Kansas Geological Survey

Eighteen GIS hydrologic maps of the Big Bend Ground-water Management District No. 5

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GEOHYDROLOGY

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Geographic Information Systems (GIS)* are powerful, computer-based tools for integrating and analyzing spatial data. Once stored, these data can be automatically extracted, reconfigured, updated, analyzed, and mapped in a format and at a scale designed to meet a specific need. We combine this GIS tool with our hydrogeologic knowledge of south-central Kansas to produce a set of maps for regional resource management and environmental analysis. We present here a series of ARC/INFO GIS-based hydrologic maps of the Big Bend Ground-water Management District No. 5 (GMD5) region of south-central Kansas at a scale of 1:380,000 [1 inch = 6 miles (i.e., a township length)]. These maps display basic ground-water-level data from (1) predevelopment time (1940–1960), (2) a flooding time (1973–1974), and (3) a near drought time (1990–1991) and the corresponding saturated thickness and ground-water-level changes during these periods. A January 1991 depth to water table or unsaturated zone thickness map is also presented. In addition, these maps display the Great Bend Prairie aquifer bedrock surface with inferred paleochannels, the GMD5 surface topography, drainage basins, the 1990 appropriated ground-water rights in GMD5, land use, soils, and 30-year average annual precipitation. Inferred ground-water recharge zones in the area are also presented based on precipitation (annual amounts and average springtime rainfall intensities), soils (soil-profile available water capacity and depth to shallowest clay layer), depth to water table, and measurements from 10 instrumented sites throughout the GMD5 (Sophocleous, 1992). The 18 maps presented here and the data sources on which they are based are listed in table 1.

*Underlined terms are explained in "Explanation of terms" section

Table 1. GIS maps for GMD5

Plate	Title	Data source and size of data base
1	Configuration of the pre-Cenozoic bedrock surface of the Great Bend Prairie region of Kansas	Sophocleous, M., Arnold, W., and McClain, T., 1990 (3,025 data points)
2	Configuration of the predevelopment ground-water level surface in the Great Bend Prairie region of Kansas	Sophocleous, M., Arnold, W., and McClain, T., 1990 (1,243 data points)
3	Configuration of the predevelopment saturated thickness in Ground-water Management District No. 5	Plates 1 and 2 (21,724 lattice points)
4	Configuration of the January 1974 ground-water-level surface in Ground-water Management District No. 5	Kansas observation well network annual measurements plus data from Stullken and Fader (1976) (337 data points)
5	Configuration of the January 1974 saturated thickness in Ground-water Management District No. 5	Plates 1 and 4 (324 data points)
6	Configuration of the January 1991 ground-water-level surface in Ground-water Management District No. 5	Kansas observation well network annual measurements plus additional measurements by GMD5 personnel (389 data points)
7	Configuration of the January 1991 saturated thickness of the Great Bend Prairie region of Kansas	Plates 1 and 6 (371 data points)
8	Configuration of the January 1992 ground-water-level surface in Ground-water Management District No. 5	Kansas observation well network annual measurements plus additional measurements by GMD5 personnel (271 data points)
9	Ground-water-level changes from predevelopment (pre-1960) to January 1991 in Ground-water Management District No. 5	Plates 2 and 6 (360 data points)
10	Ground-water level changes from predevelopment (pre-1960) to January 1974 in Ground-water Management District No. 5	Plates 2 and 4 (324 data points)
11	Ground-water-level changes from January 1974 to January 1991 in Ground-water Management District No. 5	Plates 4 and 6 (228 data points)

Table 1 (cont). GIS maps for GMD5

Plate	Title	Data source and size of data base
12	Irrigation well distribution for 1990 and ground-water recharge zones of the Great Bend Prairie region of Kansas	Division of Water Resources, Kansas State Board of Agriculture data files (4,567 data points); Sophocleous (1992).
13	Configuration of the land surface topography of the Great Bend Prairie region of Kansas	1 degree Digital Elevation Model (DEM) from USGS (39,977 data points)
14	Configuration of the depth to water table as of January 1991 (thickness of the unsaturated zone in Ground-water Management District No. 5	Kansas observation well network annual measurements plus additional measurements GMD5 personnel (427 data points)
15	Distribution and amounts of appropriated ground-water rights by section in Ground-water Management District No. 5	Division of Water Resources, Kansas State Board of Agriculture data files (4,321 data points inside GMD5)
16	Generalized 1990 land use by section in the Great Bend Prairie region of Kansas	Landsat thematic mapper satellite images interpreted by Kansas Applied Remote Sensing (KARS) Program of the University of Kansas.
17	Soil associations map of the Great Bend Prairie region of Kansas.	Soil Conservation Service State Soil Geographic Data Base (STATSGO).
18	Configuration of 30-year normal precipitation and river basins in the Great Bend Prairie region of Kansas	Kansas State University Weather Data Library and U.S. Geological Survey hydrologic cataloging unit data (contours based on 388 data points from Kansas and from one tier of counties from states surrounding Kansas)

Methodology for creating maps

Predevelopment ground water and bedrock (plates 1 and 2)

These coverages were digitized from previously hand-contoured maps by M. Sophocleous. The contours were based on the data points mentioned in table 1. Note that in most of the maps in this series, bedrock outcrops are truncated for the northwest section of the mapped region (Rush County and the northeast portion of Pawnee County) and for the easternmost tier of townships in Reno and Kingman County.

