

Behaviour of sub-soil water table under a system of irrigation and drainage: subsoil water table conditions in the Hirakud and the Kosi projects.

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BEHAVIOUR OF SUB-SOIL WATER TABLE UNDER SYSTEM
OF IRRIGATION AND DRAINAGE: SUB-SOIL WATER TABLE
CONDITIONS IN THE HIRAKUD AND THE KOSI PROJECTS*

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SUMMARY

A study of the sub-soil water-table with particular reference to the soil and surface drainage conditions, has been carried out at the two projects, *viz.* the Hirakud which is under construction and the Kosi which is contemplated to be taken up in the near future, as examples of the major multi-purpose river valley projects located in semi-humid part of India. Such a study is very important as an aid to visualize the prospective land development with the advent of canal irrigation and for a correct appraisal of an economic utilisation of irrigation water as and when it is made available in those areas.

The major differences in the Hirakud and the Kosi areas pertain to the topography of land and textural characteristics of soil of those areas.

Although the general trend of fluctuation of sub-soil water-table during the year in those two areas, are, more or less, analogous, but the main difference lies in the relatively greater range of its fluctuation, *i.e.*, the difference in the maximum and minimum levels attained, for the Hirakud area than that of the Kosi area. That wider fluctuation of water table in the Hirakud area is attributable to local factors such as the mildly rolling topography of land, the location of observational wells on high ground and the efficiency of the surface drainage.

* Comportement de la nappe phréatique en présence d'un réseau d'irrigation et de drainage—La nappe phréatique dans le projet de Hirakud et celui de Kosi.

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RÉSUMÉ

Le projet de Hirakud actuellement en cours de réalisation, et celui de Kosi qui doit démarrer prochainement, sont deux exemples typiques de vastes projets d'aménagement à multiples fins de vallées fluviales situées dans des régions semi-humides de l'Inde.

Ces projets ont comporté en particulier l'étude de l'influence du drainage de surface et de profondeur sur le comportement de la nappe phréatique. Une telle étude est de première importance si l'on veut prévoir le futur développement d'une région dans laquelle on établit un canal d'irrigation, ou établir correctement un plan d'utilisation économique de l'eau d'irrigation dont une région peut ou pourra disposer.

Ce qui différencie les régions du Hirakud et du Kosi concerne en particulier la topographie du terrain et les caractéristiques du sol.

Si la tendance générale des variations annuelles de la nappe phréatique est plus ou moins semblable dans les deux régions, par contre l'amplitude de ces variations, c'est-à-dire, la différence entre les niveaux maximum et minimum atteints en cours d'année, est beaucoup plus forte pour l'Hirakud que pour le Kosi. Cette différence provient de facteurs locaux tels que la topographie légèrement ondulée de la région de l'Hirakud, l'emplacement des puits d'observations sur les terrains élevés et l'efficacité du drainage de surface.

INTRODUCTORY

The majority of canal and tube-well irrigation projects in India have been confined in the past to its arid and semi-arid tracts mostly. The general rise of sub-soil water-table and/or the appearance of salts at soil surface observed in those areas have been considered as inevitable results of the introduction of irrigation. The rise of water table and the salt efflorescence have, moreover, been assumed to be associated phenomena, the former being regarded as the cause of the latter. However, systematic investigations in those irrigated areas have shown that factors such as the intensity of irrigation and rainfall and the presence initially of salts in the soil crust, and not the sub-soil water, contributed essentially to the development of salinity in soil to a degree harmful for economic crop cultivation⁽²⁾. Those investigations have thus brought to the fore-front the necessity of taking greater precautions to avoid water-logging and setting in of soil deterioration of land under canal irrigation⁽¹⁾⁽³⁾.

Some of the major river valley projects in India, either taken up for construction or proposed to be constructed in the near future, are intended to benefit such parts of the country as can be classed as semi-humid. Although such areas get ample rainfall during the recognized rainy season, they happen to suffer from a general deficiency of water during the remaining part of the year. Those areas are at present yielding paddy mainly

and for their water requirement are dependent entirely on rainfall during monsoon period and therefore subject to the vagaries of the latter. A provision of controlled irrigation supply would have immense potentialities by not only insuring against partial or complete failure of crops but by actually bringing about an increase in crop yield thus improving the economic conditions of those areas.

