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ESTIMATING UPLAND RECHARGE IN THE YUCCA MOUNTAIN AREA

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Abstract

Field and modeling studies were conducted recently for the Fortymile Canyon watershed and the Rock Valley area near the site of the proposed high-level nuclear waste repository at Yucca Mountain, Nevada. These investigations strongly suggest that groundwater recharge is occurring in upland areas by water percolating below the plant rooting depth. The CREAMS hydrologic model was used to compute a water balance on upland areas in Rock Valley, NV, a site located about 100 km northwest of Las Vegas and about 60 km southeast of Yucca Mountain. Computed recharge amounts are related to precipitation frequency and spatial variability in saturated hydraulic conductivity in the plant root zone. Accurate estimates of rates and amounts of upland and stream channel recharge are needed to accurately model the groundwater flow. If validated by further field measurements, then the procedures used can provide recharge estimates; and thus, source term estimates, for 2- and 3-dimensional groundwater flow modeling used to characterize the Yucca Mountain site.

Introduction

The research summarized in this paper is in support of a broader hydrologic research effort with two main objectives 1) To estimate recharge in the Yucca Mountain area streams under modern conditions and 2) To estimate paleorecharge in the Yucca Mountain area streams. Both of these objectives are in support of providing recharge data for 2- and 3-dimensional groundwater flow modeling in connection with the high-level waste studies at Yucca Mountain.

We sought to test the hypothesis that recharge in the area was limited to that derived from

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transmission losses (infiltration losses to stream channel bed and banks) in the major streams. Initial analyses included review of selected publications (i.e. French, 1986; Christensen and Spahr, 1980; and Lane et al., 1984) to obtain an overview of the area's climate and surface hydrology and to prepare data input files for a daily water balance model (the CREAMS model; Knisel, 1980).

This paper reports on applications of the daily water balance model at Rock Valley, NV and discusses the implications for estimating groundwater recharge on the Fortymile Canyon Watershed.

Assessing Possibility of Upland Recharge

To make the assessment, we used the CREAMS model as previously applied at the IPB Rock Valley site (Lane, et al., 1984) to estimate a water balance.

Considering a unit area of the land surface and ignoring runon and subsurface lateral flow, a one-dimensional water balance equation to the depth of plant rooting is

$$dS/dt = P - Q - ET - L \qquad (1)$$

where in terms of unit area:

S = Soil moisture in the profile (mm),
t = Time in days, months, or years,
P = Precipitation amount or depth (mm),
Q = Runoff amount (mm),
ET = Soil evaporation and plant transpiration or evapotranspiration (mm), and
L = Percolation below the rooting depth (mm).

Daily precipitation at Rock Valley for the period 1965 - 1976 were used in the CREAMS model to solve Eq. 1, on a daily time step, and to compute a monthly and average annual water balance. Average monthly water balance data for the 12 years of record are summarized in Table 1.

Even with a mean annual precipitation as low as 151 mm, the model predicted some percolation (average annual value of 2.1 mm). The percolation below the root zone (in this case the rooting depth was 635 mm) was predicted to occur in February and March.

Examination of the modeling results showed that all the percolation was predicted to have occurred in 1969, the wettest year during the 12 year period of record. Average monthly water balance data for 1969 are shown in Table 2. In summary, the model predicted percolation below the 635 mm deep root zone in only one year of the 12 year record, and the percolation was predicted to occur in February and March of 1969 in response to 207 mm of precipitation in January-March.

Table 1. Summary of monthly water balance estimates for Rock Valley, Nevada for 1965 - 1976 using the CREAMS model and observed precipitation data. The model parameters were taken from Lane, et al. (1984).

ANNUAL AVERAGES IN MM

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW*
JAN	15	.08	13	.00	24
FEB	27	2.01	15	1.60	31
MAR	17	.05	23	.46	34
APR	6	.00	19	.00	21
MAY	6	.00	12	.00	11
JUN	5	.00	8	.00	7
JUL	9	.00	10	.00	6
AUG	13	.00	11	.00	6
SEP	11	.10	11	.00	8
OCT	10	.05	9	.00	8
NOV	13	.00	9	.00	10
DEC	19	.28	9	.00	16
ANNUAL	151	2.57	149	2.06	15

* Average plant-available soil water.

Representativeness of the Record

Twelve years of record is too short to be statistically representative of climate in desert areas such as Rock Valley, NV. Nonetheless, the Rock Valley data do represent what has happened in the past and what, undoubtedly, will occur in the future. Recognizing the uncertainty from such a short record, we conducted a frequency analysis of the 12 years of observed annual precipitation at Rock Valley.

The 296 mm of precipitation in 1969 has a return period of about 25 years. That is, about once in every 25 years we might expect 296 mm or more of precipitation at Rock Valley. Although there is a great deal of uncertainty in this 25-year return period, we do know that annual precipitation exceeding about 300 mm at Rock valley is not a rare event in the context of the design period, or expected lifetime, of a high-level waste repository.

Table 2. Summary of monthly water balance estimates for Rock Valley, Nevada for 1969, the wettest year in the period 1965-1976, using the CREAMS model and observed precipitation data. The model parameters were taken from Lane, et al. (1984).

