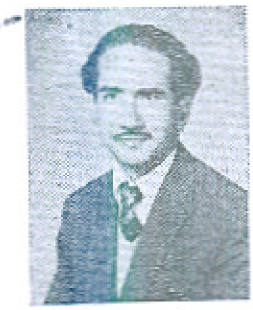
Special Publication No. 6

American Concrete Institute has published the proceedings of this Symposium which constitute collection of 14 papers printed in a booklet of 424 pages. All the important aspects of Mass Concrete are discussed by various authors. The book is available from American Concrete Institute P.O. Box 4754, Redford Station, Detroit, Michigan 48219. Cost $15.00.

* * *

OBITUARY

Late Khawaja Mohammad Afzal



On the 4th of June, 1965 Khawaja Mohammad Afzal Exective Engineer, Kalabagh Division, died in a car accident near Sargodha. By his untimely death the Irrigation Department has been deprived of an excellent young officer. He was a capable engineer and of amiable personalities. Born at Sialkot in 1927, he graduated from the Engineering College of the Technology Moghalpura and joined the Department in 1944 as a Sub-Divisional Officer. He was promoted as an Executive Engineer in 1953 and was posted to the Panjnad Division. During the 12 years as Executive Engineer he held charge of various Divisions including Burala, Lyallpur, Chunian, Kasur, Sargodha, Lyallpur Drainage, Jhang, Muzaffargarh and only recently a year earlier had joined the Kalabagh Division.

The deceased officer has left behind a widow and 4 children. May his soul rest in peace.

Recent Books of Engineers Interest

Elements of Engineering Geology

By J. E. RICHEY.

Sir Isaac Pitman & Sons Ltd., London, 1964.

This elementary book deals with rock materials, their structure, strength and other physical characteristics. The book deals with site investigations, rainfall and ground water, catchment area, reservoir and sites dam sites, etc. Foundations on sedimentary rock and crystalline rock are discussed. The last chapter deals with open excavations. A chapter on tunnels is also added.

* * *

Large Dams in Austria

Published for Osterreichische Wasserwirtchaftsverband by Springer-Verlay, Wien 1, Molkerbastei 5, Austria. English text 171, pp. 41 ff. Seven folding plates. Stout paper covers. Price £3 12*s.* 0*d.*

In this book 41 dams are included. Technical description in most cases is accompanied by drawing and photographs.

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Kempe's Engineers Year-Book 1965

Edited by C. E. PROCKTER, M.I.E.E., M. I. Mech. E., under the direction of B. W. Pendred, M. I. Mech. E., M.I.S.I. Published by Morgan Brothers (Publishers) Ltd., 28 Essex Street, Strand, London, W.C. 2. Two volumes, 3,000 pp. Price 92*s.* 6*d.*

This is a most useful English language references book for all engineers connected with engineering material and hydraulic construction.

* * *

Problems in Hydraulics and Fluid Mechanics

By J. R. D. FRANCIS and P. MINTON, Published by Edward Arnold (Publishers) Ltd., London, 1964, 134 pp. with numerous figures. Price 24*s.* net.

The book contains worked examples for engineering students at degree levels on the subject.

* * *

Dams in Japan, 1964

Published by the Japanese National Committee on Large Dams 1, 1-Chome, Shiba

Tamura-cho Minato-ku, Tokyo.

This book contains illustrations and brief descriptions of 35 large dams recently completed in Japan. The trend towards arch, buttress and fill type dams including the significant rise in the use of pumped storage are discussed.

*　*　*

Long-Term Storage

H. E. HURST, R. P. BLACK and Y. M. SIMAIKA. Constable & Co. Ltd., 10-12 Orange Street, London, W.C. 2 145 pp., 21 ff., 12 appendices. Price 30*s.* net.

Hydrologists will find this book of particular interest. It is from the three authors who have spent their whole working lives studying the hydrology of the Nile.

*　*　*

Similarity in Sediment Transport by Currents

Hydraulics Research Paper No. 6.
By M. SELIM YALIN.

Her Majesty's Stationery Office. 24 pp., 8 ff. Price 3*s.* net.