The prevailing sub-soil water-table conditions in those areas are effected by such factors as rainfall, nature of surface drainage and soil characteristics ; some of those factors are expected to manifest a change directly or indirectly with the development of those areas following the advent of irrigation there. That points to the importance of a proper understanding of the water-table conditions prevailing in those areas at the present stage in order to visualize the prospective land development following the introduction of canal irrigation. Such information at this stage can be of immense use for a correct appraisal and economic utilisation of irrigation supplies in those areas.

The studies of the prevailing sub-soil water-table with particular reference to the soil and surface drainage conditions have thus been carried at two of these new projects, *viz* the Hirakud, which is under construction, and the Kosi, the construction of which is contemplated in the near future. The results of those studies are presented briefly in this paper.

SALIENT FEATURES OF THE HIRAKUD AND THE KOSI AREAS

(a) **Geographical and topographical.**- The area to be commanded by the Hirakud canal system lies roughly between N. Latitudes 20°-50' and 21°-50' and E. Longitudes 83 and 84°-15'. The mean annual rainfall is about 54 inches, the mean annual temperature about 80° F. and mean annual maximum and minimum air temperatures 90°-3' F. and 69.4°F. respectively. The monsoon season covers the period from mid-June to October, the rainfall during the remaining part of the year being negligible. The winter is not severe and summer is dry and hot.

The topography of land is mildly undulating, that at higher elevation is either covered with scrub jungle or trees of poor timber value or serves as grazing ground and the relatively flatter land along the slope and in the valley is terraced and cultivated mainly for paddy on rain water. There is hardly any *rabi* cropping except in close proximity to tanks (*kantas*) storing rain water which serve as the main source of water supply for all purposes during the year. The surface drainage runs roughly in the north-south direction and finally drains into the Mahanadi river and seems ample and effective generally.

The Kosi area lies roughly between N. Latitudes 25°-30' and 26° 46' and E. Longitudes 85°-35' and 88°. It is bounded on the north by the Himalayan range and on the south by the river Ganga. The annual rainfall in the area varies from 40 to 80 inches, the major part coming

during monsoon season from May to September. The climate is temperate; the intensity of heat during summer and of cold in winter in the plains not being severe.

The general topography of the area is, more or less, level with a gental slope from north to south. The area is traversed by a number of drainage channels which follow the natural slope of the country and flow into the rivers Kosi, Balan, Kamla, *etc.* Those rivers are known to bring with their waters a large quantity of suspended and bed silt loads from their respective catchments and a part of that silt gets deposited along the course of the rivers after their debouch in the plains.

(b) **Soil Features :-** The soil of the Hirakud area is generally brownish or reddish as characterize semi-humid tracts and is derived mainly from metamorphic gneiss or schistic parent rock or, at a few localities, from decomposing shale. The soil profile, in general, consists of top soil which overlies a compact stratum of gravely wash material (locally termed *moorum*), the latter overlying decomposed rock stratum and finally parent rock in that order. The main variations along the depth of soil profile consist of differences in thickness of those strata and the extent and degree of weathering of subsoil from parent rock material. From the point of view of suitability of soil for agricultural operations the top soil stratum is mainly important and varies in thickness from a few inches to a few feet depending on the location of any place. The top soil stratum is invariably lighter for a few inches but becomes heavier generally with depth. With regard to soil texture of top soil, it varies from sandy to sandy loam for the top few inches of the profile to sandy clay loam and clay at its lower depth. Gravel occurs mixed up with soil at all depths. The soluble salt content of soil is very low and rarely approaches the limit at which it can be considered as toxic for agricultural purposes. The *pH* ranges between 6.5 and 7.5. Those latter features indicate that there should be little danger of salinisation and/or alkalinisation of land during the post-project period due to irrigation.

The Kosi area is comprised of a recent alluvium. The top five to six feet depth of soil is light in texture ranging from sandy to loam, and overlies a sandy stratum generally. The genetic development of soil profile is practically absent. The organic matter content in soil is low and gravel, concretionary nodules, hard pan, *etc.*, are seldom met with. The extent of the area having salt content in objectionable proportion is insignificant and the *pH* of soil is also low. The danger of salinisation and alkalinisation, over a major part of that area any way, at a later stage with irrigation seems remote also.

