Three-dimentional Unsaturated-Saturated Flow and Transport, and Subsidence
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Executive Summary

Shallow water tables, inadequate drainage and resulting accumulation of salts in the root zone have been persistent problems in the western San Joaquin Valley of California. In most areas where the ground water table is less than 5 feet from the land surface, water is drawn upward and evaporates, leaving a deposit of salts on the surface and in the root zone which retards the growth of many crops. If the present trend continues and no comprehensive action is taken to solve drainage problems, the extent of the drainage problem area with the water table less than 5 feet from the ground surface may exceed 1,00,000 acres by the year of 2040 (SJV Drainage Program 199). In the absence of comprehensive drainage management, these problems would lead to changes in farming practices and cause loss of farm income through conversion from salt-sensitive to salt-tolerant crops. Eventually, the value of the lands for irrigated agriculture would decline to a level that would force abandonment of the lands.

Since a major source of recharge to groundwater is from irrigation, problems become more complicated in the drainage problem areas where the saline water table is shallow. Because of the complexities of the interacting factors involved in solving problems, objectives of the long term percolation on lands with drainage problems and to estimate feasible groundwater pumping rates. Different strategies to reduce drainage volumes and to meet water quality objectives should be formulated based on a model that takes into account the unsaturated zone as well as the saturated because the percolation of water through the unsaturated zone is the major recharge of the local groundwater system. Groundwater management strategies must be both economically and environmentally feasible for managing shallow, saline water tables as well as for avoiding land subsidence caused by groundwater overdraft.

Land subsidence which began in the mid-1920s due to intensive pumping of groundwater for irrigation has caused widespread concern in the SJV. Water levels declined at unprecedented rates during the 1950s and early 1060s. By 1970, 5,200 square miles of irrigated land had been affected, and maximum subsidence exceeded 28 feet (Ireland et al., 1984). Subsidence in SJV caused serious and costly problems in construction and maintenance of water transport structures, repair or replacement of deep water wells. In 1956, an intensive study was initiated by Federal and State agencies to investigate the extent, rates and causes of subsidence in the SJV and to determine principles of controlling the compaction and expansion of aquifer systems under pumping stresses and the hydraulic storage parameters from field measurements (Ireland, et al., 1984). The magnitude and the rate of subsidence is directly related to change in effective stress due to decrease in water levels, and to the thickness and compressibility of the material which is under compaction. Subsidence causes not only serious and costly environmental problems, but also changes the water flow and solute transport characteristics due to the reduction in permeability with decreasing void ratio.

Our objectives will be:

1) To adapt a three-dimensional finite element model SWMS_3D which is capable of simulating unsaturated-saturated water flow and solute transport, subject to root water uptake, drainage, and various fluxes at the soil atmosphere interface due to different irrigation practices,
2) To evaluate the pumping rate of groundwater without exceeding the safe yield of the aquifers in the presence of storage coefficient term in the flow equation and to introduce alternative groundwater management strategies to reduce land subsidence as a consequence of groundwater pumping,
3) To investigate the influence of different input parameters including irrigation data (i.e., irrigation dates of different crops planted at different locations, and the corresponding irrigation amounts and salt concentrations), soil property data (i.e., initial water content and initial soil salt concentration for each type of soil layer), boundary conditions, initial conditions as well as a variety of processes such as drainage, infiltration, groundwater pumping both from the semi-confined and the confined aquifers on water and solute movement,
4) To display the spatial distribution of soil salinity profiles, drainage amounts and salt loading to groundwater, groundwater quality and levels using a powerful display and analysis tool of GIS and Data Explorer. We will visually define the areas where the greatest attention must be given, and formulate different strategies so that the downward flux of salt can be reduced through changes in irrigation and groundwater management strategies.

Choice of the present model is based on several reasons; SWMS_3D is sufficiently flexible to be applied to a wide range of problems. The model will integrate processes of saturated/unsatured flow, dispersive-sorptive solute transport, root water uptake and transpiration, bare-soil evaporation, the treatment of subsurface drains and various fluxes at the soil atmosphere interface due to different irrigation practices. The study by Dursun Buyuktas (Ph.D supported by the Salinity/Drainage Task Force) was a guideline for the selection of the model. He showed that the model is capable of simulating various unsaturated/saturated water flow and transport problems composed of heterogeneous materials and complex geometry by comparing model-generated values with analytical/experimental data. The proposed model will have general applicability, not only in studying the movement of water and solute in shallow groundwater systems in which the role of the unsaturated zoned can be of considerable importance but also in studying a variety of problems related to ground settlement. It is believed that the model will be of practical interest in unsaturated and saturated systems undergoing simultaneous desaturation and deformation. The results from the proposed research can be critical as a guide for management strategies.

A very high nonlinearity of the flow equation in the unsaturated zone due to nonlinear hydraulic properties and pressure head relationship may result in large computer memory requirement and computer execution time, but our lab is able to access super computers to accomplish this task.