Geostatistical Estimates of Future Recharge for the Death Valley Region

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Introduction

Spatially distributed estimates of regional ground water recharge rates under both current and potential future climates are needed to evaluate a potential geologic repository for high-level nuclear waste at Yucca Mountain, Nevada, which is located within the Death Valley ground-water region (DVGWR)[1]. Determining the spatial distribution of recharge is important for regional saturated-zone ground-water flow models[2]. In the southern Nevada region, the Maxey-Eakin method has been used for estimating recharge based on average annual precipitation[3]. Although this method does not directly account for a variety of location-specific factors which control recharge (such as bedrock permeability, soil cover, and net radiation), precipitation is the primary factor that controls in the region. Estimates of recharge obtained by using the Maxey-Eakin method are comparable to estimates of recharge obtained by using chloride balance studies[4,5]. The authors consider the Maxey-Eakin approach as a relatively simple method of obtaining preliminary estimates of recharge on a regional scale.

Methods

Estimates of present-day average annual precipitation were obtained for the DVGWR by using a multivariate geostatistical model, which accounts for orographic effects on the spatial distribution of precipitation[6,7]. The model was developed using geostatistical analysis of the spatial cross-correlation between average annual precipitation and elevation for precipitation stations located in the south-central Great Basin. The geostatistical model was applied using available digital elevation data[8] and the method of cokriging to produce a spatially detailed average annual precipitation map for present-day climate. A continuous function was visually fitted to the original Maxey-Eakin step function, which defines recharge as different percentages of average annual precipitation depending on the magnitude of average annual precipitation. Estimates of recharge obtained by using the chloride balance method[4] were also considered in fitting the model. The modified Maxey-Eakin model was applied using the detailed present-day average annual precipitation map to obtain an average annual recharge map for the DVGWR under present-day conditions.

Simulations of the regional distribution of average annual precipitation for two potential future climate scenarios were provided by the National Center for Atmospheric Research (NCAR) (S.L. Thompson, C.A. Shields, D. Pollard, C.A. D'Ambra, National Center for Atmospheric Research, written commun., 1996; S.L. Thompson, C.A. Shields, D. Pollard, National Center for Atmospheric Research, written commun., 1996). The two climates consist of a double carbon-dioxide climate (potential greenhouse near-future climate) and a paleoclimate which was simulated using boundary conditions for the glacial period of 21,000 years ago (potential long-term future climate). The level of detail provided by the NCAR estimates of average annual precipitation for the 50 km grid spacing of the nested general circulation model used by NCAR was considered insufficient for the 0.2785 km grid spacing needed for creating a recharge map over the DVGWR. To analyze the relative differences in future versus present day precipitation predicted by the NCAR results, the NCAR simulation of average annual precipitation for each potential future climate was divided by the corresponding NCAR simulation of baseline (present-day) average annual precipitation. Calculated sample variograms provided evidence of strong spatial correlation in the ratios of average annual precipitation for distances less than 50 km. By using a simple spherical variogram model and the method of kriging, the calculated ratios were interpolated onto the denser grid (0.2785 km spacing) of the available digital elevation data (figure 1). The kriged ratio maps, which indicate the relative changes in precipitation for the double carbon-dioxide climate (figure 1) and the 21,000 year paleoclimate relative to present-day climate, were multiplied with the cokriged present-day average annual precipitation map (obtained by using the multivariate geostatistical model) to provide spatially detailed

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average annual precipitation maps for the potential future climates. These results were applied using the modified Maxey-Eakin relation to obtain spatially detailed recharge maps for the potential future climates.