EXPERIMENTAL

A study has been made of the depth of sub-soil water-table and of its fluctuation during the year in sets of observational wells selected for that purpose and spread over each of the Hirakud and the Kosi areas.

The wells are not very common in the Hirakud area and rain water stored in tanks, located suitably, serves the requirements of the population mainly. As such only 39 wells were selected for the present investigation in that area. Those wells are located, more or less along six arbitrary lines in east-west direction *i.e.* across the direction of the drainage channels. The depth of sub-soil water table below natural surface has been recorded once each month for the period August 1951 to July 1953. The average variations of water table in wells along each of the six lines during the year are diagrammatically represented in Figure 1. The maximum and minimum levels of water-table below N.S. attained in each well during the year are presented in Table 1.

About 470 wells scattered over North Bihar served for water-table observations in the Kosi area. The wells are located along six arbitrary lines numbered I, II, IIA, III, IV, and V running in east-west direction *i.e.* across the direction of the local drainage lines. Two series of water-table observations have been made. Firstly the depth of sub-soil water table has been observed in all those wells before and after the monsoon season for a period of five years (1948-52); secondly, in about 10 per cent of the wells, observations of sub-soil water table have been recorded once in each month for a period of four years (1949-52). The average fluctuations of sub-soil water table in each of these wells for the first set of observations are presented in Figure 2. For the purpose of diagrammatic representation of the results of the second study, and to bring out if the division of the area into three major parts by the Kosi and the Parman rivers affects the water table in any conspicuous manner, the data relating to the monthly variation of sub-soil water table is plotted in Figure 3 on the basis of the division of observational wells along 12 lines instead of six main lines along which they were located originally.

A comparison of the mean fluctuations of the sub-soil water-table, as indicated by those observational wells, for the Hirakud area, with those for the Kosi area is presented in Figure 4.

DISCUSSION OF RESULTS

A comparison of the geographical and soil features of the Hirakud and the Kosi areas brings out that the main differences in the areas relate to the topography of the land and textural characteristics of soil of those areas. The general trend of the fluctuation of water table in those two areas seems, more or less, analogous, *i.e.* it rises near to the natural surface during rainy season but recedes to lower depths in the course of the drier part of the year. However, the main difference in the behaviour of water table in the two areas lies in the difference between the maximum and minimum levels attained during the year which is more for the Hirakud area than that of the Kosi. For instance, it is seen from the Table I and Figure 1, that whereas the difference for the Hirakud area ranges on the average between 10 to 25 feet, the highest and the lowest figures of that difference being of the order of 39 feet and 8 feet respectively; that for the Kosi area,

TABLE I

Hirakud Area: Showing the maximum and minimum depths of sub-soil water table (below N.S.) attained in each well during the year. Depth (natural surface) in well Nos. along various lines

Line No.	Well Nos.	1	2	3	4	5	6	7	8	9	10	11	12	13
Line I	Maximum depth	24'-6"	26'-0"	17'-2"										
	Minimum depth	2'-6"	12'-7"	5'-0"										
Line II	Maximum depth	26'-5"	40'-0"	17'-4"	24'-10"	13'-9"	25'-0"	30'-6"	19'-11"	28'-10"	23'-11"	16'-10"	28'-9"	23'-10"
	Minimum depth	2'-5"	1'-8"	0'-9"	4'-10"	2'-11"	7'-7"	7'-7"	5'-10"	6'-4"	6'-7"	2'-11"	10'-5"	3'-0"
Line III	Maximum depth	24'-10"	20'-11"	26'-8"	15'-5"									
	Minimum depth	5'-11"	5'-9"	9'-1"	7'-8"									
Line IV	Maximum depth	26'-2"	16'-7"	24'-9"	22'-8"									
	Minimum depth	2'-6"	4'-10"	8'-8"	4'-9"									
Line V	Maximum depth	15'-8"	26'-11"	26'-3"	21'-3"									
	Minimum depth	2'-10"	6'-4"	1'-0"	3'-1"									
Line VI	Maximum depth	27'-7"	24'-2"	25'-0"	16'-6"	16'-4"	27'-5"	35'-7"	25'-4"	22'-10"	23'-0"	22'-4"		
	Minimum depth	7'-7"	5'-3"	3'-2"	3'-3"	7'-2"	3'-5"	18'-0"	5'-1"	0'-9"	3'-11"	4'-11"		

