Attachment G

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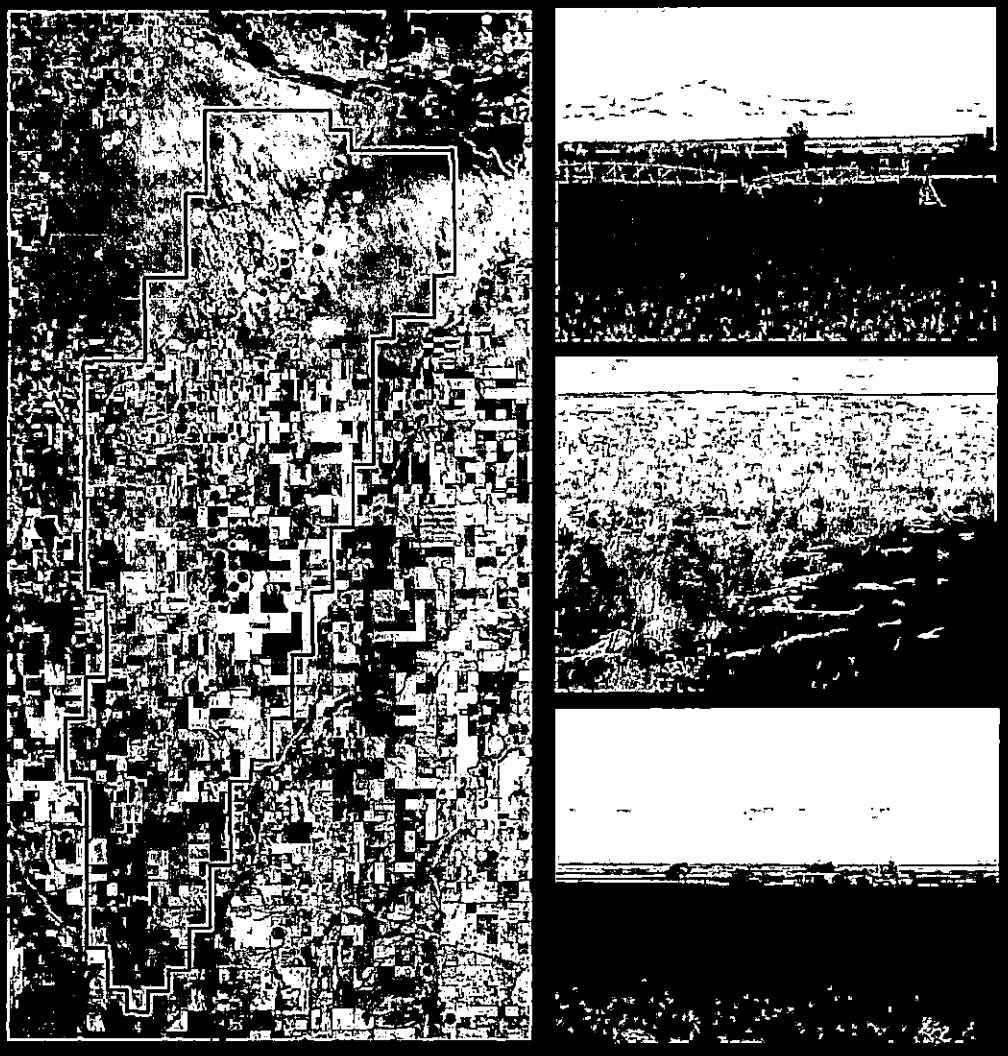
Prepared in cooperation with the Lost Creek Ground Water Management District and the Colorado Water Conservation Board

Hydrogeology and Steady-State Numerical Simulation of Groundwater Flow in the Lost Creek Designated Ground Water Basin, Weld, Adams, and Arapahoe Counties, Colorado



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Hydrogeology and Steady-State Numerical Simulation of Groundwater Flow in the Lost Creek Designated Ground Water Basin, Weld, Adams, and Arapahoe Counties, Colorado

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Abstract

The Lost Creek Designated Ground Water Basin (Lost Creek basin) is an important alluvial aquifer for irrigation, public supply, and domestic water uses in northeastern Colorado. Urban growth in the adjacent Front Range urban corridor has increased demand for groundwater in the basin, and potential exportation of groundwater from the basin has raised concerns about the long-term sustainability and management of the basin's groundwater resources. Beginning in 2005, the U.S. Geological Survey, in cooperation with the Lost Creek Ground Water Management District and the Colorado Water Conservation Board, collected hydrologic data and constructed a numerical groundwater flow model of the Lost Creek basin. The steady-state model builds upon the work of previous investigators to provide an updated tool for simulating the potential effects of various hydrologic stresses on groundwater flow and evaluating possible aquifer-management strategies.

