Table 2. Estimated annual water budget for the Arnold Air Force Base area from 1960 to 2005.

[All values are in inches per year]

Year	Precipitation	Evapotranspiration	Streamflow	Direct runoff	Recharge	Soil moisture storage
1960	44.1	30.7	13.4	9.4	4.0	0.0
1961	57.8	30.8	27.0	18.9	8.1	0.0
1962	61.2	31.1	30.1	21.1	9.0	0.0
1963	47.8	31.6	18.5	13.0	5.6	–2.3
1964	65.4	33.2	29.8	20.9	9.0	2.3
1965	45.1	33.0	14.3	10.0	4.3	–2.2
1966	49.1	31.3	15.5	10.9	4.7	2.2
1967	58.8	31.1	27.6	19.3	8.3	0.0
1968	45.0	29.4	19.3	13.5	5.8	–3.7
1969	58.1	30.7	23.7	16.6	7.1	3.7
1970	50.7	32.3	18.4	12.9	5.5	0.0
1971	56.3	33.1	23.2	16.2	7.0	0.0
1972	67.6	32.1	35.5	24.9	10.7	0.0
1973	76.8	34.0	42.8	30.0	12.8	0.0
1974	65.5	32.6	32.9	23.0	9.9	0.0
1975	66.1	31.7	34.4	24.1	10.3	0.0
1976	50.5	29.9	20.6	14.4	6.2	0.0
1977	62.4	33.5	28.9	20.3	8.7	0.0
1978	50.5	32.9	17.7	12.4	5.3	0.0
1979	67.4	31.5	35.9	25.1	10.8	0.0
1980	46.3	31.1	21.4	15.0	6.4	–6.2
1981	42.4	31.8	4.4	3.1	1.3	6.2
1982	62.2	32.1	30.1	21.1	9.0	0.0
1983	61.4	29.7	31.7	22.2	9.5	0.0
1984	55.5	31.3	24.2	16.9	7.3	0.0
1985	42.1	32.7	9.9	6.9	3.0	–0.5
1986	53.7	33.4	19.7	13.8	5.9	0.5
1987	44.7	32.3	12.4	8.7	3.7	0.0
1988	47.9	29.2	18.6	13.0	5.6	0.0
1989	73.6	31.7	41.9	29.3	12.6	0.0
1990	72.9	33.1	39.8	27.9	11.9	0.0
1991	64.5	31.9	32.6	22.8	9.8	0.0
1992	55.8	29.0	26.8	18.8	8.0	0.0
1993	51.8	29.4	22.3	15.6	6.7	0.0
1994	74.6	31.4	43.3	30.3	13.0	0.0
1995	62.0	31.9	30.1	21.1	9.0	0.0
1996	65.6	29.9	35.7	25.0	10.7	0.0
1997	70.2	29.3	41.0	28.7	12.3	0.0
1998	75.2	34.8	40.4	28.3	12.1	0.0
1999	56.3	31.2	29.1	20.3	8.7	–3.9
2000	58.3	31.2	23.2	16.3	7.0	3.9
2001	60.9	31.3	29.6	20.7	8.9	0.0
2002	58.8	30.9	27.9	19.5	8.4	0.0
2003	72.4	31.9	40.5	28.3	12.1	0.0
2004	72.9	32.9	40.0	28.0	12.0	0.0
2005	39.2	30.7	11.1	7.8	3.3	–2.61
Average	58.4	32.7	26.9	18.8	8.1	–0.1

area show that Spring Creek has fewer peaks and higher base flows than the other sites, Little Duck River and Crumpton Creek (Robinson and Haugh, 2004, fig. 2). This further supports the concept that in the Spring Creek Basin more recharge occurs, which results in less runoff and higher base flows.

Based on this information, the AAFB study area can be divided into four areas with different recharge rates. The four areas are: The Barrens area along the regional drainage divide; the Spring Creek, Dry Creek (at Estill Springs), and Taylor Creek Basins in the southwestern part of the study area; Sinking Pond; and the rest of the study area.