Results

Estimates of average annual precipitation for the DVGWR under current climate resulted in a region-wide average precipitation rate of 176 mm/year, with a maximum of 591 mm/year and a minimum of 62 mm/year. The corresponding estimates of recharge resulted in a region-wide average of 3.8 mm/year, with a maximum of 195 mm/year and a minimum of 0 mm/year. For the double carbon-dioxide climate, estimates of precipitation resulted in a 21 percent increase (relative to present-day climate) in total precipitation for the DVGWR, with a region-wide average rate of 213 mm/year, a maximum of 643 mm/year, and a minimum of 78 mm/year (figure 2). The corresponding estimates of recharge resulted in a 107 percent increase in total recharge, with a region-wide average of 7.9 mm/year, a maximum of 254 mm/year, and a minimum of 0 mm/year (figure 3). For the 21,000 year paleoclimate, estimates of precipitation resulted in a 68 percent increase in region-wide precipitation, with an average rate of 297 mm/year, a maximum rate of 961 mm/year, and a minimum rate of 79 mm/year. The corresponding estimates of recharge resulted in a 648 percent increase in total recharge, a region-wide average recharge rate of 29 mm/year, maximum recharge rates in excess of 600 mm/year, and a minimum rate of 0 mm/year. For both potential future climates, maximum recharge estimates occur at elevations that exceed 3,000 m, whereas minimum estimates of 0 mm/year occur for elevations of 1,000 m and less in Death Valley. Maximum recharge estimates in excess of 500 to 600 mm/year were questionable because of extrapolation of the modified Maxey-Eakin relation, which was developed in an arid environment, to such wet conditions.

Summary and Conclusions

Spatially detailed estimates of recharge were obtained for the Death Valley ground-water region (DVGWR) by use of a geostatistical model of average annual precipitation, simulations of regionally distributed average annual precipitation which were provided by NCAR for two potential future climates along with the corresponding baseline simulations of present-day conditions, and by use an empirical Maxey-Eakin type model for estimating recharge based on modeled average annual precipitation. Although the 50 km grid spacing used in the NCAR simulations did not provide sufficient detail in terms of orographic influences on precipitation throughout the DVGWR, the calculated ratio of potential future climate to present-day precipitation indicated strong spatial correlation was interpolated onto the denser 0.2785 km grid spacing of available digital elevation data for the DVGWR. Multiplying the calculated ratios with the cokriged present-day average annual precipitation map resulted in spatially detailed average annual precipitation maps for potential future climates, which were used for modeling recharge based on the empirical Maxey-Eakin type model. The results indicate that recharge magnitudes for the DVGWR are likely to increase substantially for potential wetter future climates, with a 107 percent increase in total recharge for the double carbon-dioxide climate, and a 648 percent increase in total recharge to the DVGWR for the 21,000 year paleoclimate.

References

1. Bedinger, M.S., Sargent, K.A., and Langer, W.H., 1989, Studies of geology and hydrology in the Basin and Range province, southwestern United States, for isolation of high-level radioactive waste-characterization of the Death Valley region, Nevada and California: U.S. Geological Survey Professional Paper 1370-F, 49 p.

2. D'Agnese, F.A., Faunt, C.C, Turner, K.A., and Hill M.C., 1997, Hydrogeologic Evaluation and Numerical Simulation of the Death Valley Regional Ground-Water Flow System, Nevada and California: U.S. Geological Survey Water-Resources Investigations Report 96-4300, 124 p.

3. Maxey, G.B., and Eakin, T.E., 1949, Ground-water in White River Valley, White Pine, Nye, and Lincoln Counties, Nevada: Reno, Nevada State Engineer Water Resources Bulletin 8, 59 p.

4. Lichty, R.W., and McKinley, P.W., 1995, Estimates of ground-water recharge rates for two small basins in central Nevada: U.S. Geological Survey Water-Resources Investigations Report 94-4104, 31 p.

5. Dettinger, M.D., 1989, Reconnaissance estimates of natural recharge to desert basins in Nevada, U.S.A., by using chloride-balance calculations: Journal of Hydrology, v. 106, p. 55-78

6. Hevesi, J.A., Istok, J.D. and Flint, A.L., 1992, Precipitation estimation in mountainous terrain using multi variate geostatistics--part I, Structural analysis: Journal of Applied Meteorology, v. 31, no. 7, p. 661-676.

References (continued)

7. Hevesi, J.A., Flint, A.L., and Istok, J.D., 1992, Precipitation estimation in mountainous terrain using multi variate geostatistics--part II, Isohyetal maps: Journal of Applied Meteorology, v. 31, no. 7, p. 677-688.

