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VERTICAL DRAINAGE FOR RECLAMATION OF SALINE LAND

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ABSTRACT

Well drainage is an alternative method to gravity drainage. A brief account of the problems of salty soils, their origin, occurrence, and reclamation are given. Some theoritical and practical aspects of well drainage are discussed in this paper. Factors affecting the feasibility of drainage wells are outlined. Its adoptability and limitations, the problem of interference in multiple well system, types of drainage wells, spacing and drainage criteria, and design considerations are described. Recent approaches for design of drainage well system are presented.

Origin and Occurrence of Salty Soils

The original sources of salts are the exposed rocks and minirals of the earth's crest. Chemical decomposition and physical weathering result in gradual release of soluble salts. Salty soils are those having high contents of soluble salts and/or a high percentage of exchangeable sodium. Soils with excessive concentration of soluble salts are known as saline soils, those with high content of adsorbed sodium are called alkali or sodic soils and saline-alkali soils contain excessive quantities of both soluble salts and adsorbed sodium.

In the past, salty soils were most often formed as a result of salt accumulation due to netural causes, such as floods, impaired drainage, wind-borne salt spray and the evaporation of salt ground waters. In recent centuries vast areas of salt-affected soils have developed from man-made causes, such as irrigation without provision of adequate drainage, application of insufficient amount of irrigation water, use of poor quality irrigation waters or from combination of these. The majority of salty soils, however, have been developed as a result of the upward capillary flow of water exceeding its downward movement. When this occurs, water, more of less saline, moves upwards by capillarity and salts are deposited in the surface soil as a result of both evaporation and transpiration. The problems of salinity and alkalinity also arise even when drainage facilities are adequate unless sufficient irrigation water is applied to provide for both crop needs and the necessary leaching of excess salts out of the soil.

Effects of Salts on Soils and Plants

The soil salinity is predominating factor for plant growth, where as the exchangeable sodium level determines the possible decline of soil structure.

Saline soils are often recognized by the presence of white surface crusts, by dump oily looking surfaces devoids of vegetation and by stuned

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growth of crop plants. Excess salinity delays or prevents seeds germination, and reduces the amount and rate of plant growth. These effects primary are associated with high osmotic pressures of the soil solution which impair the plant's ability to absorb water but some of these effects may be due to nutritional impalance or toxicity caused by specific ions.

The soils tend to become dispersed and impermeable to water and air with the increase of exchangeable sodium. With the decreased permeability, it becomes increasingly difficult to replenish the water supply in the root zone by irrigation. Also because of the dispersed condition of the soil, it becomes more difficult to establish a condition of surface tilth favourable for seed germination and plant growth.

Reclamation of Salt-Affected Soils

The general principles of reclaiming salt-affected soils comprises of (a) the prevention of further accumulation of salts, (b) the leaching of salts and (c) the replacement of exchangeable sodium by exchangeable calcium. Water salts can be removed from saline soils by leaching alone, but for alkali (sodic) soils a source of calcium or other divalent cation generally is required.

Attempts have been made to reclaim saline soil by growing a crop that takes up relatively large amount of salt and by flushing salts from the surface by passing water over the land surface.None of these methods were found effective and practical.

Reclamation of alkali soils is difficult and costly.A common practice is to apply enough gypsum or other amendment to replace the adsorbed sodium from top soil.Application of suitable chemical amendments improves the soil structure. Sometimes deep ploughing is done to increase the permeability of the soil which aids reclamation.

Well Drainage

Once a salty soil is reclaimed it will be threatend with resalinization through salts moving into root zone by upward capillary transport. It is therefore desirable to keep the capillary rise within limits by lowering the ground water table. This can be achieved by providing a suitable drainage system. In many areas water tables have been successfully controlled by means of pumping from wells. The drainage water is pumped into the canal and the water is used for irrigation purposes.

Drainage wells are classified as (a) gravity well and (b) artesion well. Gravity well, shallow or deep is located in an unconfined aquifer and removes water directly from the root zone. Artesion well taps water from confined aquifer by pumping or it may be free flowing.

Physical Factors Affecting the Choice of Vertical or Horizontal Drainage

The choice between the selection of vertical and horizontal drainage methods is essentially dependent on the physical conditions of the area and economic considerations.

Vertical drainage is not feasible if deep homogeneous material has very low permeability. It is also not possible if the drainable layer is very thin and not underlain by fairly permeable substrata of sufficient thickness to yield considerable water to wells. Soil of good permeability which lie upon shallow formations of very low permeability should not be drained by vertical drainage method. Some of the most successful drainage wells have been located in deep sandy soils and fractured granite underlies a permeable soil. In some cases it is feasible to use pump drainage in an aquifer of limited extent in order to drain rather small areas, however, the success is greater when the aquifer is of great extent. Many successful drainage wells are pumping from aquifers those are 25 to 90 metres beneath the ground surface.