Ground-water level (plates 4, 6, and 8)

Points were gathered from the data sources indicated in table 1 and were converted from legal coordinates to latitude-longitude coordinates; some additional points on rivers that were known to be flowing at the time were added to help in areas with scarce well sites. These contours were created by using the ARCTIN command and then the TINCONTOUR command in ARC/INFO, using the linear model. They were then edited for obvious errors or to smooth out the extreme sharp contour turns. Bedrock outcrops were taken into consideration in contouring ground-water levels.

Saturated thickness (plates 3, 5, and 7)

The bedrock contours were converted into a lattice and placed in a grid. The ground-water-level data points for a particular year were then intersected into this grid so that each ground-water-level data point would have the corresponding bedrock lattice point. The bedrock elevation could then be subtracted from the water elevation. These points were then tinned, contoured, and edited similarly to the ground-water-level data. Bedrock outcrops were taken into consideration in contouring saturated thickness. To approximately distinguish marginal quality ground waters, we present in plate 3 the Cretaceous-Permian subcrop boundary (presumably

separating fresher ground water to the west from saltier ground water to the east of that line) and the deeper-quifer region of greater than 500 mg/L chloride concentration (Whittemore, 1993).

Ground-water elevation changes (plates 9, 10, and 11)

For ground-water-level changes between predevelopment and subsequent years, the same approach as that used for saturated thickness was employed. For changes between other years (1974–1991), the maps were created using the same approach (creating a grid and intersecting points), but neither point coverage was a lattice.

Recharge zonation (plate 12)

This coverage was the result of overlaying four coverages: annual precipitation, spring rainfall rate, soil type (based on soil-profile available water capacity with depth to shallowest clay layer used to reclass soil types), and depth to water. A multiple (stepwise) regression analysis was used to assign weights to each coverage. A description of the process can be found in appendix A.

Land surface topography (plate 13)

One-degree Digital Elevation Model (DEM) maps from the USGS with original 30-m sampling interval data were resampled on a 0.5-mi grid and averaged over a 0.5-mi square box.

Depth to water table (plate 14)

This map was created much in the same way as the ground-water elevation maps were, but depth to water table information at each observation well was used, and the map was contoured by hand.

Water rights appropriation (plate 15)

This map was created by summing the ground-water-rights appropriation for each section. Each section was then ranked, and a color was assigned to each rank.

Land use (plate 16)

This map was created from a 1990 Landsat Thematic Mapper (TM) satellite image. After original transformation from image to GIS coverage, the predominant land use for each section was selected and displayed.

Soil associations map (plate 17)

This map was created by extracting the study area from the existing STATSGO coverage available from the Soil Conservation Service and organizing it according to soil textural classes.

Thirty-year normal precipitation and drainage basins map (plate 18)

This map was created and contoured based on all official National Oceanic and Atmospheric Administration (NOAA) climatic stations of Kansas and extracting the Great Bend Prairie region from it. The major river (drainage) basins of the area are also presented.

Explanation of terms

appropriated ground-water right: A right to divert from a definite ground-water supply a specific quantity of water at a specific rate of diversion, provided such water is available in excess of the requirements of all vested rights that relate to such supply and all appropriation rights of earlier date that relate to such supply, and to apply such water to a specific beneficial use or uses in preference to all appropriation rights of later date. It is a real property right appertaining to and severable from the land on or in connection with which the water is used. Such water right passes as an appurtenance with a conveyance of the land by deed, lease, mortgage, will, or other voluntary disposal, or by inheritance.

ARC/INFO: GIS software used at the Kansas Geological Survey. The software was created by Environmental Systems Research Institute (ESRI); the version used is 5.0.1.1.

ARCTIN command: A command in ARC/INFO that converts a coverage containing arcs and/or points to a TIN.

coverage: A digital map.

Digital Elevation Model (DEM): Any digital representation of the continuous variation of relief over space.

INFO: The data base portion of ARC/INFO

GIS: Geographical Information System. A tool for storing, manipulating, and displaying geographic information on a computer.

