INITIAL ESTIMATES OF TRANSMISSIVITY AND LEAKANCE

Initial estimates of transmissivity for the upper model layer are grouped into three geologic units. The estimates were made to provide a starting point for the calibration process in which transmissivities were modified. The geologic units within the modeled area are grouped into three principal types (Harrill and others, 1988; Plume and Carlton, 1988): (1) basin fill, which includes Tertiary tuffs, terrigenous sediments, and Quaternary stream, alluvial fan, and lacustrine deposits; (2) thick sequences of carbonate rocks of Paleozoic and early Mesozoic age; and (3) other consolidated rocks, which include clastic sedimentary rocks, intrusive and extrusive igneous rocks, metamorphic rocks, and locally thick units of Tertiary clay and silt. Figure 15 shows how the principal rock types are distributed in the upper layer. The basin-and-range physiography can be easily distinguished with the resolution provided by the 5-mi by 7.5-mi grid.

Carbonate rocks are assumed to have the highest transmissivity. The initial transmissivity assigned to cells in the upper model layer representing carbonate rocks was 0.25 ft^2/s, within the range of values reported by Winograd and Thordarson (1975, table 3 and p. 73), Bunch and Harrill (1984, p. 119), and Plume (1989). Reported values range from about 0.002 ft^2/s (200 ft^2/d) to about 9 ft^2/s (800,000 ft^2/d). Initial transmissivity assigned to cells representing other consolidated rocks was 0.002 ft^2/s; the initial value assigned to cells representing basin fill was 0.02 ft^2/s, within the range of values presented by Winograd and Thordarson (1975, table 3) and Bunch and Harrill (1984, p. 115). A uniform value of 0.25 ft^2/s was initially assigned to all cells in the lower layer.

Transmissivities of each rock type actually vary widely due to either changes in thickness or differing hydrologic properties of the rocks. The transmissivities for each model cell changed during model calibration. The vertical resistance to ground-water flow is simulated in the model with a vertical leakance term. Vertical leakance is defined as the vertical hydraulic conductivity divided by length of flow path (Lohman, 1972, p. 30). A vertical leakance of 1×10^{-11} per second was initially assumed for all cells. No attempt was made to distinguish leakance values according to hydrogeologic conditions because of the uncertainty of the geologic units at depth and because of uncertainties in estimating the vertical hydraulic conductivity and the length of the flow path. The vertical leakances also changed during model calibration.

MODEL CALIBRATION

Initial model calibration began by assigning an estimated water level to each model cell. In many cells, particularly in the lower layer, the assigned water levels were interpolated and extrapolated from data many miles away. Transmissivities of cells in the upper and lower model layers and vertical leakances of cells between layers were initially adjusted on the basis of comparing simulated water levels to those assigned to the model cells. Two computer programs were written and used to automatically adjust both transmissivities and vertical leakances. The first program adjusted transmissivities in cells where the simulated water levels were either too high or too low compared to the assigned water levels. Transmissivities were increased or decreased depending on the ratio of the simulated water level to the assigned water level. The method worked reasonably well because simulated heads were either too high or too low over large regions of the model.

The second program adjusted vertical leakances between adjacent cells in the upper and lower model layers during alternate simulations. Vertical leakances were adjusted using the ratio of the simulated water-level difference to the assigned water-level difference as expressed in the following equation (Williamson and others, 1989, p. 32):

$$Lnew = Lold * FAC * (\Delta HVmod/\Delta HVas)$$

where Lnew = the adjusted vertical leakance value;