Ground-Water Flow

Regional potentiometric surface maps of the Manchester aquifer for May and October 2002 (Robinson and others, 2005) show that the topography and surface drainage patterns influence ground-water flow in the AAFB area (fig. 13). The AEDC facility is on the regional ground-water divide, which runs southwest to northeast and generally coincides with the Duck River-Elk River surface-water divide. A broad saddle in the main ground-water divide separates a ground-water high southwest of AEDC from a larger, broader ground-water high north of AEDC. Ground water generally flows from the regional ground-water divide area toward the northwest or toward the south or southeast, and discharges to the principal streams and reservoirs (Mahoney and Robinson, 1993; Haugh and Mahoney, 1994; Robinson and others, 2005).

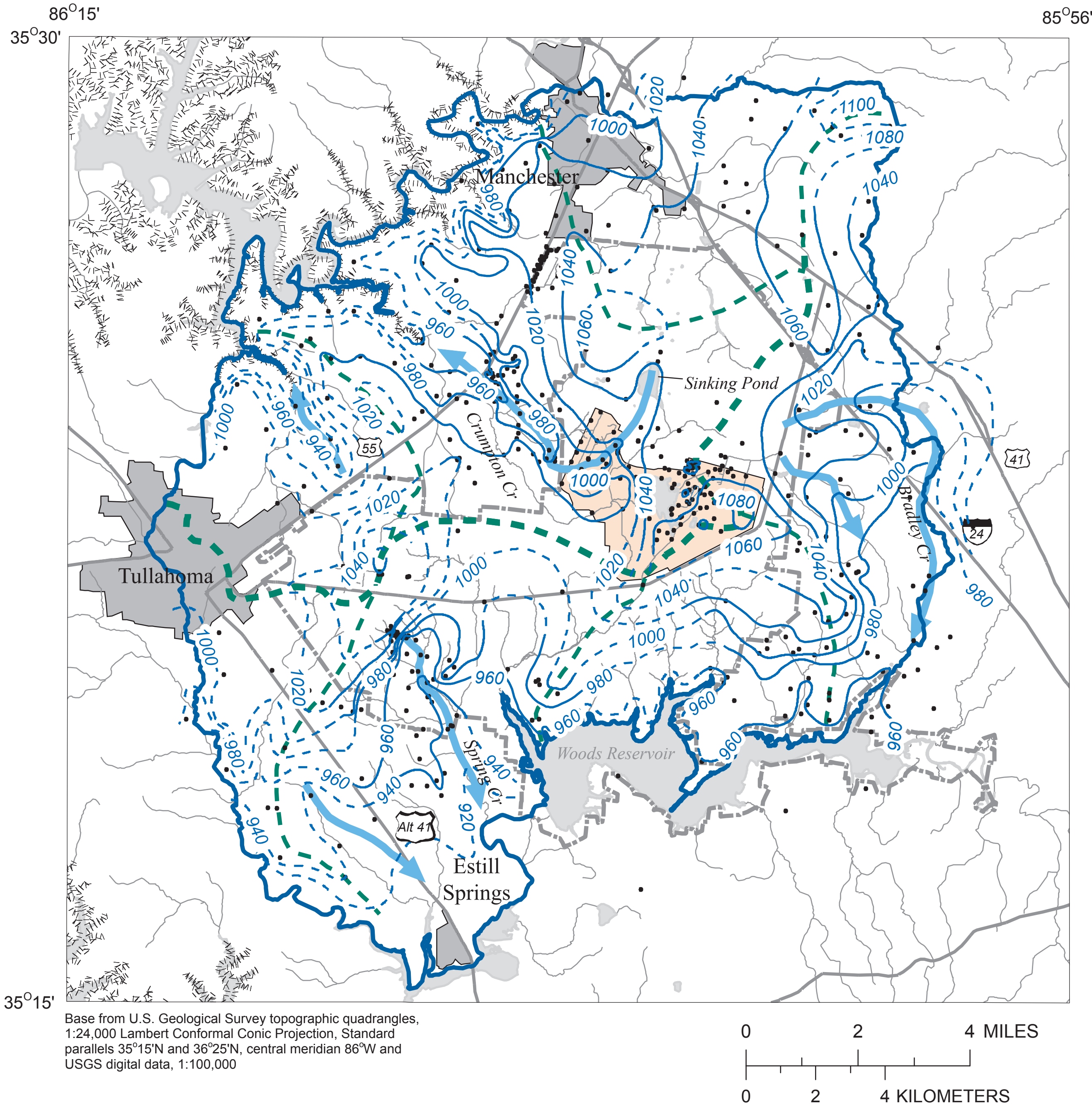
Several troughs are present in the potentiometric surface. The most prominent trough trends northwest to southeast in the Crumpton Creek Basin (fig. 13) (Robinson and others, 2005, figs. 2 and 4). This trough parallels the main axis of Crumpton Creek, but generally is not coincident with Crumpton Creek, but is aligned with a trough in the bedrock surface (fig. 5). During seasonal water-level lows in October 2002, this trough extended upgradient and toward the northeast to the Sinking Pond area (fig. 13) (Robinson and others, 2005, fig. 4). At the downgradient end of this trough is Big Spring at Rutledge Falls which has a steady discharge of about 3.3 ft^3/s (Williams and Farmer, 2003). Similar troughs in the potentiometric surface exist in the Bradley Creek Basin and discharge to several springs along the lower reach of Bradley Creek, in the Spring Creek Basin and discharge to several springs along the lower reach of Spring Creek, in the Dry Creek Basin and discharge to Estill Springs, and in the Bobo Creek Basin and discharge to Short Springs (fig. 13) (Robinson and others, 2005, figs. 2 and 4; Robinson and Haugh, 2004, tables 3 and 5). These troughs in the potentiometric surface are believed to be associated with zones of high permeability within the aquifer that are important regional flow paths (Haugh, 1996a; CH2M Hill, 1999, 2001; ACS, 2002).