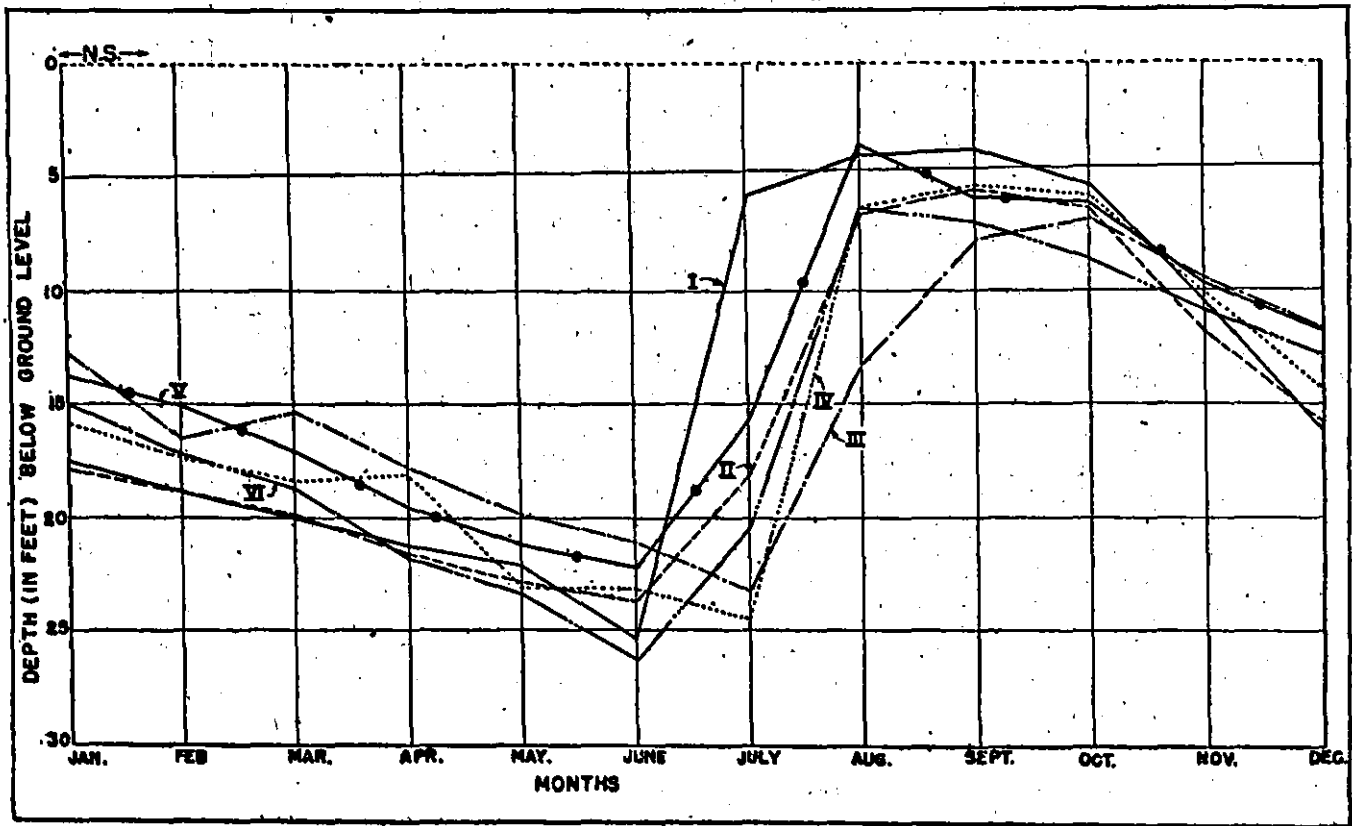


FIGURE 1:— Showing the monthly variations of sub-soil water table below natural surface along each of the six lines of observational wells.

