Undated Sid. I believe To be from 2000 or 2001

A Study of Ground-Water Flow and Ground-Water/Surface-Water Interaction in part of the Republican River Basin, Nebraska, Kansas, and Colorado

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U.S. Geological Survey

Outline

- Study Overview
- Model Design & Data Sources
- Important Elements of Study
- Products, Benefits, & Timelines

Cooperators and Funding

- Nebraska Republican River Basin Management Districts
- Southwest Nebraska Resource Conservation and Development Area
- Grant from the Nebraska Environmental Trust Fund to the Management Districts
- Study funded for April 1997 – March 2001

Study Components

- Modeling of ground-water (GW) flow and ground-water/surface-water (GW/SW) interaction in the Republican River Basin (in progress)
- Field studies of GW/SW interaction along tributaries (USGS Report by Gregory Steele)

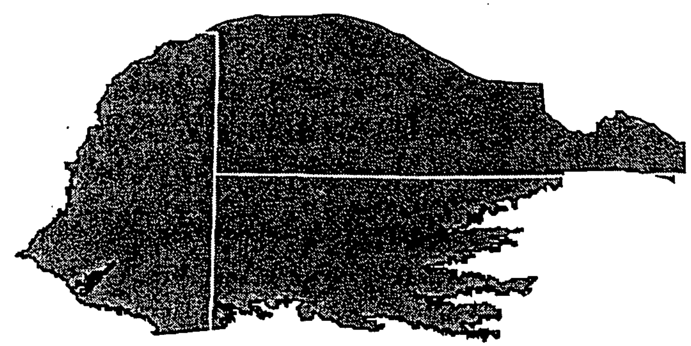
Study Components - con.

- GW quality in the Nebraska part of the Republican River Basin (USGS Report by Jennifer Stanton)