Water Levels

Natural seasonal fluctuations of the water table are related to seasonal changes in precipitation and evapotranspiration and, thus, to changes in ground-water recharge. Ground-water levels normally are highest during the spring months following the winter period of high precipitation and low evapotranspiration. Water levels recede during the summer in response to diminishing precipitation and higher evapotranspiration and are lowest in the fall. Hydrographs of wells at AAFB exhibit these characteristic seasonal variations (figs. 14, 15, and 16) (Haugh and others, 1992, figs. 4–6; Haugh and Mahoney, 1994, figs. 15–22; Haugh, 1996a, figs. 14–16; and Robinson and others, 2005, fig. 5). Seasonal water-level fluctuations range from about 5 ft to greater than 25 ft. In general, water-level fluctuations are 10 to 15 ft (AEDC-135, -146, -185, -305, -551). The smallest water-level fluctuations occur near the regional discharge areas (AEDC-189, figs. 14 and 15). The largest water-level fluctuations occur in the northern half of the study area (AEDC-177, -353, -359, -488, figs. 14, 15, and 16).

The larger seasonal water-level fluctuations in the northern half of the study area result in seasonal water-level gradient reversals locally between the area just north of the retention pond (as represented by wells AEDC-551 and -305) and the area around Sinking Pond (as represented by wells AEDC-359, -201, and 353) (figs. 14 and 16). This gradient change coincides with the draining and filling of Sinking Pond (fig. 16). The seasonal change in water-level gradients in this area may explain the broad spreading observed in the "northwest plume" in the area north of the retention pond (fig. 2). This gradient change existed for about 4 months during average rainfall years of 2001 and 2002, 6 months during the lower than average rainfall year of 2005, and less than 1 month during the higher than average rainfall year of 2004 (figs. 12 and 16). Regionally, ground water throughout this area (as represented by wells AEDC-551, -305, -201, -359, and -353) flows toward the ground-water trough of the Crumpton Creek Basin (as represented by well AEDC-464) (figs. 14 and 16).