8. Turner, A.K., D'Agnese, F.A., and Faunt, C.C., 1996, Digital elevation model (DEM) file of topographic elevations for the Death Valley region of Southern Nevada and Southeastern California processed from U.S. Geological Survey 1-degree digital elevation model data files: U.S. Geological Survey Open-File Report 95-287, 9 p.

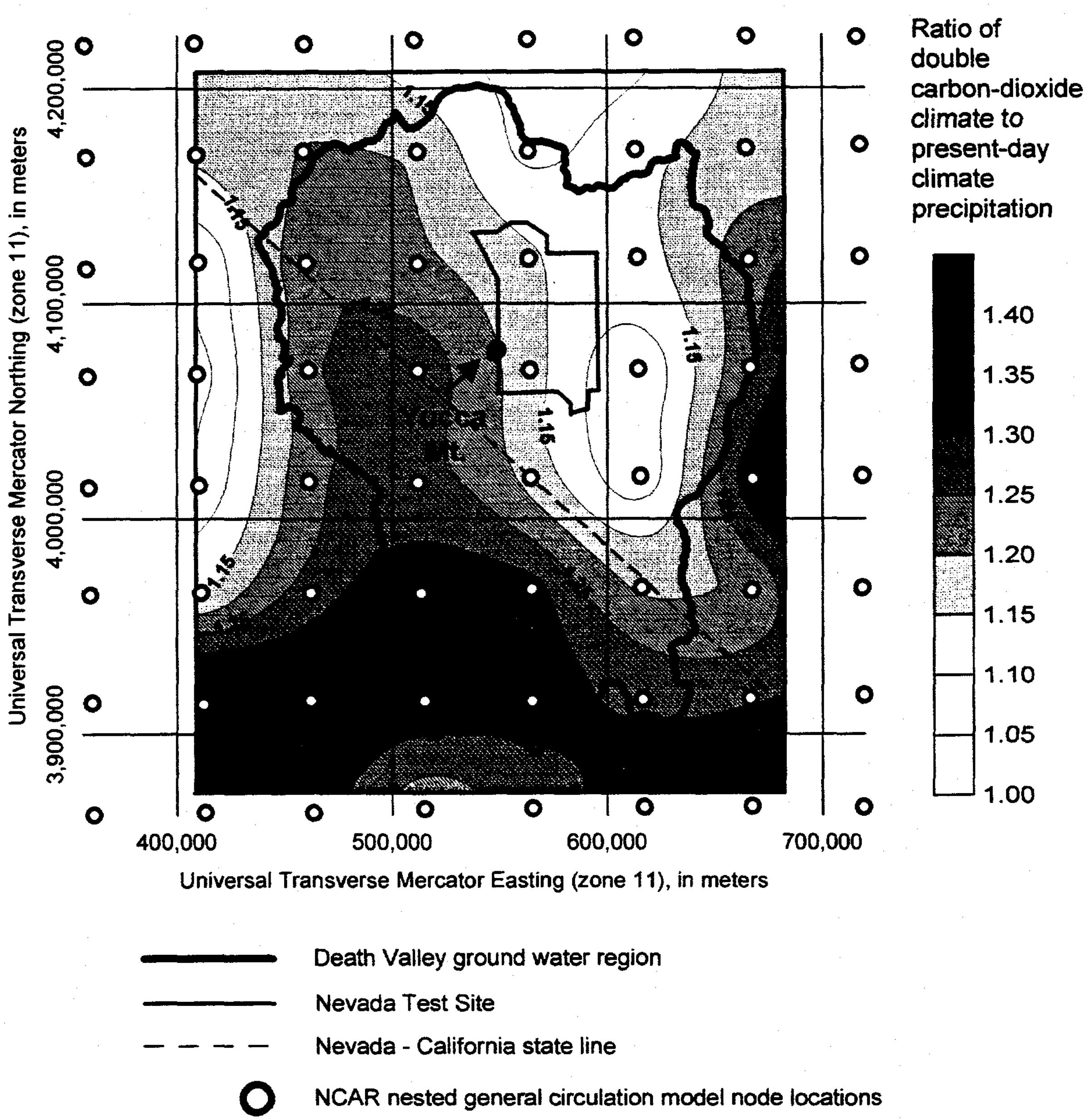

Figure 1. Kriged ratio of average annual precipitation for NCAR simulated double carbon-dioxide (greenhouse) climate and NCAR simulated present-day climate