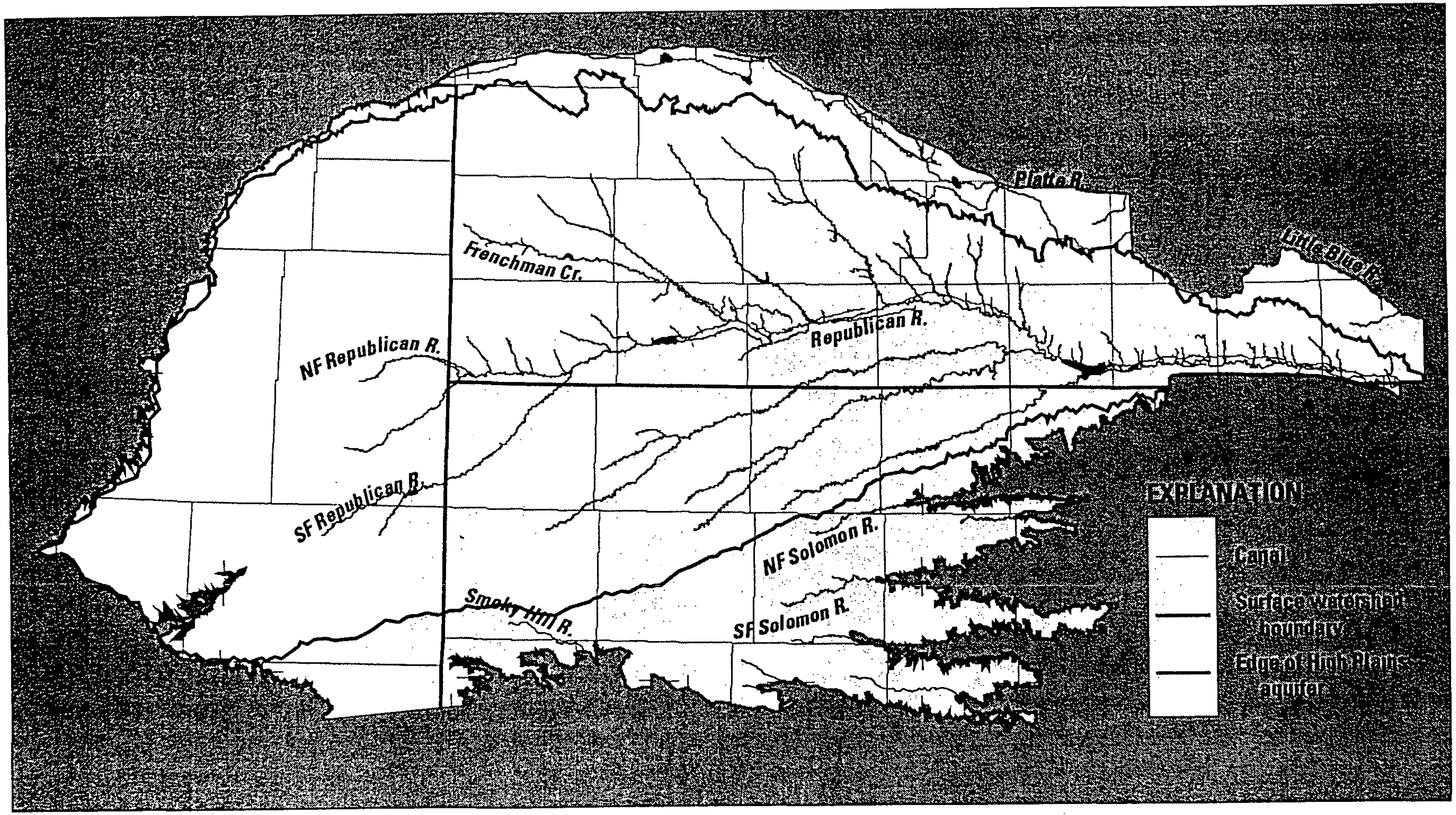
Modeling Objectives

- Quantify GW/SW interaction
- Evaluate the effects of GW pumping scenarios on future streamflow

Republican River Basin Study Area



Republican River Basin Study Area



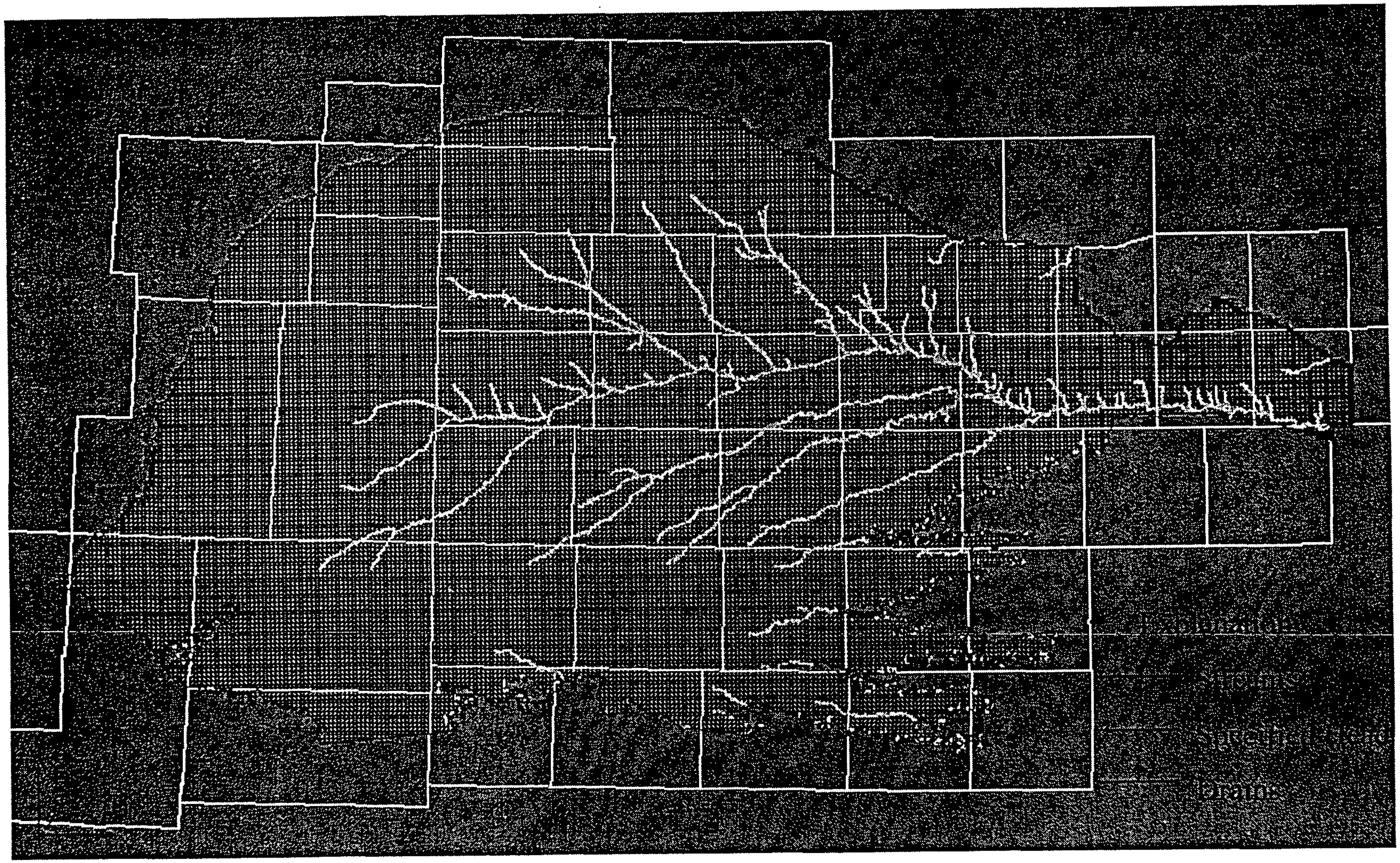
Definitions

- Base flow is streamflow derived from GW discharge to streams
- Runoff is streamflow derived from overland flow of water from precipitation to streams