This is a research paper foreword by F. H. Allen, recently Director of Hydraulics Research at the Wallingford, England. The paper describes the research undertaken in the interest of pure science and is an attempt to provide standard references to assess the validity of laws formulated for practical application. This paper will be of greater interest to research workers rather than to those concerned with the design of the conventional models. It also shows that the theory of the dimensions can be used in studying any mechanical phenomena.

*　*　*

Water Power Development, Vol. II: High-Head Power Plants, Midget Stations and Pumped -Storage Schemes

By E. MOSONYI.
Second Edition. Akademai Kiado, Budapest. 1,146 pp., 748 ff. Price $18.00.

The author of this book has already issued volume I on Low-Head Power Plant. The book came into the market in 1963 and contains photographs and diagrams of many dams. The present volume deals with High-Head Power Plant. A third volume is also expected which will cover most aspects of dams and tunnel design and their construction. These water power development treatise will be such that no hydro-power engineer can neglect them. These are richly illustrated.

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Measurement of Liquid Flow in Open Channels.

Part 4A : 1965. Thin Plate Weirs and Venturi Flumes.

B. S. 3680. British Standards Institution, Sales Branch, 2 Part Street, London, W. I. 89 pp., 9 ff. Price £2 2*s.* 0*d.* Postage extra to non-subscribers.

This is the fourth of a series of booklets intended to cover all methods of measuring liquid flow open channels and will constitute a new British Standard of great value and importance.

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Chemistry of the Soil, 2nd Edition

Edited by FIRMAN E. BEAR. American Chemical Society Monograph No. 160, Reinhold Publishing Corp., 430 Park Avenue, New York, N.Y. 10022. 1964. 515 pp. $20.00

This is a book contributed by several famous authors. It is the best collection of reference material on soil chemistry available and will be useful to the professional soil scientists and students.

* * *

Turbidites

By A. H. BOUMA and A. BROUWER

American Elsevier Publishing Co., 52 Vanderbilt Ave., New York 22, N.Y. 1964. 264 pp. $12.50.

Contribution of sediment deposited from turbidity currents of the type of density current which moves along the bottom slope of bodies of standing water. The book is of general interest to soil scientists.

* * *

Soil Science Dictionary

Edited by OBREJANU, G. *et. al.* Rumania Publishing House, Bucharest, Rumania, 691 pp. 1964 (about $7.25 at official exchange rate).

This dictionary was assembled by the Rumanian Soil Scientists at the time of 8th International Congress of Soil Science, which gives equivalent soil terms for five languages—English, French, German, Rumanian and Russian. It is a good beginning for an international understanding of the terms.

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Physics and Chemistry of the Earth, Vol. 5

By L. H. AHRENS, FRANK PRESS, and S. K. RUNCORN Macmillan Co., 60 Fifth Ave., New York 11, N.Y. 398 pp. 1964, $15.00.

The publication contains 6 topics, three of which are of special interest to soil chemist, physicist and mineralogist.

* * *

Soil Physics

By I. B. REVUT. (In Russian). Kolos Publisher, Leningrad. 319 pp. 1964. 79 Kopecs. (The book may be purchased from the Victor Kamkin Bookstore, 1410 Columbia Road, N.W., Washington, D.C. 20009. $1.35).

This book is meant for a large range of readers such as Soil Scientists and Scientific Workers. It deals with the solution of the problem associated with cultivation of soil, its irrigation and melioration.

* * *

Hunger Signs in Crops, 3rd Edition

By HOWARD B. SPRAGUE, Editor-in-Chief. David Mckay Co., 750 Third Ave., New York, N.Y. 10017. 462 pp. 1964. $15.00.

Each chapter of the book deals with the nutrient deficiences of a particular crop or group of crops and includes a discussion of the causes and conditions under which a given nutrient deficiency symptoms may occur. The book is illustrated with colour plates and black and white photographs.

* * *

Bituminous Materials: Asphalts, Tars and Pitches, Vol. 1

By A. J. HOIBERG

Published by John Wiley & Sons Ltd Green House, Stag Place, London S.W. October 1964. $9\frac{1}{4}$ in × 6 in; pp. 432+; illust. numerous; tables; references; indices. Price 132*s*.