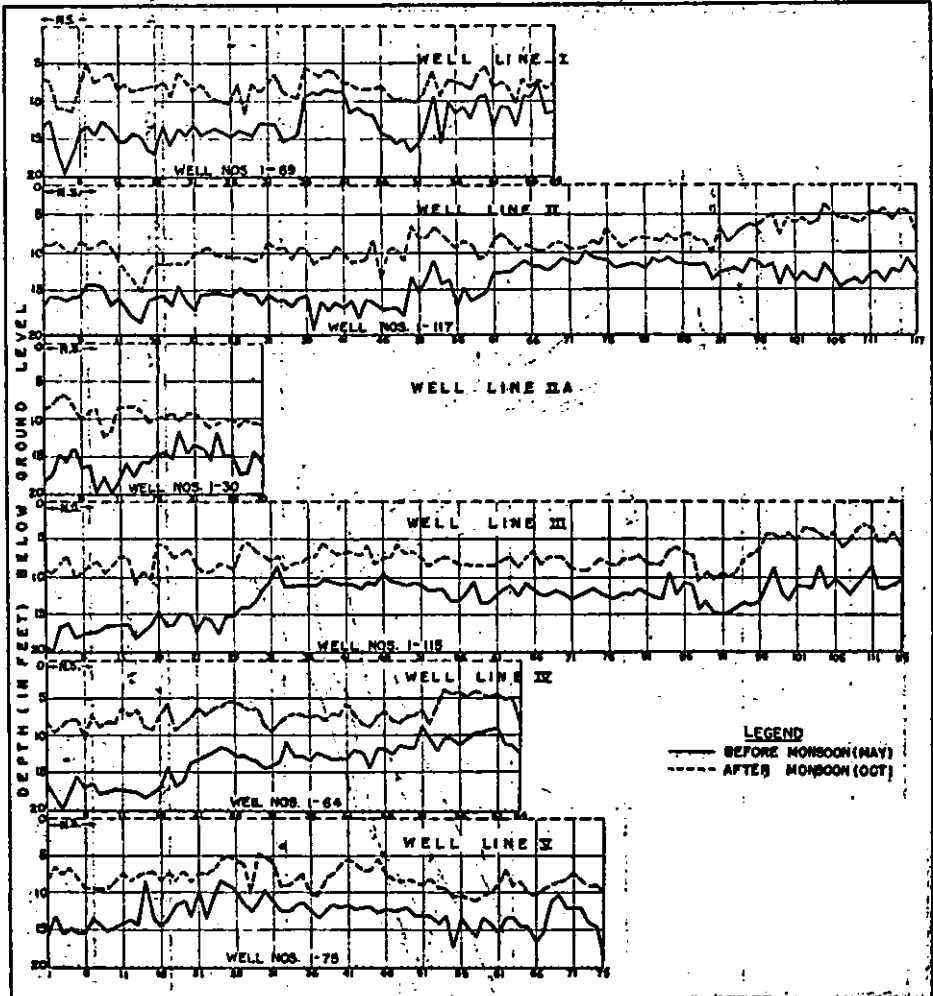