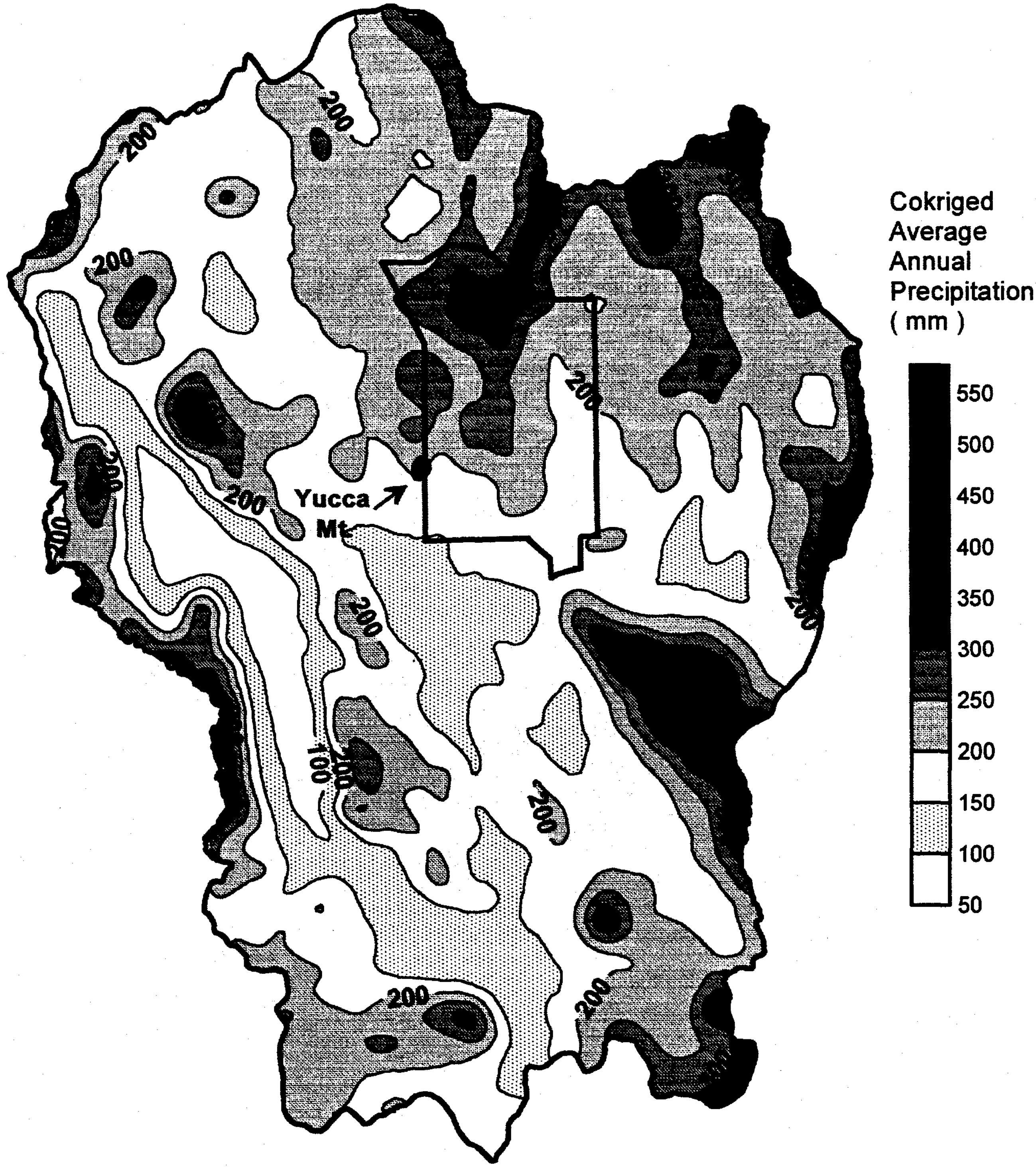

Figure 2. Cokriged average annual precipitation for NCAR simulated double carbon-dioxide (greenhouse) climate. (black indicates estimates greater than 530 mm)

