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100-N AREA AQUIFER EVALUATION

by

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100-N AREA AQUIFER EVALUATION

INTRODUCTION

The principal methods for quantitatively evaluating ground-water aquifers involve the determination of certain aquifer coefficients. The values of these coefficients are utilized in basic hydrological equations to evaluate other hydraulic characteristics associated with that particular water-bearing formation. The two coefficients most often used to make such evaluations are transmissibility and storage.

Many methods have been developed for determining the transmissibility and storage capacity of an aquifer. The methods which have been used at Hanford were discussed by Bierschenk (1), who pointed out many of the advantages and limitations of each method. Recently, a method was developed by Rowe (2) for estimating these two aquifer characteristics from the response in wells to river-level fluctuations. The purpose of this paper is to evaluate the hydraulic characteristics of the ground-water aquifer underlying the 100-N Area, using the equation developed by Rowe.

SUMMARY

The hydraulic characteristics of the unconfined aquifer adjacent to the Columbia River change considerably during certain seasons of the year. These changes are the direct result of fluctuations in the river level. During the low stages of the river the ground water percolates through partially cemented sands and gravels of the Ringold formation. As the river approaches the flood state the water table rises into the more permeable fluviatile and glaciofluviatile rocks.

Using a method developed by Rowe the transmissibility and coefficient of storage of the unconfined aquifer underlying the 100-N Area were determined. The measurements for these determinations were made when the river was nearing its flood stage in order to obtain the most representative values for these coefficients. Based on these data the calculated average permeability values ranges from 1,500 gpd/ft^2 to 3,000 gpd/ft^2. These permeability values are consistent with those determined elsewhere on the project in similar earth materials.

The calculated hydraulic characteristics of the 100-N aquifer were used to evaluate the performance of a waste water disposal facility. A tentative evaluation indicates that the infiltration capacity of the soil (estimated to be 10-20 gpd/ft^2) may control the size needed. It is estimated that the proposed 30-foot trench parrallel to the river would not create a problem as a result of its effect on the water table.

GENERAL UNCONFINED GROUND-WATER CONDITIONS AND CONTAINING EARTH MATERIALS

An unconfined ground-water aquifer is defined as the zone from the surface of the saturated ground-water body down to the first extensive stratum having an average permeability significantly lower than that of the overlying materials.

In the northern part of the Hanford Project the extensive beds of clay found in the Ringold formation are taken to be the bottom of the unconfined aquifer. These clay deposits are generally situated several tens of feet below the surface of the saturated zone. The top of the saturated zone is referred to as the water table.

Along the Columbia River the water table rises and falls in response to the river level fluctuations. Noticeable changes in the water table have been observed several miles inland, however the most pronounced changes occur within a half mile of the river. Some observation wells have recorded water-level changes of up to fifteen feet. When such radical changes occur in the thickness of the aquifer it becomes extremely difficult to determine its hydraulic characteristics. The characteristic coefficients may vary significantly from one season to another as the water table rises and falls.

In the region surrounding the 100-N Area during the low stage of the river the elevation of the water table reaches a minimum. In this position the groundwater body is entirely within the sands, silts, and gravels of the Ringold formation. These materials for the most part are unconsolidated; in certain areas, however, they have been cemented by calcium carbonate and iron oxides. Bierschenk (1) reported the average permeability of these rocks to range from 100 gpd/ft^2 to 600 gpd/ft^2 on unit gradient, depending largely on the amount of fines and the degree to which the material had become cemented. It is conceivable that the permeability of the material comprising this zone could differ by one or two orders of magnitude from one location to another.

In the late spring and early summer flood waters moving down the Columbia river cause the water table to rise. During this rising stage the water table moves upward into more permeable fluviatile and glaciofluviatile rocks. The rock fragments associated with these deposits are generally coarse sands and gravels with only small amounts of silt and clay.

The methods used to calculate aquifer characteristics generally give average values over the whole aquifer thickness. The aquifer thickness and the type of material through which the ground water is percolating establish the measured characteristics. It would be expected that the values measured during the winter months would be significantly different from those measured in the summer.

Figure 1 is a geologic cross section constructed through the 100-N Area normal to the Columbia River. In this figure, two relative positions of the water table are shown. The lower of the two is based on an average minimum flow rate of the Columbia River and the other is based on an average maximum flow rate. The rocks through which the ground water percolates at these two extreme stages are also indicated. The sands and gravels of the Ringold formation are shown to be locally cemented although the degree of cementation and the areal extent of the cemented zones are not known. The total aquifer thickness may be as much as 80 or 90 feet.