As part of model development, the thickness and extent of regolith sediments in the basin were mapped, and data were collected concerning aquifer recharge beneath native grassland, nonirrigated agricultural fields, irrigated agricultural fields, and ephemeral stream channels. The thickness and extent of regolith in the Lost Creek basin indicate the presence of a 2- to 7-mile-wide buried paleovalley that extends along the Lost Creek basin from south to north, where it joins the alluvial valley of the South Platte River valley. Regolith that fills the paleovalley is as much as about 190 ft thick. Recharge from infiltration of precipitation on native grassland and nonirrigated agricultural fields was estimated by using the chloride mass-balance method at four sites in the Lost Creek basin. Recharge from infiltration of ephemeral streamflow was estimated by using apparent downward velocities of chloride peaks in soil profiles at two sites in the basin. Recharge from deep percolation of water applied to irrigated agricultural fields was estimated by using passive-wick lysimeters installed at four sites in the basin and by using a water-balance approach. Average annual recharge from infiltration of precipitation on native grassland and nonirrigated agricultural fields was estimated to range from 0.1 to 0.6 inch, which represents about 1–4 percent of long-term average precipitation. Average annual recharge from infiltration of ephemeral streamflow was estimated to range from 5.7 to 8.2 inches. Average annual recharge beneath irrigated agricultural fields was estimated to range from 0 to 11.3 inches, depending on irrigation method, soil type, crop type, and the net quantity of irrigation water applied. Estimated average annual recharge beneath irrigated agricultural fields represents about 0–43 percent of net irrigation.

The U.S. Geological Survey modular groundwater modeling program, MODFLOW–2000, was used to develop a steady-state groundwater flow model of the Lost Creek basin. The model primarily was calibrated to average hydrologic conditions representing the period 1990–2001 by using the inverse modeling capabilities of MODFLOW–2000. Simulated water levels generally have acceptable agreement with water levels measured at 43 locations in the Lost Creek basin, and calibration statistics indicate that residuals between simulated and measured values of hydraulic head likely are random, independent, and normally distributed. Composite scaled sensitivities were highest for parameters representing withdrawals from wells lacking pumping data, recharge beneath nonirrigated areas, and recharge beneath flood-irrigated fields, indicating that these parameters likely are the most important to accurately define for model simulations.

Groundwater in the simulated Lost Creek basin generally flows from basin margins toward the center of the basin and northward along the paleovalley of the basin. The largest source of inflow to the model occurs from recharge beneath flood- and sprinkler-irrigated agricultural fields (14,510 acre-ft/yr), which represents 39.7 percent of total simulated inflow. Other substantial sources of inflow to the model are recharge from precipitation and stream-channel infiltration in nonirrigated areas (13,810 acre-feet per year [acre-ft/yr]), seepage from Olds Reservoir (4,280 acre-ft/yr), and subsurface inflow from ditches and irrigated fields outside the model domain (2,490 acre-ft/yr),

which contribute 37.7, 11.7, and 6.8 percent, respectively, of total inflow. The largest outflow from the model occurs from irrigation well withdrawals (26,760 acre-ft/yr), which represent 73.2 percent of total outflow. Groundwater discharge (6,640 acre-ft/yr) at the downgradient end of the Lost Creek basin represents 18.2 percent of total outflow, and evapotranspiration (3,140 acre-ft/yr) represents about 8.6 percent of total outflow.