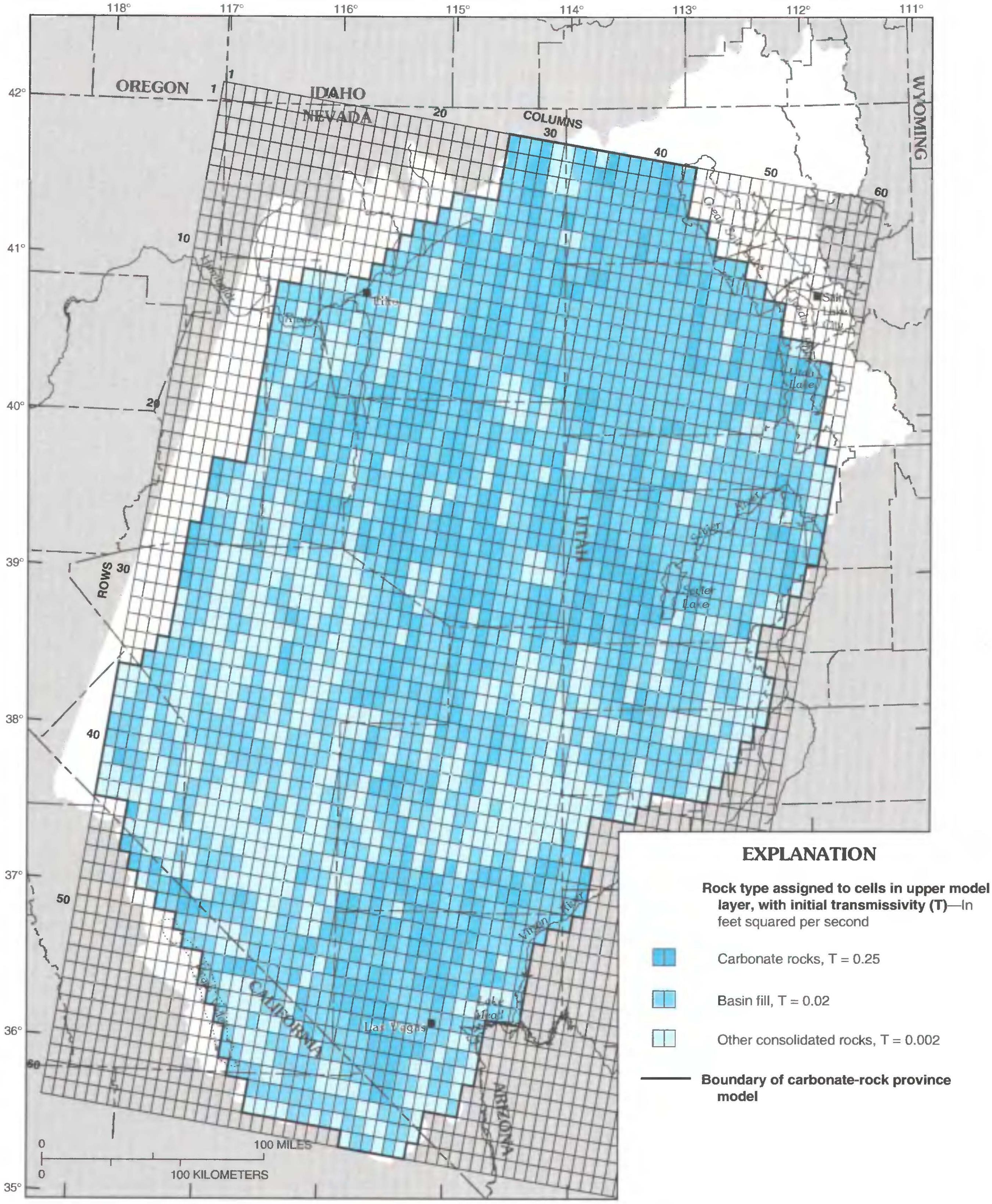
Lold = the previous vertical leakance value;

ΔHVmod = the simulated water-level difference of adjacent cells between the upper and lower model layers;

ΔHVas = the assigned water-level difference of adjacent cells between the upper and lower model layers; and

FAC = 0.9 when the ratio of ΔHVmod to ΔHVas is less than 1, 1.1 when the ratio is greater than 1, and 1.0 when the ratio is 1.

The computer programs do not correctly adjust transmissivities or vertical leakances on the first



Base modified from U.S. Geological Survey digital linegraph data, 1:100,000 and 1:250,000, 1987
Albers Equal-Area Conic projection
Standard parallels 29°30' and 45°30', central meridian -114°

FIGURE 15.—Principal rock types assigned to cells in upper model layer, and initial transmissivities used.

computation because flow to and from a cell may change after adjusting the vertical leakance and the transmissivities in adjacent cells. Thus, the process involved numerous simulations that alternately adjusted transmissivities and vertical leakances. The use of these programs ceased once the simulated water levels over the entire model generally matched the water levels presented by Thomas and others (1986).