Ground-Water Model Design

- USGS Modular GW Flow Model (MODFLOW)
- One-square mile grid cells (~30,000 active)
- One-layer areal model simulating two-dimensional ground-water flow
- Using existing information
- Simulates ground-water levels & flow, aquifer/stream water fluxes, and base flow
- Does not simulate surface runoff

GW Model Grid and Boundary Conditions



GW Model Simulations

- "Predevelopment": long-term average conditions prior to extensive GW irrigation (pre-1950)
- "Development": changes during May 1950 – September 1997, two stress periods per year: May – September & October – April

Sources of Aquifer Configuration Data

- Aquifer base and boundaries: state maps, 1980's USGS High Plains RASA Study
- Land surface: 90 meter Digital Elevation Models

Sources of Stream Geometry Data

- Perennial streams: streamflow gain/loss studies, hydrologic reports, water-table & land-surface elevations
- Stream elevations: gaging stations and digital topographic maps
- Stream widths: gaging station records

Sources Aquifer Properties Data

- Aquifer hydraulic properties: initial values generalized from USGS High Plains RASA; refined in model calibration
- Streambed hydraulic properties: classified from bed descriptions, grain-size data, and regional soils & geology

Sources of Model Calibration Data

- Ground-water levels: USGS databases for each state
- Base flow: base-flow separation, streamflow gain/loss data, predevelopment fall streamflows

Sources of Aquifer Inflow Data

- Areal recharge from precipitation and irrigation: initial values from soil-water balance model; refined in GW model calibration
- Recharge from canals: from canal operation records

Sources of Aquifer Outflow Data

- Ground-water pumping: rates from soil-water balance model; locations from state well-registration databases
- Ground-water evapotranspiration: soil-water balance model and riparian tree distribution

Important Elements of Study

- Base-flow separation and trend analysis
- Soil-water balance simulations to estimate ground-water recharge and pumping
- Estimation of ground-water loss to evapotranspiration (GWET) in riparian areas
- Simulation of ground-water system

Base-Flow Separation

- Computerized separation (BFI) of base-flow and runoff components of streamflow
- Analysis done to generate base-flow data for model calibration
- 60 gaging stations analyzed; 45 unregulated; unregulated periods for 15 regulated stations

Base-Flow Separation

- Selected optimal program parameters based on drainage area, hydrograph inspection, and bank storage effects
- Kendall's Tau test used to determine significance ($\alpha = 0.05$) of trends in streamflow, base flow, runoff, and precipitation

Results of Trend Analysis

- Compared streamflow, base flow, and runoff trend values at each station to evaluate whether streamflow declines are primarily due to declines in base flow, runoff, or both

Recharge/Pumping Estimation

- Recharge and pumping vary widely due to climate, soils, and land use; data are sparse
- Used the Deep Percolation and Irrigation Requirement Model (DPIRM), which incorporates climatic, soil, and land-use variables, to generate estimates over the entire study area and period using a consistent approach

DPIRM Features

- Daily soil-water balance for the upper 5 feet for unique combinations of soil, land use, and climate
- Water balance includes precipitation, irrigation, snowpack, interception, runoff, soil-water storage, direct evaporation from soil, plant transpiration, and deep percolation

Calibration of DPIRM

- Compare simulated runoff (as a percentage of precipitation) to runoff at gaging stations, adjust curve number to get best fit
- Compare simulated irrigation applications and efficiencies to historical reported values, adjust soil-water content at which irrigation is applied, daily irrigation application rate, and runoff proportion to get best fit

Distributing DPIRM Output

- Digital soils and composite land use data sets are overlain to delineate areas with unique climate, soil, and land use features

- Recharge and pumping values simulated with DPIRM for each GW model stress period are assigned to areas with unique features

Ground-Water Evapotranspiration (GWET)

- Soil-water balance for deciduous trees simulated with DPIRM
- Simulations determine Potential tree transpiration and Actual tree transpiration (from available soil water)
- Maximum rate of ground-water use by trees calculated as Potential minus Actual tree transpiration from soil water

Ground-Water Evapotranspiration (GWET)

- Riparian tree areas determined from digital spatial data sets
- Using these inputs, actual GWET is simulated in MODFLOW, which considers relation of GWET to depth of water table below land surface