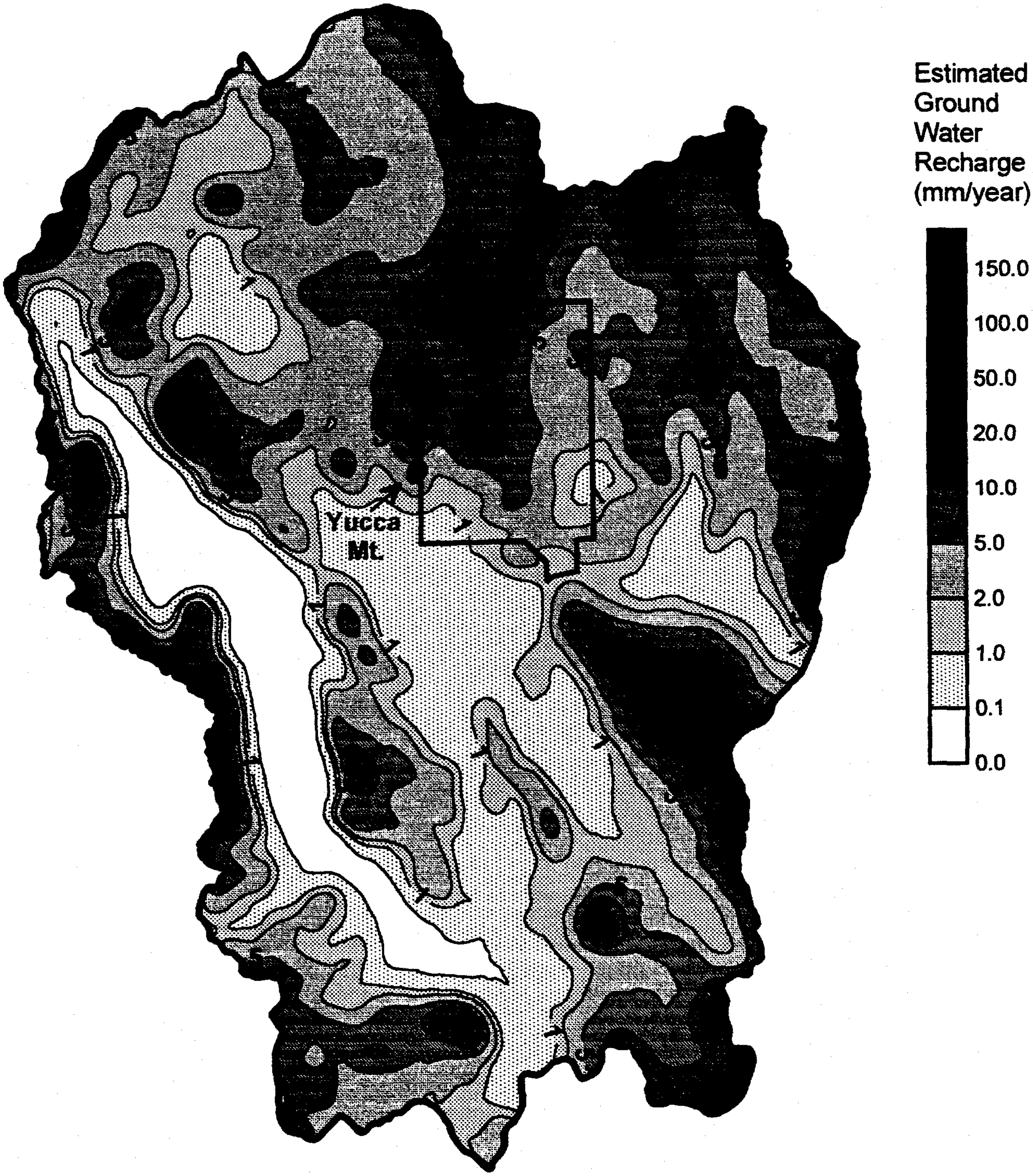

Figure 3. Estimated ground water recharge for double carbon-dioxide (greenhouse) climate. (black indicates recharge estimates greater then 150 mm/year)