The **ideal conditions** for vertical drainage include : (a) a highly permeable sand or sand-gravel aquifer underlies the drained layer, (b) the drainage water is of good quality and can be utilised for irrigation or some other purpose, (c) the drained layer is relatively impermeable but not so as to prevent downward movement of water. and (d) the horizontal permeability of the drained layer is not very high because few continuous sand or gravel layers are present.

Under above conditions vertical drainage has a clear physical advantage over horizontal drainage.

The hydrologic conditions of the area also plays an important role in deciding between vertical and horizontal drainage. Surface hydrology will be one of the main factors influencing the economics of method selected where drainage layer of low permeability overlies a deep highly permeable layer. In arid and semi-arid regions, rainfall may not cause serious drainage problems and therefore only excess irrigation and leaching water is to be drained. Shallow drains are most economical in such case provided there is no need to develop and use groundwater for irrigation. In regions where irrigation application rates and rainfall intensities are high the relatively poor permeability of shallow layers may prevent rapid horizontal drainage. This may result in a periodic rising of the groundwater into the root zone and may cause critical damage to the crops. Under such circumstances, vertical drainage will cause rapid lowering of the shallow water table.

Advantages of Well Drainage

Well drainage has following advantages when compared with gravity drainage :

(a) Well drainage lowers the ground water table to a much greater depth than does gravity drainage.

(b) It does not provide hinderance to farming operations as in case of open drains.

(c) On lands with undulating topography not having natural outlets, the pumped water is generally disposed off through pipe lines connecting various wells.

(d) The drainage water can be used for irrigation and other purposes provided it is of good quality.

(e) If pervious layer lies at a depth 5 m or more the well drainage can successfully be used.

Disadvantages of Well Drainage

Well drainage is not favoured over gravity drainage because of undermentioned limitations :

(a) It has more complex design and high construction and operational cost.

(b) It require external source of energy to run the pump.

(c) It is not feasible in areas where artesian pressure in the aquifer to be pumped is too high or seepage is excessive.

(d) Well drainage is successful only if aquifer conditions are favourable.

(e) Well drainage may not be feasible if ground water is saline.

(f) It is not economical on small areas as pumped water is mostly the contribution from surrounding fields.

Spacing of Wells

When water is pumped continuously from well the cone of influence expands with time. The flow approaches a quasi-steady state when no appreciable additional drawdown around the well is observed beyond certain distance. The distance between centre of the well and the point where pumping does not affect the level of the overall water table is known as radius of influence.

In a multiple well system if the wells are spaced too closely togather, the pumping of one may interfere with the yield of other. The overlapping of cone of influence (zone of depression) of a well with those of neighbouring wells is called interference of wells. The rate at which the water is to be removed to lower the water table determines the spacing between the well. A dense network of wells would be necessay to lower the water table at an appreciable rate. The spacing of the wells for most economical operation is decided by performing field test using piezometers and observing drawdown of water table caused by pumping from the wells. The data obtained in the pumping test is used as a guide for the location of additional well.

Depth and Size of Drainage Wells

The depth of the well is decided from the log maintained during drilling of the well, log of test bore or log of wells in vicinity. Generally, a well is taken deep to the bottom of the aquifer to have higher spacific capacity. This allows more drawdown and rapid removal of of water.

The design of diameter of well requires careful consideration of the hydraulic factors those influence well performance. Choice of proper diameter is important because it affects significantly the cost of the structure. The yield of a well depends upon the diameter but increase in well diameter increases the yield slightly. For a set of conditions, doubling the diameter of well will increase discharge only about 10 to 15 percent. Table 1 shows the approximate increase in yield in sand and gravel wells due to increase in diameter.

Table 1 : Effect of increase in well diameter on well yield

Well diameter, cm	10	15	20	30	45	60	90
Percent increase in yield	0	5	10	15	23	28	38
		0	5	10	18	23	33
			0	5	13	18	28
				0	8	13	23
					0	5	15
						0	10

Source : A. M. Michael, 1978.

Flow from Wells in Unconfined Aquifer

There are several approaches to the development of equations for performance of wells. Dupuits formula for steady flow toward a well assuming no recharge gives quite accurate values. The equation reads :

$$Q = \frac{\pi K\ (h_e^2 - h_w^2)}{\ln\ (r_e/r_w)} \qquad (1)$$

Where

Q = discharge of pumped well, m^3/day

K = hydraulic conductivity of the aquifer, m/day

h_e = Undisturbed hydraulic head, metre

h_w = hydraulic head in well, metre

r_e = radius of influence, metre

r_w = radius of the well, metre

A specific solution to this equation can be obtained by substituting a pair of values of h and r as observed in two piezometers at different distances from the centre of the well. This equation fails to describe the drawdown curve close to the well where sharp curvature of water table contradicts the Dupuit-Forchheimer assumptions.