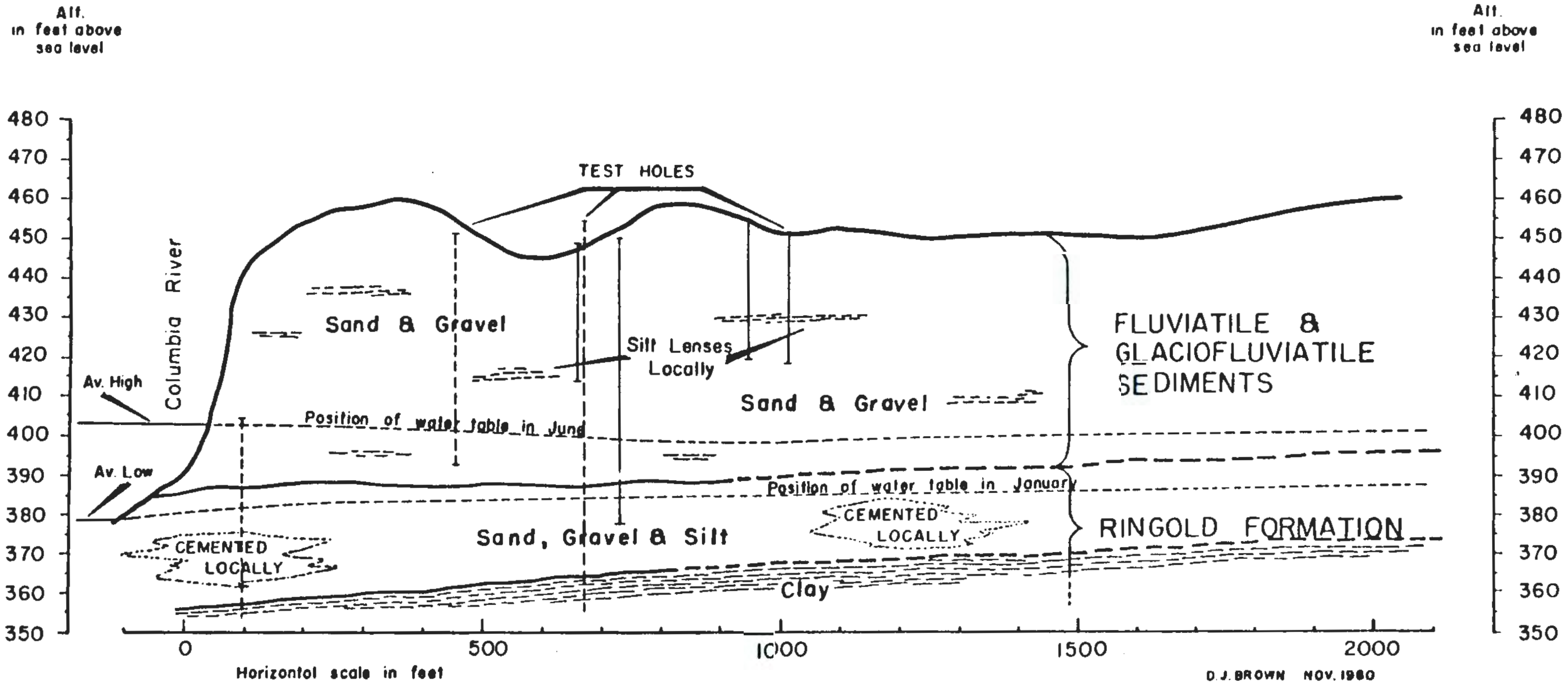


FIG.1. GEOLOGIC CROSS SECTION OF THE 100-N AREA.

DETERMINATION OF HYDRAULIC CHARACTERISTICS

The equation given by Rowe (2) for estimating transmissibility and coefficient of storage from river level fluctuations is expressed as follows:

$$h = ct \left[1 - \frac{4}{\sqrt{\pi}} \text{intf} \left(\frac{X}{2} \sqrt{\frac{S}{tT}} \right) \right]$$

where h is the change in water level in feet observed in a well during an observation period t (days), c is the rate at which the river rises (ft/day), intf is an abbreviation for the integral function, derived by Rowe and tabulated by him (see Table I), x is the distance from the river to the observation well (ft), S is the coefficient of storage, and T is the coefficient of transmissibility (gal/ft/day).

TABLE I

Values of the "Integral Function"

after Rowe (2)

$$\text{intf}\ (U) = U + \frac{U^3}{3} - \frac{U^5}{2!(3)\ (5)} + \frac{U^7}{3!(5)\ (7)} - \frac{U^9}{4!(7)\ (9)} + \dots$$

U	intf (U)	U	intf (U)
0.000	0.000	0.220	0.224
0.010	0.010	0.230	0.234
0.020	0.020	0.240	0.244
0.030	0.030	0.250	0.255
0.040	0.040	0.260	0.266
0.050	0.050	0.270	0.276
0.060	0.060	0.280	0.287
0.070	0.070	0.290	0.298

(Table I contd. on Page 9).

TABLE I (contd.)