This is a contributed book in which various experts have taken part to write different chapters.

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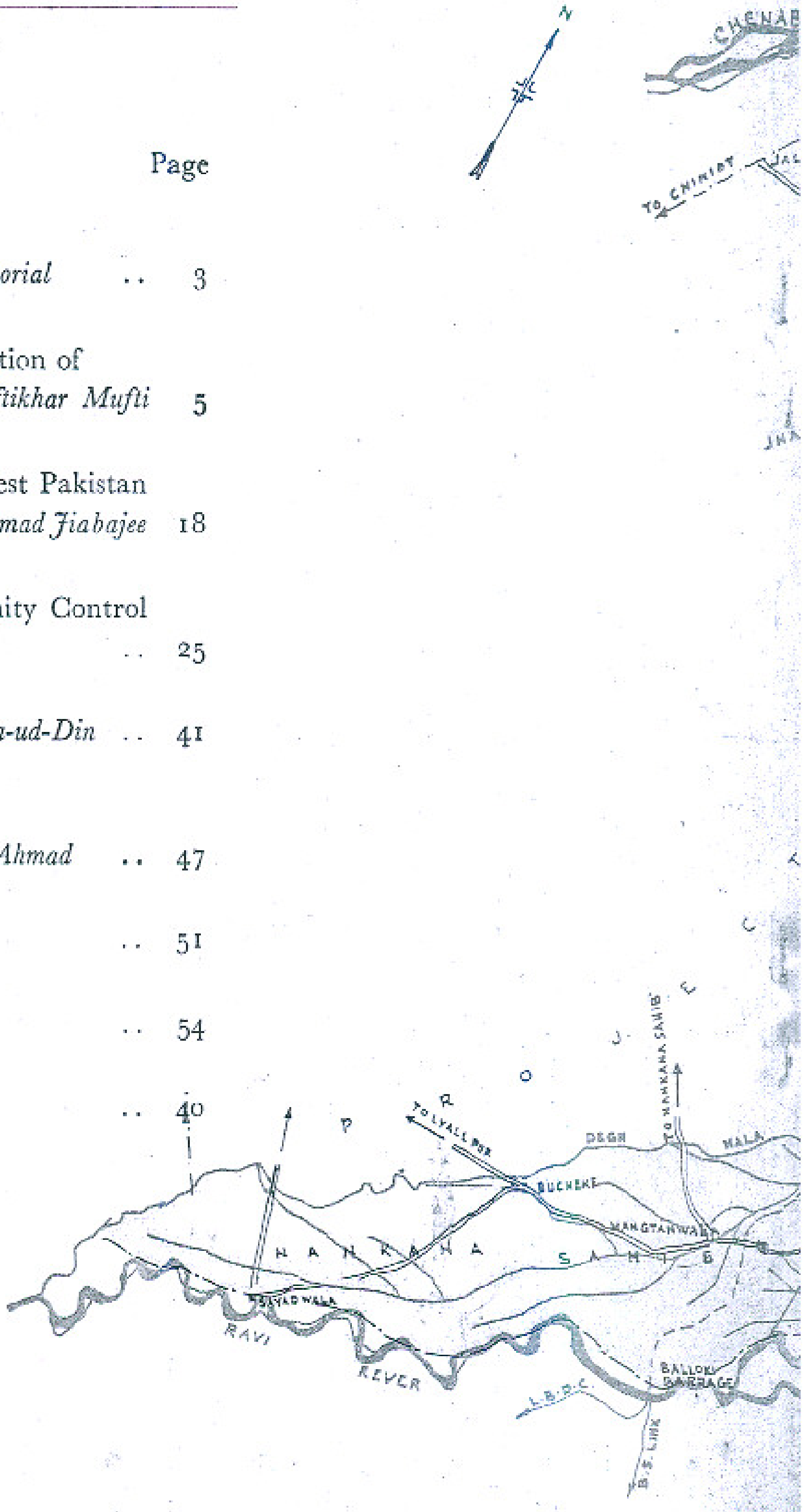

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