Natural vertical hydraulic gradients between aquifers are typically small (less than 3 ft). Large natural vertical gradients (greater than 5 ft) have been noted locally between the shallow and Manchester aquifers where ground water in the shallow aquifer appears to be perched, and between the lower part of the Manchester aquifer and the Fort Payne aquifer at a few well clusters in the northern part of the study area where the bedrock is thick (greater than 100 ft).



EXPLANATION

ARNOLD ENGINEERING DEVELOPMENT CENTER

940 POTENTIOMETRIC-SURFACE CONTOUR—Shows altitude at which water level would have stood in tightly cased wells. Dashed where approximately located. Hachures indicate depression. Contour interval 20 feet. Datum is NGVD 29

HYDROLOGIC BOUNDARY—Delineation of regional ground-water flow system underlying Arnold Air Force Base

GROUND-WATER DIVIDE—Thinner line represents subdivide

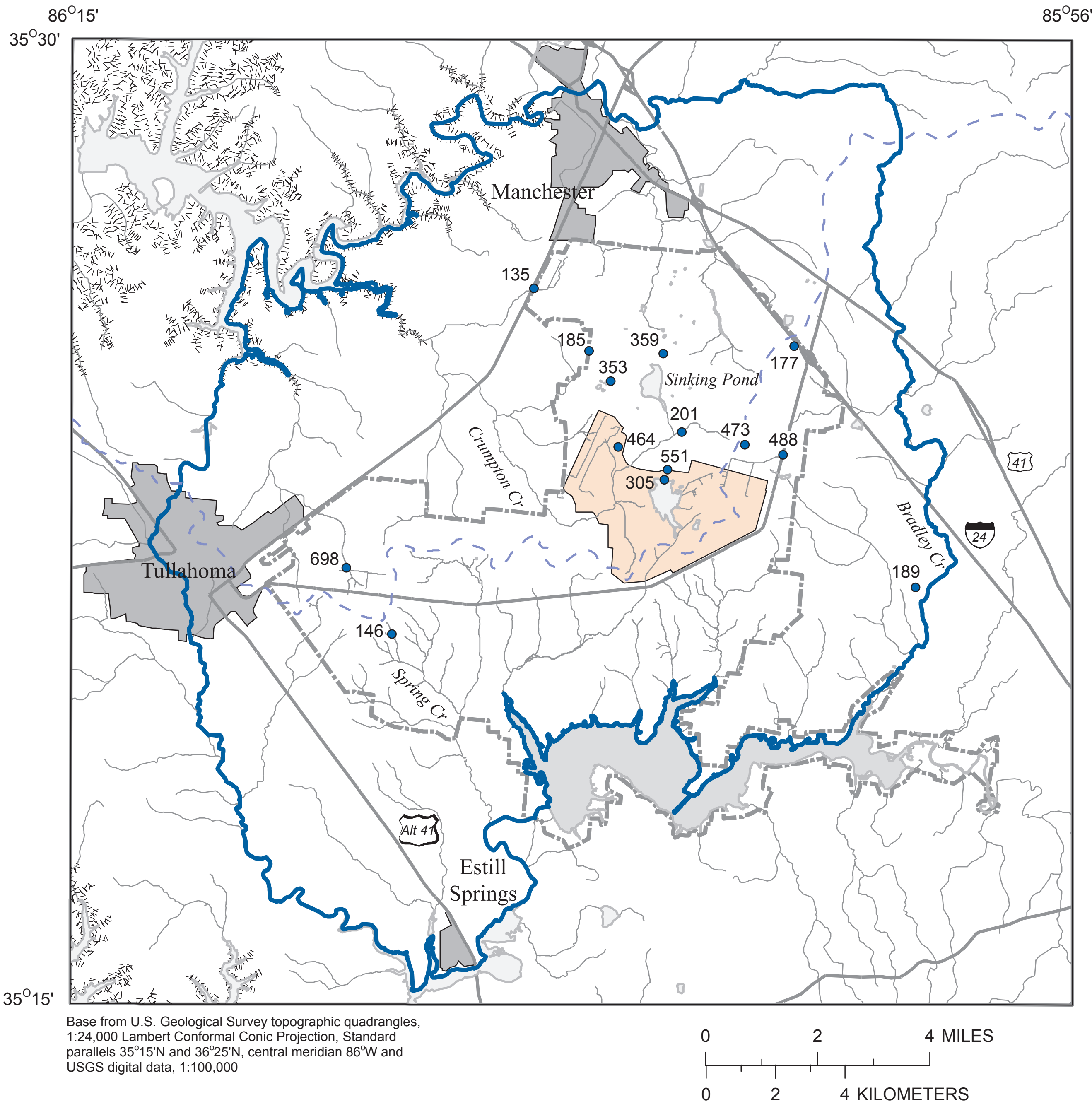
GROUND-WATER TROUGH—Arrow indicates ground-water flow direction