U	intf (U)	U	intf (U)
0.080	0.080	0.300	0.309
0.090	0.090	0.310	0.320
0.100	0.100	0.320	0.331
0.110	0.110	0.330	0.342
0.120	0.120	0.340	0.353
0.130	0.131	0.350	0.364
0.140	0.141	0.360	0.379
0.150	0.151	0.370	0.387
0.160	0.161	0.380	0.398
0.170	0.172	0.390	0.409
0.180	0.182	0.400	0.421
0.190	0.192	0.410	0.433
0.200	0.203	0.420	0.444
0.210	0.213		

It was recognized that the aquifer characteristics change significantly from one season to the next as a result of water table fluctuations. Therefore, the measurements of the water table and river-level elevations to determine the transmissibility were made during the high water stage to include contributions of all geologic units that might comprise the aquifer. The transmissibility obtained from these measurements is representative of the unconfined aquifer underlying the 100-N Area, involved in most waste disposal problems.

Substituting into this equation the values obtained for the river-level and water-table measurements, the transmissibility as calculated ranges from 30,000 to 60,000 gpd/foot of aquifer width. The value of the coefficient of storage used to determine these transmissibilities was 0.1.

Based on the transmissibility data and the coefficient of storage of the aquifer and using an average aquifer thickness of 20 feet, the average permeability of the aquifer ranges from 1,500 gpd/ft^2 to 3,000 gpd/ft^2. These permeability values appear to be consistent with those obtained by Bierschenk (1).

The seepage velocity, based on the calculated average permeability and the maximum gradient observed during the period studied was determined to be three to four feet/day. The natural ground water would not attain this velocity. Sometimes the river level rises so rapidly that the normal gradient toward the river is reversed. This reverse gradient away from the river has been detected several thousand feet inland at certain locations on the project. Beneath the 100-N Area the reversed gradient might extend as much as 1000 feet from the river.