VALUES FOR 1969 IN MM

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW
JAN	72	.97	18	.00	16
FEB	113	22.53	23	19.08	53
MAR	22	.00	36	5.59	91
APR	1	.00	29	.00	66
MAY	3	.00	25	.00	40
JUN	18	.00	20	.00	29
JUL	5	.00	18	.00	21
AUG	36	.00	26	.00	26
SEP	0	.00	15	.00	16
OCT	7	.00	10	.00	7
NOV	19	.00	11	.00	11
DEC	0	.00	8	.00	10
ANNUAL	296	23.50	239	24.67	32

Probability of Upland Recharge

From soils descriptions at Rock Valley (i.e. Romney, et al., 1973) textures range from sand to gravelly, sandy loam. As a result, a minimum saturated hydraulic conductivity for the 635 mm root zone was estimated as 16 mm/h. If the root zone is underlain by hardpan (calcrete), then the minimum saturated conductivity might be an order of magnitude smaller.

Moreover, one might expect significant spatial variability in saturated hydraulic conductivity which would affect the spatial estimates of upland recharge. Therefore, we estimated likely spatial variations in saturated hydraulic conductivity for the case where the sandy soils continue below the rooting depth and for the case where they are underlain by calcrete.

We assumed a spatial mean of 16 mm/h in the first case and 2.5 mm/h in the second case. Next, we assumed a log-normal distribution for saturated hydraulic conductivity variations in space and assumed a coefficient of variation of 1.0. Probability distributions under these assumptions for the continuous sandy soil case and for the sandy soil over calcrete case suggest the following. Under the continuous sandy soil case, under one percent of the area has values of saturated hydraulic conductivities less than 4 mm/h. In the sand over calcrete case, one percent of the area is expected to have saturated hydraulic conductivities less than about 0.5 mm/h.

Values of saturated hydraulic conductivity in the CREAMS model were varied from 0.0 to 16 mm/h and the water balance was calculated. Estimates of mean annual percolation below the root zone as a function of saturated hydraulic conductivity are shown in Fig. 1. Notice that percolation is predicted for all values of saturated hydraulic conductivity above 0.25 mm/h.

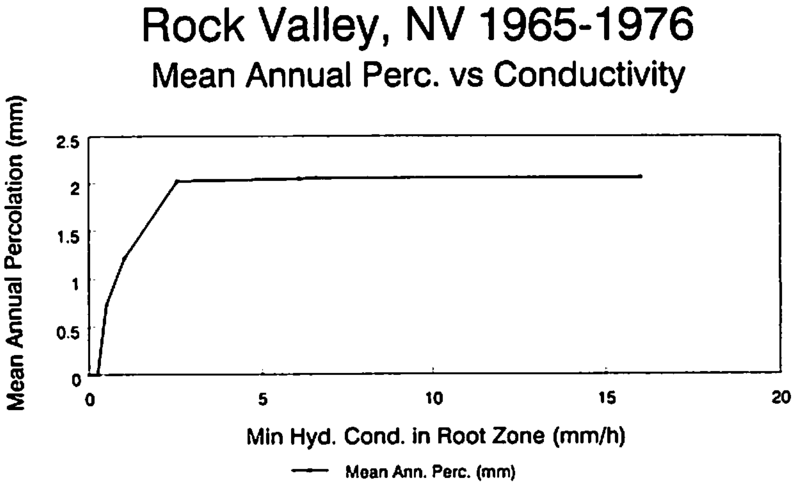

Figure 1. Variation of estimated percolation below a 635 mm root zone with variations in assumed saturated hydraulic conductivity.

Summary of Interpretations

If variations in mean annual precipitation follow a log-normal distribution, spatial variations in saturated hydraulic conductivity are approximately log-normally distributed with a coefficient of variation of 1.0, and the CREAMS model is valid, then about once every 25 years we might expect some percolation below the rooting depth at Rock Valley. Moreover, some percolation probably occurs over most of the area.

The CREAMS model assumes no percolation below the root zone so long as soil moisture remains below field capacity. If unsaturated flow occurs at soil moisture levels lower than field capacity, then there could be unsaturated flow when the CREAMS model predicts none.

Although tentative, there is a strong suggestion from the water balance calculations that percolation below the root zone, and thus upland recharge, can occur in areas similar to Rock Valley. If true, then upland recharge would also be expected to occur in the Fortymile Canyon Watershed. This may be especially true given the higher precipitation in the upper drainage areas of Fortymile Canyon and the greater variations in soils and vegetation than in Rock Valley.

Recharge Rates in Ephemeral Stream Channels

Just as procedures have been developed to estimate a water balance on upland areas, approximate estimation methods are also available to estimate transmission losses (infiltration to stream channel bed and banks) and thus potential groundwater recharge through the stream channel network (Lane, 1990).

To apply the model on Fortymile Canyon and its tributaries, values of the model parameters would need to be obtained by calibration or indirect estimation. Available streamflow data in the Nevada Test Site region and water level data in wells in and adjacent to Fortymile Canyon need to be examined for their suitability in calibrating the transmission loss model.

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