The final part of model calibration involved (1) testing the range in transmissivities and vertical leakances calculated from the initial calibration by comparing the simulated water levels in 773 selected cells in the upper layer and 144 cells in the lower layer where water levels had been estimated from the maps by Thomas and others (1986), (2) making regional and local changes to transmissivities and vertical leakances until simulated discharge as evapotranspiration in the upper model layer and regional spring flow in the lower layer approximated estimated values, and (3) adjusting conductance values at head-dependent flow boundaries.

Transmissivities following the initial calibration ranged from 2.5×10^{-4} to 2.5 ft^2/s in the upper layer and from 2.5×10^{-4} to 2.5×10^{-1} ft^2/s in the lower layer. During the final phase of model calibration, both transmissivities and vertical leakances were rounded to the nearest exponent (1×10^{-4}; 1×10^{-3}; 1×10^{-2}; and so forth) without affecting the simulation results. The rounding of both transmissivities and vertical leakances is reasonable because of the lack of information on the extent and distribution of aquifers, their hydraulic properties, and the lack of ground-water levels in many areas. Such groupings also simplified the final calibration while reasonably duplicating regional ground-water levels, and the distribution and quantity of discharge. The best match with estimated water levels and discharge was simulated when the grouped transmissivities were multiplied by a factor of 2.2 in the upper layer and when the values were multiplied by a factor of 3.3 in the lower layer. In a few areas, transmissivities were further multiplied by a factor ranging from 2 to 5. Even though transmissivities are generally grouped by a factor of 10, the range in simulated transmissivities did not change greatly from the initial calibration. In the upper layer, transmissivities following final calibration ranged from 2.2×10^{-5} to 2.2×10^{-1} ft^2/s; both the minimum and maximum values are about 10 times less than the initially calibrated values. In the lower layer, transmissivities following model calibration ranged from 3.3×10^{-5} to 6.6×10^{-1} ft^2/s.

Vertical leakances following initial calibration ranged from 1×10^{-16} to 3×10^{-9} per second. During final calibration, increasing vertical leakances of less than 1×10^{-13} to that value produced little difference in simulated water levels and discharge. Similarly, decreasing values greater than 1×10^{-11} to that value also produced little differences. Finally, all other leakance values were rounded to values of 1×10^{-11}, 1×10^{-12}, or 1×10^{-13} per second. The distribution of vertical leakances is shown in figure 16.

The average vertical leakance for all model cells is 4×10^{-12} per second. Overall, 62 percent of cells (1,517 of 2,456) have a value of 1×10^{-12} per second, 34 percent (833 cells) have a value of 1×10^{-11} per second, and only 4 percent (106 cells) have a value of 1×10^{-13} per second. Most of the cells (95 out of 106) having the lowest vertical leakances are in or adjacent to the Great Salt Lake Desert. More than half of the cells having the highest leakances (455 out of 833) are in the central third of the modeled area (rows 21 to 40). In contrast, only 17 percent of the cells having the highest leakances (140 out of 833) are in the southern third of the modeled area (rows 41 to 61). In the central part, about half of the highest leakances correspond to mountain ranges, whereas in the southern third, 60 percent correspond to mountain ranges.

The magnitudes of the computed transmissivities and vertical leakances are dependent on the quantity of assigned recharge. Increasing recharge results in a corresponding increase in discharge and requires a proportional increase in transmissivities and vertical leakances to maintain the same head gradients. The estimates of recharge are only approximations; thus, recharge was increased by a factor of 2 and decreased by a factor of 2 during model calibration to evaluate its effect on transmissivities and vertical leakances.