Lansdat: An unmanned earth-orbiting NASA satellite at a nominal altitude of 570 mi that transmits multispectal images in the 0.4 to 1.1 μm region to earth receiving stations.

lattice: A representation of a surface by regularly sampled points (lattice points).

linear model: A linear interpolation between points in a TIN used to create contours.

multiple regression: Any of several statistical methods developed to investigate relationships between multiple variables. A *stepwise* regression is a method of selecting the "best" set of variables for a regression equation.

normal precipitation: The average value of precipitation for the year as a whole over a specific 30-year period. It is an arithmetic mean generally used as a standard of comparison.

polygon: An areal feature defined by the series of arcs (i.e., lines) composing its boundary. A polygon contains a label point inside its boundary and has attributes that describe the geographic feature it represents.

soil association: A group of defined and named soil units occurring together in an individual and characteristic pattern over a geographic area.

STATSGO: A STATe Soil GeOgraphic data base designed to be used for regional multicounty resource planning and management.

Thematic Mapper (TM): A digital scanning system that records reflected and emitted energy in seven specially selected bands of the electromagnetic spectrum to maximize vegetation analysis. It gathers data on 30 m by 30 m ground cells, referred to as *pixels*.

TINCONTOUR command: A command in ARC/INFO that converts a TIN to a coverage containing contours.

TIN: A series of triangles interconnected with each other. Each point in the TIN (vertices of the triangle) is a data point specified with *x*, *y*, and *z* coordinates.

tinned coverage: A coverage that has been created using the ARCTIN command.

UNION command: A command in ARC/INFO used to create a new coverage by overlaying two other coverages. The attributes in both coverages are maintained in the new coverage.

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References

Stullken, L. E., and Fader, S. W., 1976. Hydrogeologic data from the Great Bend Prairie, south-central Kansas. Kansas Geological Survey, Basic Data Series, Ground-water Release 5, 50 p.

Sophocleous, M. A., 1992. Groundwater recharge estimation and regionalization: The Great Bend Prairie of central Kansas and its recharge statistics. Journal of Hydrology, v. 127, p. 113–140.

Whittemore, D. O., 1993. Ground-water geochemistry in the mineral intrusion area of Groundwater Management District No. 5, south-central Kansas. Kansas Geological Survey, Open-File Report 93-2, 102 p., 3 maps.

Appendix A:
Description of the recharge zonation procedure

The four coverages used for recharge zonation were:

Feature	Coverage name	Class
Soil (awc)	G5SOIL.A.PY	polygon
Depth to water table (dtw)	G5DTW.A.PY	polygon
Annual rainfall (precip)	G5RN.A.PY	polygon
Spring rainfall rate (rate)	G5SRT.A.PY	polygon

These coverages where unioned with each other. First, soil and the depth to water table coverages were unioned; then annual rainfall was unioned with that combination, and, last, the spring rainfall rate was unioned with the previous union. A union preserves all the information that exists in the coverages used to make it.

G5SRT.A.PY contains the items Rate and Sclass. Rate is in inches of rainfall/spring season (spring season consists of the months of April, May, and June):

Rate	Sclass
0.52	1
0.57	2
0.62	3
0.67	4
0.72	5
0.77	6

G5RN.A.PY contains the items Precip and Pclass. Precip is in inches/year.

Precip	Pclass
20	1
22	2
24	3
26	4
28	5
30	6

G5DTW91.A.PY contains the items Dtw and Class. Dtw is in feet.

Dtw	Class
45	1
35	2
25	3
15	4
7.5	5
2.5	6

G5SOIL.A.PY contains the items Awc, soil type, and Dtc. Soil type is based on available water capacity (Awc); Awc for the soil type is in inches. Dtc (Depth to clay) was used to reclass the soil types. If the Dtc is less than or equal to 30 inches, the soil type is considered to be class 1, regardless of the actual Awc.

Awc	Soil type
>10	1
9–10	2
8–9	3
7–8	4
6–7	5
5–6	6

A series of UNION commands were executed on the four coverages to create the final recharge coverage (G5RECH.A.PY). Once this was done, the following commands were given in INFO:

```
SELECT G5RECH.A.PY.PAT
RESELECT FOR DTC LE 30
CALC SOILTYPE = 1
RESELECT
NSELECT
CALC JFINDEX = .3681 * PCLASS + .2364 * SOILTYPE + .2238 * CLASS + .1717 *
SCLASS
RESELECT FOR CLASS = 6
CALC JFINDEX = .4820 * PCLASS + .2931 * CLASS + .2249 * SCLASS
RESELECT
NSELECT
RESELECT FOR JFINDEX GE 1 AND JFINDEX LT 2
CALC JRANK = 1
NSELECT
RESELECT FOR JFINDEX GE 2 AND JFINDEX LT 3
CALC JRANK = 2
NSELECT
RESELECT FOR JFINDEX GE 3 AND JFINDEX LT 4
CALC JRANK = 3
NSELECT
RESELECT FOR JFINDEX GE 4 AND JFINDEX LT 5
CALC JRANK = 4
NSELECT
RESELECT FOR JFINDEX GE 5
CALC JRANK = 5
RESELECT
NSELECT
RESELECT FOR CLASS = 1
CALC JRANK = 1
```