Introduction

The Lost Creek Designated Ground Water Basin (Lost Creek basin; fig. 1) consists of an alluvial aquifer that is an important source of water for irrigation, public supply, and domestic use in northeastern Colorado. Perennial streams do not exist within the basin, and groundwater in the basin historically has been used primarily for irrigation of agricultural land within the basin's boundaries. However, urban growth in the adjacent Front Range urban corridor has increased demand for groundwater in the basin, and potential exportation of groundwater from the basin has raised concerns about the long-term sustainability and management of the basin's groundwater resources.

The hydrogeology and groundwater resources of the Lost Creek basin originally were characterized in 1967 by Nelson, Haley, Patterson,and Quirk, Inc. (1967) in a report to the Colorado Ground Water Commission. The purpose of the report was to provide information for legally defining the basin as a Designated Ground Water Basin, subject to a set of water rules separate from the Doctrine of Prior Appropriation used for regulation of tributary waters in the State of Colorado. Designated groundwater in alluvial aquifers generally is defined as groundwater in areas not adjacent to a continuously flowing natural stream wherein groundwater withdrawals have constituted the principal water usage for at least 15 years (Jones and Cech, 2009). Data from the Nelson, Haley, Patterson, and Quirk, Inc. report were used in the development of a steady-state numerical groundwater flow model of the Lost Creek basin in 1995 (Thomas Hatton, J.R. Engineering, Inc., written commun., 2004), and the model subsequently was modified between 1995 and 2004 (Barbara Ford, HRS Water Consultants, Inc., written commun., 2005) for use in simulating the effects of several pumping scenarios under different recharge and hydrogeologic conditions. Since development of the previous groundwater models, new hydrogeologic information has been collected in the Lost Creek basin as part of the U.S. Geological Survey (USGS) National Water Quality Assessment (NAWQA) program and the State of Colorado's South Platte Decision Support System (SPDSS) program.

In 2005 the USGS began a study in cooperation with the Lost Creek Ground Water Management District to review and summarize the 2004 version of the existing groundwater model and to construct an updated numerical groundwater flow model of the Lost Creek basin using new data and numerical simulation capabilities. In 2007, the study was expanded in cooperation with the Colorado Water Conservation Board to collect data concerning aquifer recharge occurring from deep percolation of water applied to agricultural fields within the basin in order to improve estimates of irrigation recharge and reduce model uncertainty as related to irrigation recharge.

Purpose and Scope

The purpose of this report is to describe the hydrogeology and a steady-state numerical groundwater flow model of the Lost Creek Designated Ground Water Basin in Weld, Adams, and Arapahoe Counties in Colorado. The description of hydrogeology provides new information, with particular emphasis on aquifer geometry and recharge, that builds upon the work of previous investigators. The steady-state model also builds upon the work of previous investigators to provide an updated tool for simulating the potential effects of various hydrologic stresses on groundwater flow and evaluating possible aquifer-management strategies.

The extent and thickness of regolith (unconsolidated sediments) in the basin were mapped to better characterize the subsurface geometry of the basin. Water-level data were compiled for the period 1990–2001 for use in calibrating the steady-state groundwater flow model. Data concerning infiltration of precipitation, infiltration from stream channels, deep percolation of water applied to irrigated agricultural fields, ditch and reservoir seepage, and subsurface inflow were collected to improve estimates of recharge to the basin. Data concerning well withdrawals, evapotranspiration, and subsurface outflow were used to estimate discharge from the basin. The USGS modular groundwater modeling program MODFLOW–2000 (Harbaugh and others, 2000; Hill and others, 2000) was used to construct and calibrate the updated steady-state groundwater flow model using inverse-modeling methods.

Study-Area Description

The Lost Creek basin occupies an area of about 432 square miles (mi^2) in parts of Weld, Adams, and Arapahoe Counties in northeastern Colorado (fig. 1). The administrative boundary of the Lost Creek basin is defined approximately by the drainage basin of Lost Creek and its tributaries. Population centers in the basin include the towns of Keenesburg, Roggen, Prospect Valley, and Bennett. The Lost Creek basin is about 43 mi long and extends from about 6 mi south of Bennett northward to the South Platte River valley. The basin is as much as 14 mi wide.

Physiography and Climate

The Lost Creek basin lies within the Colorado Piedmont section of the Great Plains physiographic province (Fenneman, 1946) and generally is characterized by relatively flat to gently sloping terrain with local relief of tens of feet. North of Roggen,