HIGHLAND RIM ESCARPMENT

BOUNDARY OF ARNOLD AIR FORCE BASE

WELL OR SPRING IN WHICH WATER-LEVEL MEASUREMENT WAS USED AS CONTROL

Figure 13. Altitude of the potentiometric surface of the Manchester aquifer in the Arnold Air Force Base area, October 2002. (Robinson and others, 2005.)



EXPLANATION

ARNOLD ENGINEERING DEVELOPMENT CENTER

HYDROLOGIC BOUNDARY—Delineation of regional ground-water flow system underlying Arnold Air Force Base

SURFACE-WATER DRAINAGE DIVIDE

BOUNDARY OF ARNOLD AIR FORCE BASE

146 WELL—Shows location and number of well with continuous water-level data

Figure 14. Location of selected wells with continuous water-level data in the Arnold Air Force Base area.

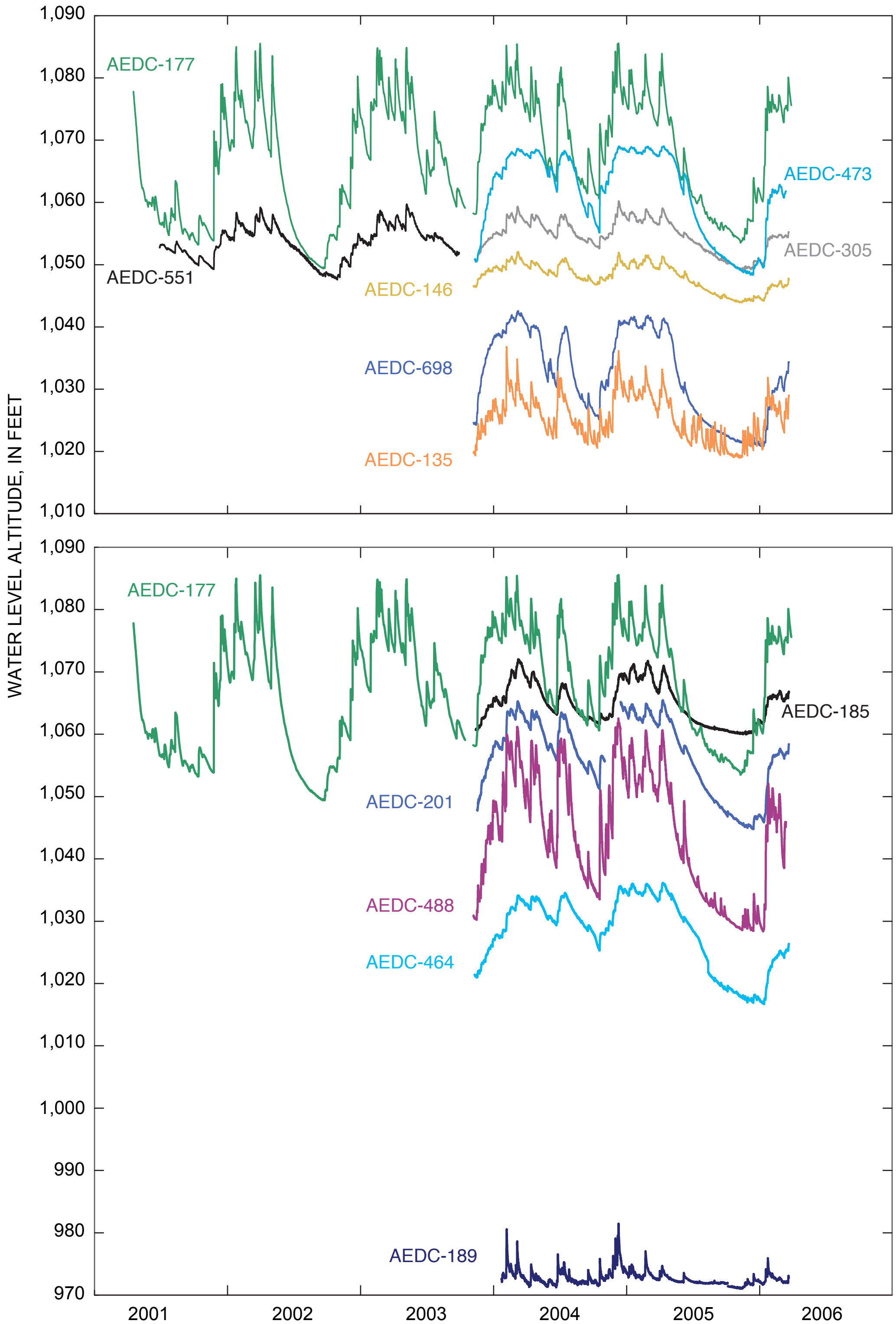


Figure 15. Water levels in selected wells in the Arnold Air Force Base area from 2001 to 2006.

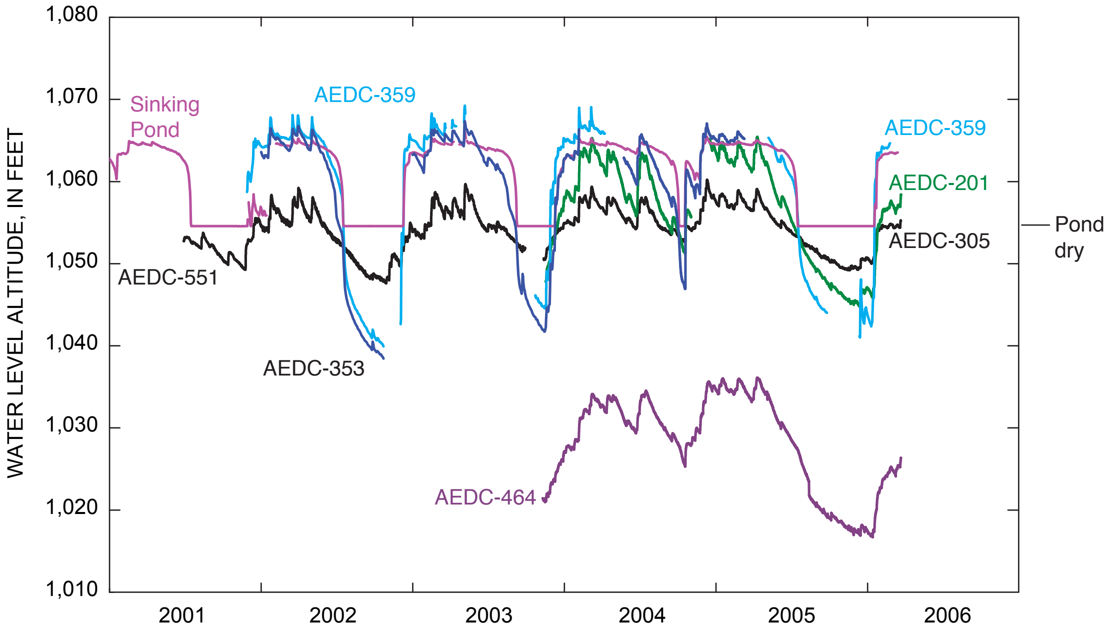


Figure 16. Water levels in wells 353, 359, 201, 551, 305, 464, and Sinking Pond from 2001 to 2006.