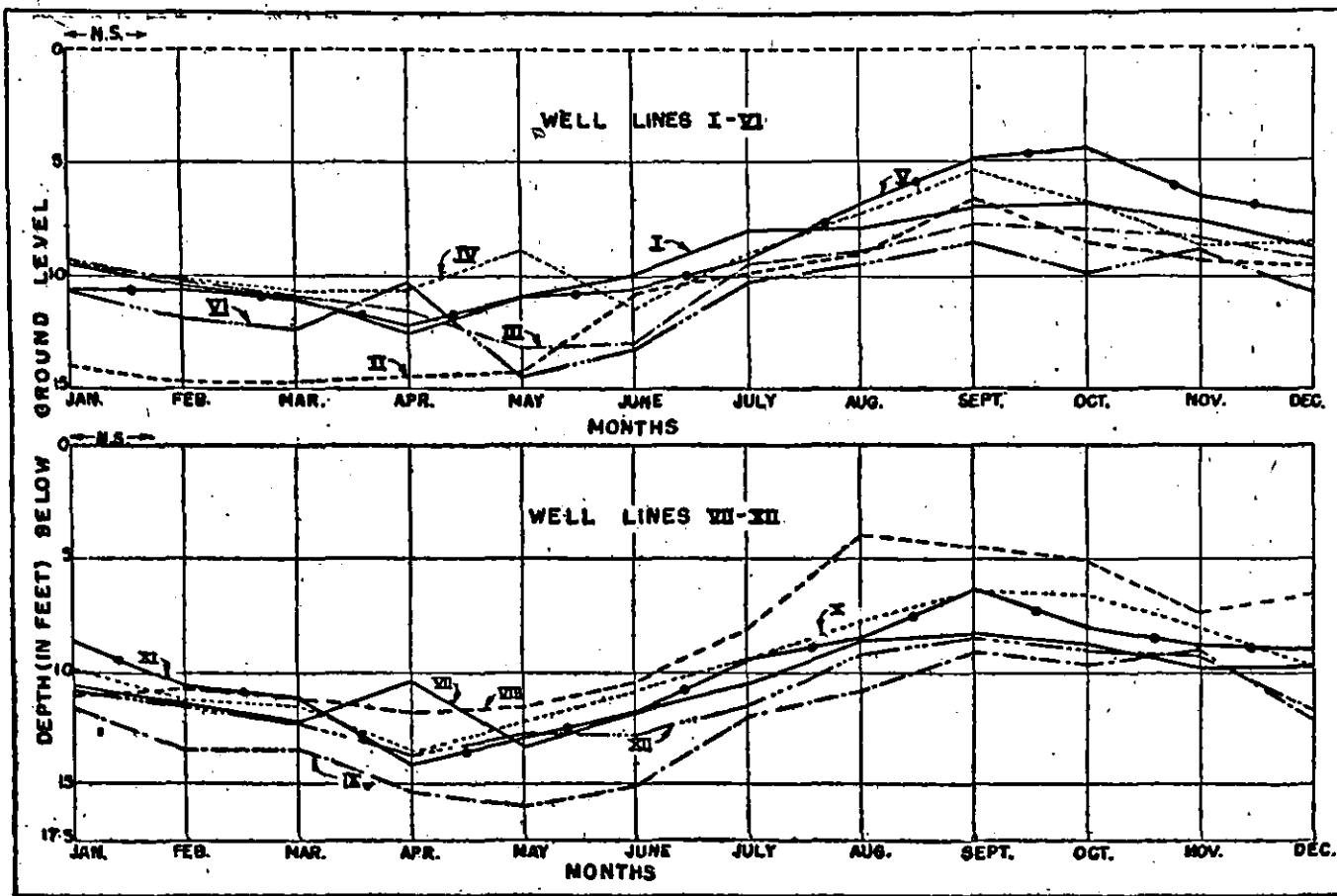