In a multiple well system drawdown at any point P can be computed as sum of the drawdowns due to pumping the individual wells. The drawdown in such condition is given as

$$h_e^2 - h^2 = \sum_{i=1}^{N} \frac{Q_i}{\pi K} \ln\ (r_{ei}/r_i) \qquad (2)$$

Where

h = hydraulic head during pumping, metre

Q_i = Constant discharge from ith well, m^3/day

N = number of wells

r_i = distance between ith well and P, metre

r_{ei} = radius of influence of ith well, metre

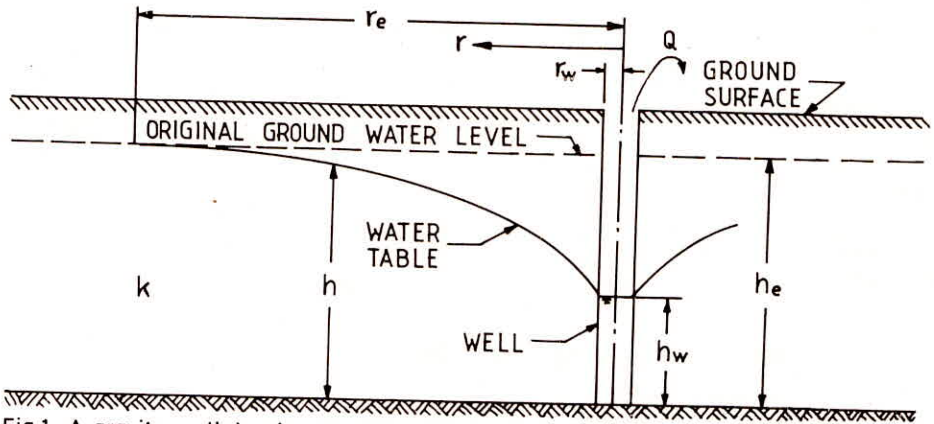

Fig.1. A gravity well having water-table shape according to Dupuit assumptions.

If the two wells of same diameter are spaced a distance L apart and run simultaneously for time t then the discharge from each well is expressed as :

$$Q = \frac{2\pi K(h_e^2 - h_w^2)}{W(r_w^2\mu/4KDt) + W(L^2\mu/4KDt)} \qquad (3)$$

Where

W = Theiss well function, an exponential integral $= \int_u^\infty \frac{e^{-y}}{y} dy$

y = dummy variable

u = $\frac{r^2S}{4KDt}$, dimensionless

r = distance from the well, metre

S = storage coefficient, dimensionless

KD = transmissivity of aquifer, m^2/day

t = elapsed times, day

μ = effective porosity , dimensionless

If the pumping time is more such that $L^2\mu/4KDt<0.05$ then equation (iii) can be rewritten as :

$$Q = \frac{\pi K(h_e^2 - h_w^2)}{\ln(2.25\ KD/L\mu r_w)} \qquad (4)$$

If three wells are arranged forming an equilateral triangle and spaced distance L apart the discharge from each well is obtained from following relationship :

$$Q = \frac{2\pi K(h_e^2 - h_w^2)}{W(r_w^2\mu/4KDt) + 2W(L^2\mu/4KDt)} \quad (5)$$

Above equation can be replaced by equation 6 for higher values of t so that $L^2\mu/4KDt < 0.05$.

$$Q = \frac{\pi K(h_e^2 - h_w^2)}{\ln(R^3/L^2 r_w)} \quad (6)$$

Where $R = 1.5\ (KDt/\mu)^{\frac{1}{2}}$

In case three wells are arranged in a straight line for condition $L^2\mu/KDt < 0.05$, the discharge from inner well is given by :

$$Q_2 = \frac{\pi K(h_e^2 - h_w^2)\ln(L/2r_w)}{2\ln(R/L)\ \ln(L/r_w) + \ln(L/2r_w)\ln(R/r_w)} \quad (7)$$

and the discharge of each outer wells is expressed as

$$Q_1 = Q_3 = \frac{\pi K(h_e^2 - h_w^2)\ln(L/r_w)}{2\ln(R/L)\ln(L/r_w) + \ln(L/2r_w)\ln(R/r_w)} \quad (8)$$

For four wells arranged in a square with sides L, and the condition $L^2\mu/2KDt < 0.05$ is satisfied the discharge from each of the four wells are given by :

$$Q = \frac{\pi K(h_e^2 - h_w^2)}{\ln(R^4/r_w L^3\sqrt{2})} \quad (9)$$

Conclusions

Vertical drainage is one of the feasible technology to reclaim salty lands. Ideal conditions for vertical drainage includes highly permeable sand aquifer underlies relatively impermeable drained layer and good quality of drainage water. This is an efficient method to lower the water table quickly. Complex design, high construction and operational cost and unsuitability for small areas are its limitations. Design of a multiple well system acquires careful consideration of hydraulic factors those influence well performance. Equations developed for various arrangements of multi well system can be used without appreciable errors for all practical purposes.

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