Simulation of Ground-Water Flow

The physical system described in the hydrogeology section of this report provides the framework for development of a ground-water flow model for AAFB. The resulting model provides a useful tool to test the understanding and concepts of the ground-water flow system. Although a model is necessarily a simplification of the physical system, the model should be consistent with all known hydrogeologic observations. The ground-water flow model code used in this study, MODFLOW-2000 (Harbaugh and others, 2000), uses finite-difference techniques to solve the ground-water flow equation for three-dimensional, steady or nonsteady flow in anisotropic, heterogeneous media. The model simulations presented in this report represent steady-state, average annual conditions.

Previous Ground-Water Flow Model

The 1992 ground-water flow model (Haugh and Mahoney, 1994) provides the foundation for the current updated flow model. The previous flow model was constructed using MODFLOW88 (McDonald and Harbaugh, 1988) and had 106 columns and 95 rows. Three layers, each of which varied in thickness but had a uniform value of hydraulic conductivity, represented the shallow, Manchester, and Fort Payne aquifers. Recharge was divided into two zones. The model was calibrated using manual methods to minimize the difference between simulated and observed water levels in 158 wells and streamflows at 7 sites. The updated 2002 model, described in this report, retains the same flow boundaries and basic concepts as the previous model, but is a more detailed representation of the flow system.

Conceptual Model

The Highland Rim aquifer system was divided into four layers to simulate ground-water flow (fig. 3). The layers were defined on the basis of differences in physical characteristics that affect hydrologic properties. Model layers are: layer 1 corresponds to the shallow aquifer, layer 2 corresponds to the upper part of the Manchester aquifer, layer 3 corresponds to the lower part of the Manchester aquifer, and layer 4 corresponds to the Fort Payne aquifer. Layers 2 and 3 are interconnected and support most of the regional ground-water flow as indicated by hydraulic-conductivity and geochemical data (Haugh and Mahoney, 1994). Layer 4, because of its lower hydraulic conductivity, supports much less of the regional ground-water flow. Geochemical and potentiometric data indicate that the Chattanooga Shale is an effective underlying confining unit for the Highland Rim aquifer system; therefore, the Chattanooga Shale is the base of the model (Haugh and Mahoney, 1994).

The streams draining the area are assumed to be hydraulically connected to layer 1 through leaky streambeds. Recharge by direct infiltration of precipitation occurs across the study area and is greater in The Barrens area north of AEDC and in the Spring, Taylor, and Dry Creek Basins. The system receives no subsurface recharge from outside the hydrologic boundaries. Ground-water discharge occurs as flow to streams, springs, Woods Reservoir, Tims Ford Lake, wells, and dewatering facilities.

Model Assumptions

The following assumptions were made in the development of the flow model of the hydrologic system in the Arnold Air Force Base area.

1. Fracture and dissolution zones are extensive enough in both aerial and vertical distribution that the hydrogeologic units can be simulated as porous media.
2. Over most of the model area, fracture and dissolution openings are small enough that flow is laminar.
3. The upper model boundary is assumed to be the water-table surface.
4. The lower model boundary is assumed to be a no-flow boundary corresponding to the Chattanooga Shale.
5. The hydraulic properties of hydrogeologic units are homogeneous within a block of the finite-difference grid.
6. Flow within a layer is horizontal; flow between layers is vertical.
7. The model grid is aligned with primary axes of fracture traces and any anisotropy is uniform within a layer.
8. The ground-water system is a closed system.
9. Use of steady-state, annual average conditions is representative of long-term flow conditions for simulation of advective transport with particle tracking.