FIGURE 2:-- Kosi area showing the seasonal variation (before and after monsoon) of subsoil water table in each of the wells.



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FIGURE 3:— Kosi area—Showing the monthly variations of sub-soil water table (below natural surface) along each of the 12 lines of observational wells.

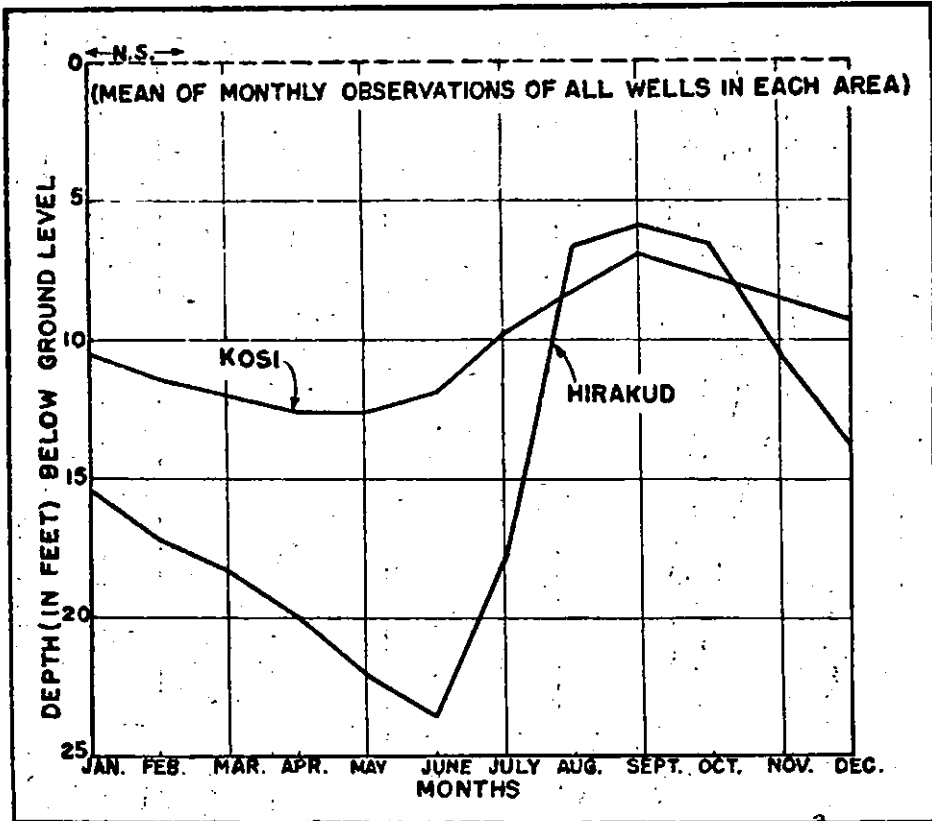


FIGURE 4:— Showing the average monthly variation of sub-soil water table (below natural surface) in the HiraKud and Kosi areas.

on the other hand as shown in Figures 2 and 3, ranges between 4 feet and 8 feet, the maximum and minimum figures being about 11 feet and a few inches respectively.

A comparison of the fluctuation of the water table during each month of the year in the HiraKud and the Kosi areas, expressed on the basis of the average of observations of all wells in each of those areas separately is presented in Figure 4.

The drop of water table in the HiraKud area during the post-monsoon period is quicker during the period October to December. In that area the water from the land at higher elevation (*at* and *mal*) and slopes (*berna*) tends to drain out at a quicker rate and once an equilibrium is established with the water table of the valley land (*bahal*) further drop of the water-table takes place at a relatively slower rate. In comparison the drop of water table in the Kosi area during corresponding periods is steadier and not of that order.

That wider fluctuation of water table in the Hirakud area can be ascribed to such locally prevailing factors as the mildly rolling topography of land, the location of observational wells which are confined to higher land, the efficiency of surface drainage, *etc.* There should be little danger of water-logging in the major portion of the Hirakud area. Even in the low-lying valley land (*bahal*) the observation has been that where drainage is effective in that type of land, as it is over a greater part of it, the excessive water after the rainy season gets drained off very quickly leaving the top soil free. However, due to the general characteristic of soil of the area to become increasingly heavy with depth and the general tendency on the part of the cultivators to block artificially the natural drainage at places in that low-lying land to derive the maximum benefit from rain-water thus accumulated for paddy cultivation, it may be advisable to maintain the natural drainage as clear as possible in those low-lying areas when a perennial supply of irrigation water becomes available.

It may be of interest to investigate further the trend of fluctuation of water table in that low-lying valley land, which although is comparatively a small part of the total irrigable area but is most productive agriculturally. That aspect could not be fully investigated for the purpose of the present paper as few wells were found located in the low-lying area. That intended investigation may have to be carried out with the help of strainer pipes installed at some suitable locations in the low lying valley land in the Hirakud area.

The light and permeable nature of soil of the Kosi area coupled with efficient surface drainage should ensure good drainability of that soil. As the sub-soil stratum consists of sand and the top-cover of light soil is not very thick, it may be advisable to keep the surface drainage in that area, more particularly in low-lying patches of land, as open as possible to ensure the top few feet of the soil free from excessive moisture.

As there is little salt in the soil crust of both the Hirakud and the Kosi areas, the chances of salinisation and alkalinisation of soil in the post-irrigation period are very remote. Moreover, the drainage water is not saline to an extent that it would be harmful for use in crop production. It can thus be pumped into the irrigation water channels at points permitting doing so economically if that eventuality arises.

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