Products (By Spring 2001)

- Interpretative technical report describing the hydrogeologic system and simulation results
- Interpretative technical report describing base-flow separation results and trend analyses
- Fact Sheet summarizing study results in non-technical terms
- Data compiled by study and model

Data Products

- Data sets:
  - Base of aquifer elevation
  - 1997 water-table elevation
  - 1997 aquifer saturated thickness
  - Historical changes in perennial stream length
  - Streamflow gain/loss
  - base-flow separation

Study Benefits

- A refined understanding of GW flow and GW/SW interactions
- A model capable of simulating the water balance of the basin-wide aquifer system and estimates of major inflows and outflows including:
  - Recharge
  - Pumping
  - Ground-water evapotranspiration

Study Benefits

- Relative contributions of changes in runoff and base flow to streamflow declines
- Response of the aquifer system to historical changes in pumping, land use, and riparian tree area
- A tool to evaluate the effects of future scenarios on ground-water flow and ground-water/surface-water interaction

Selected U.S. Geological Reports on the Hydrology of the Republican River Basin

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Jenkins, E.D., and Pabst, M.E., 1975, Water development for irrigation in northwestern Kansas: U.S. Geological Survey Open-File Report 4-75, 39 p.

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Kastner, W.M., 1974, Application of statistical techniques to the estimation of ground-water withdrawals in northwestern Kansas: U.S. Geological Survey Water-Resources Investigations Report 41-74, 11 p.

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Lugn, A.L., and Wenzel, L.K., 1938, Geology and ground-water resources of south-central Nebraska, with special reference to the Platte River valley between Chapman and Gothenburg: U.S. Geological Survey Water-Supply Paper 779, 242 p.

Ground-Water/Surface-Water Interaction

The component of the study involving field investigations of ground-water/surface-water interactions has been completed. The results of the study were published in USGS Water-Resources Investigations Report 99-4200, "Interaction of streams and ground water in selected tributaries of the Republican River, Nebraska, 1998-99," by Gregory V. Steele.

Ground-Water Quality

The component of the study involving investigations of areal ground-water quality in the Nebraska part of the Republican River Basin has been completed. The results of the study were published in USGS Water Resources Investigations Report 00-4056, "Distribution of nitrate in ground water in the Republican River Basin, Southwest Nebraska, 1996-98" by Jennifer S. Stanton.

REPUBLICAN RIVER BASIN MODELING, GROUND-WATER/SURFACE-WATER INTERACTION AND WATER-QUALITY PROJECT
October 5, 2000

Modeling

Simulations of ground-water flow and ground-water/surface-water interaction are proceeding and adjustments to the ground-water flow model are being made to calibrate the model to historical ground-water levels and base flows (streamflow derived from ground-water discharge to streams). The calibration process has thus far involved making some adjustments to values of ground-water recharge, aquifer properties, evapotranspiration parameters, streambed properties, springs located along the edge of the aquifer, and aquifer bottom and top elevations in the model. The process of calibrating the model to reproduce observed ground-water levels and base flow has been more difficult than was expected, primarily due to the complexity of the aquifer/stream system across the 30,000 square mile area being simulated. The simulations are therefore taking longer than was originally expected and the study is slightly behind schedule.

Soil-water balance simulations to estimate ground-water recharge, ground-water pumping, and ground-water evapotranspiration (ET) losses to riparian trees during the development period of 1950-97 were completed. These major aquifer inflows and outflows were the last critical input data needed for the ground-water flow model and were estimated using a model called the Deep Percolation and Irrigation Requirement Model (DPIRM). Irrigation parameters in DPIRM were adjusted so that simulated pumping values reasonably matched reported historical pumping data and estimated irrigation efficiencies compiled from various sources. The ground-water recharge, pumping, and ET values determined for unique combinations of soils, climate, and land use using the DPIRM are being loaded into a Geographic Information System (GIS) database to assign recharge and pumping values to areas on maps. These recharge and pumping data are then being loaded into the ground-water flow model.

Writing of the final interpretative reports is continuing. Portions of the reports have been written and some figures and tables have been prepared.

Changes in riparian tree area were determined from aerial photos at 16 locations in the study area for three time periods between the late 1930s and the mid 1990s. The changes in tree area are currently being interpreted and combined with tree water use values to estimate how much total ground-water use by riparian trees has changed during the study period in response to changes in riparian tree area.

In the next quarter, ground-water flow model simulations of 1950-97 will be completed. The effects of selected hypothetical future scenarios on ground-water flow and streamflow will be simulated using the model. Writing of the final reports documenting the methods and results of the study will continue. The first draft of the reports should be completed in the winter of 2000/2001 and the reports published in the spring of 2001.