Conductances used for the head-dependent flow boundaries range from 0.005 to 0.5 ft^2/s and average 0.13 ft^2/s for the 94 cells. Only one cell has a value of 0.005, and three have a value of 0.5. Conductances are slightly different between the different areas. Conductances for the Humboldt River range from 0.1 to 0.5 ft^2/s and average 0.24 ft^2/s; more than half of the cells (11 of 20) have a value of 0.3 ft^2/s. Conductances for the Great Salt Lake and Utah Lake are 0.1 ft^2/s, except for four cells along the Great Salt Lake, which

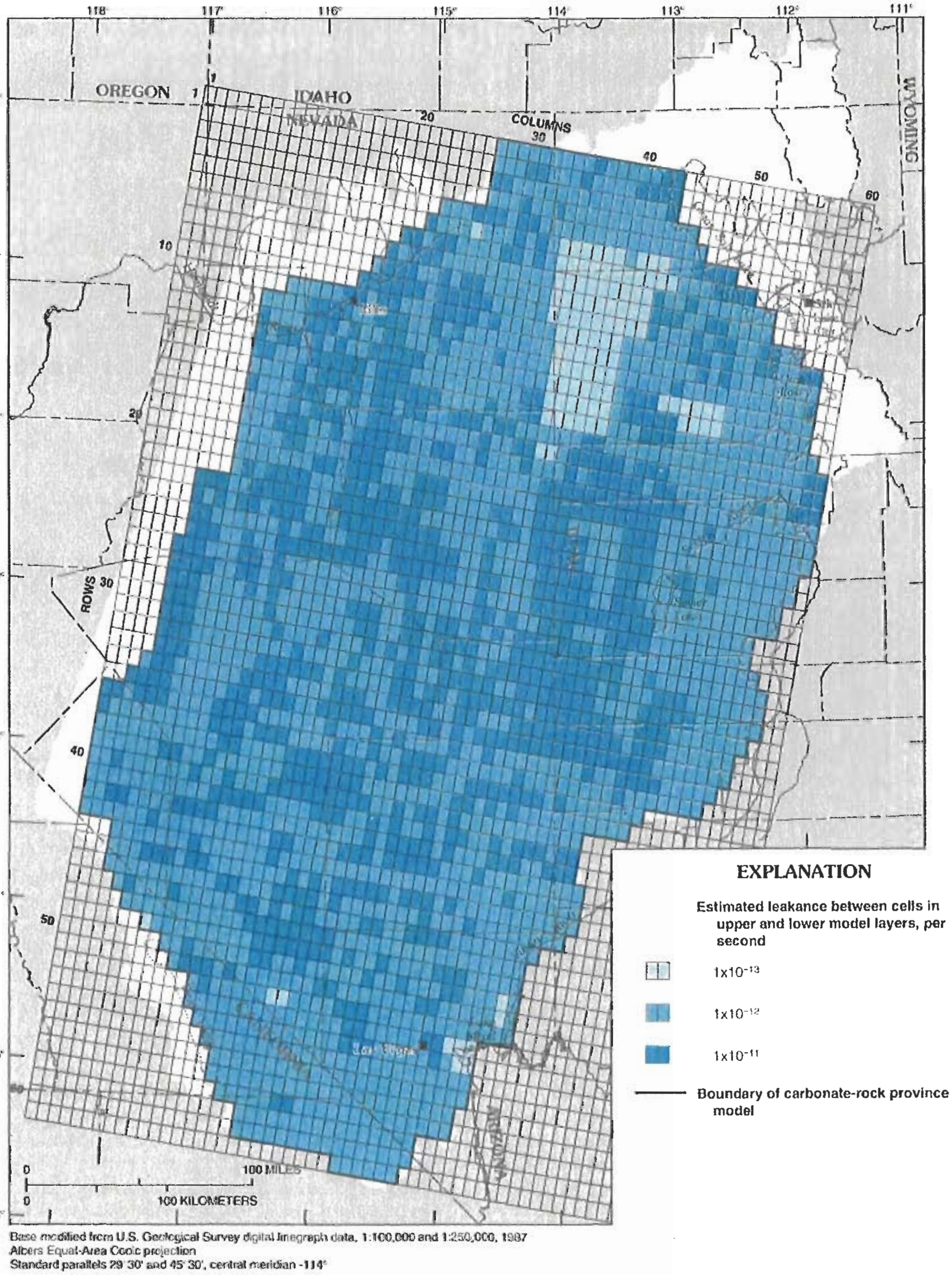


FIGURE 16.—Estimated vertical leakance between cells in upper and lower model layers.