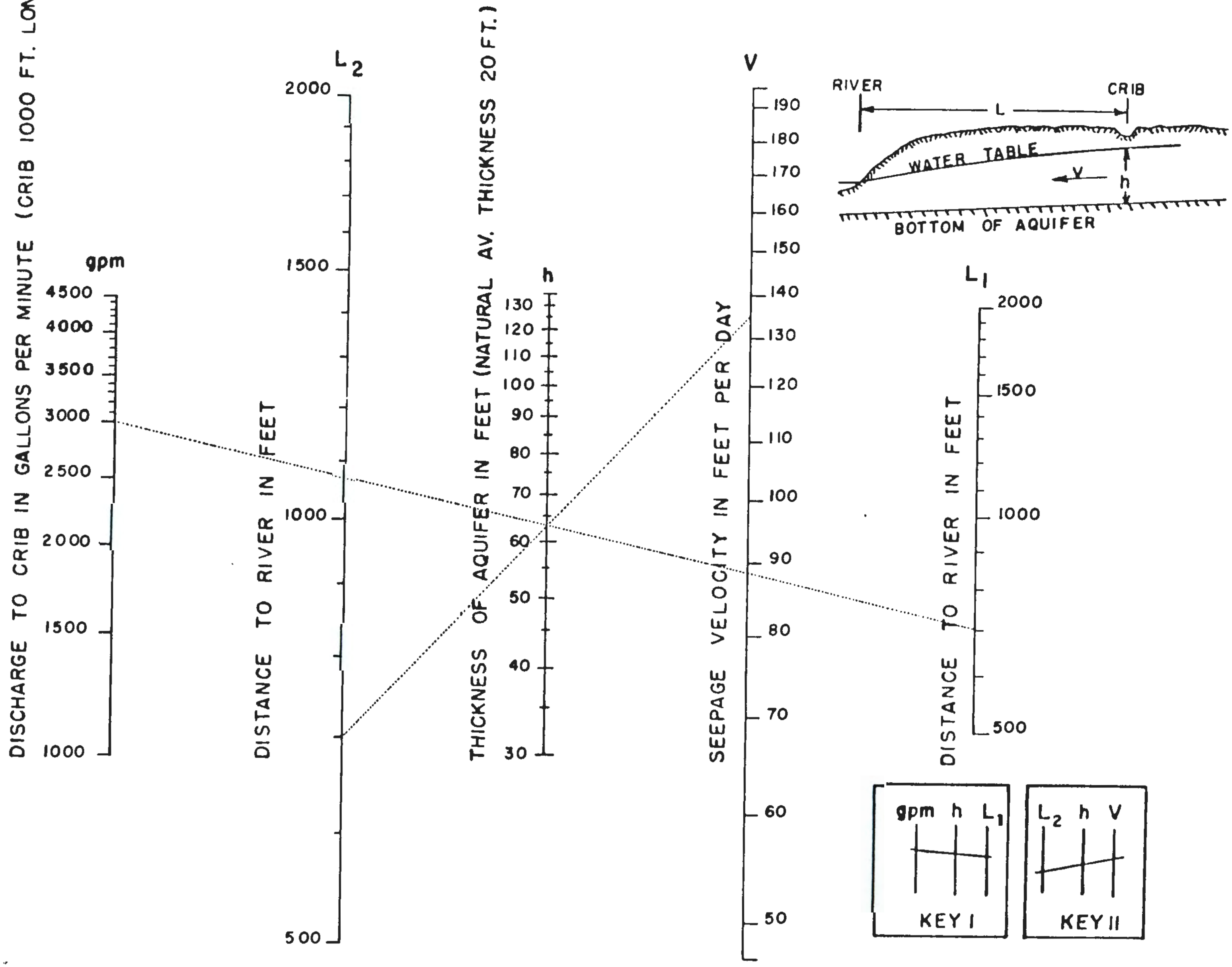
CHANGES IN THE UNCONFINED AQUIFER RESULTING FROM LIQUID DISPOSAL TO GROUND

Large volumes of waste water from the NPR reactor will routinely be disposed to the ground within the 100-N Area according to present plans. The disposal of this water will involve downward seepage to the water table and lateral movement with the natural ground water to the river. This paper is concerned with the problem of lateral transport.

Knowing the hydraulic characteristics of the unconfined aquifer underlying the 100-N Area and given a particular injection rate to the ground, it is possible to calculate the water-table elevation and the velocity when equilibrium conditions are reached. Considering the number of variables involved it is not practicable to present all possible changes in elevation and velocity in this report.

A nomogram for calculating changes in aquifer thickness and seepage velocity over a range of conditions believed to be of most interest is presented in Figure 2. It should be borne in mine that this nomogram is based on simplifying linear assumptions and gives good estimates over the indicated ranges. In constructing the nomogram, the numerical value of each aquifer coefficient was chosen to give minimum values for the aquifer thickness and velocity. All calculations were based on an assumed recharge from a crib 1,000 feet long.

To use the nomogram to determine the net change in water-table elevation and the seepage velocity under known conditions, the key diagrams in Figure 2 indicate the sequence of operations. First, a straight line is established, passing through the scale points corresponding values of crib discharge (on "gpm" scale) and distance from the crib to the river (on "L_1" scale). This line will intersect the "h" scale at a point indicating the minimum thickness of the aquifer. Subtracting 20 feet from this value, the average aquifer thickness prior to discharge, the new change in water-table elevation is obtained. A second line established by the point on the "h" scale and the value corresponding to crib distance on the "L_2" scale will intersect the "v" scale at a point which establishes the velocity in ft/day. Dividing the distance by this velocity gives an indication of the average travel time to the river in units of days.



NOMOGRAM FOR CALCULATING CHANGES IN THE GROUND-WATER AQUIFER UNDERLYING THE 100-N AREA

FIGURE 2.

The design of a crib to receive the large flow of waste water proposed must be tested with regard to two possible limitations. The area of the crib bottom must be sufficient to permit infiltration at the discharge rate. In addition the equilibrium attitude of the water table beneath the site must not affect the behavior of the crib or intersect the ground surface to form springs and surface streams. This latter condition may be evaluated by proper application of aquifer coefficient data similar to that used in preparing the nomogram of Figure 2. Experience at Hanford indicates that a conservative infiltration rate for this area is 10 to 20 gpd/ft^2. This is based on equilibrium after several months of use and with a head of one to three feet of water. From this it may be seen that a 30-foot wide trench receiving 3600 gpm waste water should be more than 8,000 feet long to assure adequate infiltration capacity. It may be shown from the aquifer characteristics reported here that this crib would not raise the water table enough to overflow the ground surface when the trench is roughly parallel to the river.

CONCLUSIONS

The water level changes in wells at the 100-N Area indicate a "field" permeability for the saturated earth materials of 1500 to 3000 gpd/ft^2 on unit gradient. From this it is possible to estimate the water table changes that might be expected at this site as a result of waste water discharge to a pond or trench. The proposed 100-N waste facility could be a trench parallel to the river. It

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is estimated that such a trench built 30 feet wide would not result in water table changes so great that surface springs would form or the utility of the trench would be impaired. From the integrated average permeability of the aquifer beneath 100-N it is also possible to estimate the average velocity of the ground water toward the river, as exemplified by the nomogram of Figure 2. The maximum velocity of the ground water may be several times this average because the relative permeabilities of geologic units occurring in the saturated zone are known to differ widely. These averages, however, assist with rough estimates of the movement rates that may be expected.

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2. Rowe, P. P. An Equation for Estimating Transmissibility and Coefficient of Storage from River Level Fluctuations, Journal of Geophysical Research, Vol. 65, No. 10, p. 3419-3424, October, 1960.

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