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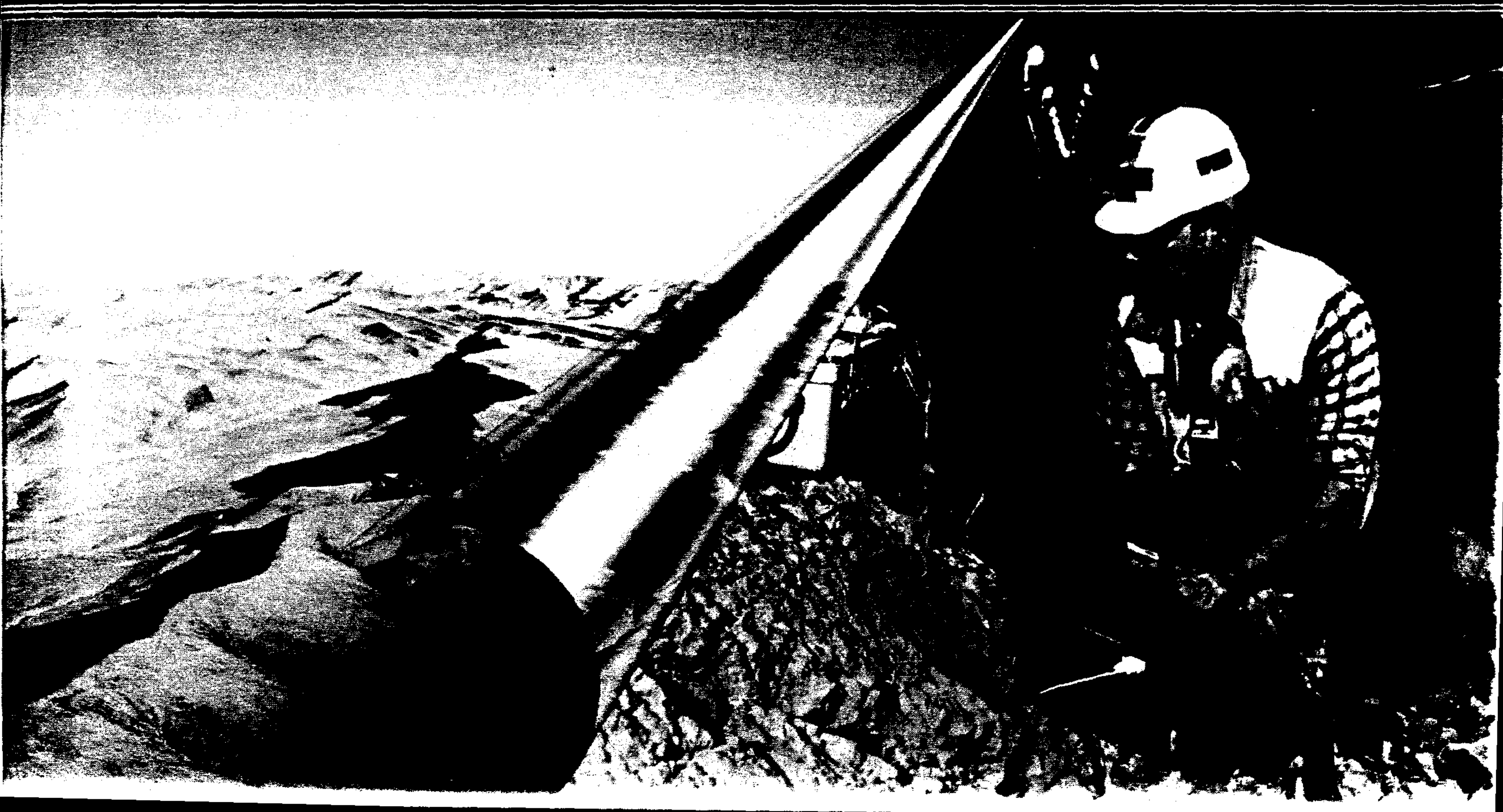

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