Model Boundaries

The boundaries of the model correspond to natural boundaries wherever possible and are the same as defined by the 1992 regional study (Haugh and Mahoney, 1994) (fig. 11). Most of the lateral boundaries are streams and are simulated as head-dependent flow boundaries (river nodes) in layer 1 and as no-flow boundaries in layers 2, 3, and 4. The western and northern boundaries that are parts of the drainage divide are simulated as no-flow boundaries in all layers. Along the southern boundary, Woods Reservoir is simulated as a constant-head boundary in layers 1 and 2. Tims Ford Lake, being more deeply incised than Woods Reservoir, is simulated as a constant-head boundary in layers 3 and 4. Layers 1 and 2 crop out above the shoreline of Tims Ford Lake, therefore, water in layers 1 and 2 must drain vertically to layers 3 or 4 to discharge to Tims Ford Lake. The northwestern boundary, where all four layers crop out along the Highland Rim escarpment, is simulated as head-dependent flow (drain nodes) in layers 3 and 4. In these areas, water in layers 1 and 2 must drain vertically to layers 3 or 4 to discharge from the model. Vertically, the upper boundary of the model is the water table. The lower boundary of the model is the Chattanooga Shale, which serves as a no-flow boundary.

Model Construction

The model grid is approximately a 12- by 17-mile rectangle consisting of variably sized grid cells (fig. 17). The grid consists of 150 columns and 132 rows. About 142 square miles (mi^2) of the model grid is active. The smallest grid cells, located near the J4 test cell, are about 160 by 160 ft, and the largest grid cells, located near the model boundaries, are about 1,300 by 1,300 ft. The grid is oriented N. 55^o E., N. 35^o W. so that flow between model cells is parallel to the primary axes of fracture traces (Haugh and Mahoney, 1994, figs. 7 and 8).

Model parameters (Harbaugh and others, 2000) were defined for recharge and hydraulic-conductivity zones and vertical and horizontal anisotropy (table 3). Recharge to the model is from direct infiltration of precipitation. Based on the information in the recharge section of this report, the model was divided into four recharge zones representing the following areas: The Barrens area along the regional drainage divide (RCH_divide); the Spring Creek, Dry Creek (at Estill Springs), and Taylor Creek Basins (RCH_spcr); Sinking Pond (RCH_sp); and the rest of the study area (RCH_base) (fig. 18). The recharge rates for all zones were adjusted during model calibration using ranges estimated from previous work (described in the recharge section of this report) (table 3). Recharge rates input to the model are net recharge rates; therefore, evapotranspiration of ground water, typically less than 2 in/yr (Rutledge and Mesko, 1996), is not explicitly included in the model.

Hydraulic-conductivity zones were determined by integrating information from several data sets. The spatial distribution of the hydraulic-conductivity data set is highly biased to the SWMU sites, so the distribution of values is not adequate to define regional conductivity zones (fig. 7). Also, the hydraulic-conductivity values represent point measurements and are highly variable at a small local scale. Which of the point values are most appropriate to use in a model zone is dependent on how the local heterogeneities are connected on a regional scale. Therefore, the shapes of the hydraulic-conductivity zones within the model layer are based more on geology, lithology, top-of-rock surface, potentiometric data, locations of important springs and discharge points, conceptual models of the flow system, and trial and error during model calibration than the distribution of the hydraulic-conductivity data. The hydraulic-conductivity data set is used to define a reasonable range of values for each layer (fig. 8).

Layer 1 consists of a uniform hydraulic-conductivity value defined by hydraulic-conductivity parameter (HK_1). Layer 2 consists of six hydraulic-conductivity zones (fig. 19). The HK_3 zone covers most of the model area where data indicate hydraulic conductivity is near the average of the unit. Three of the zones (HK_5, HK_7, and HK_9) cover areas where data indicate hydraulic conductivity is higher than the average of the unit based on the following characteristics: a depression or trough in the bedrock surface, a trough in the ground-water surface, low gradients in the ground-water surface, and a large spring or group of springs at the

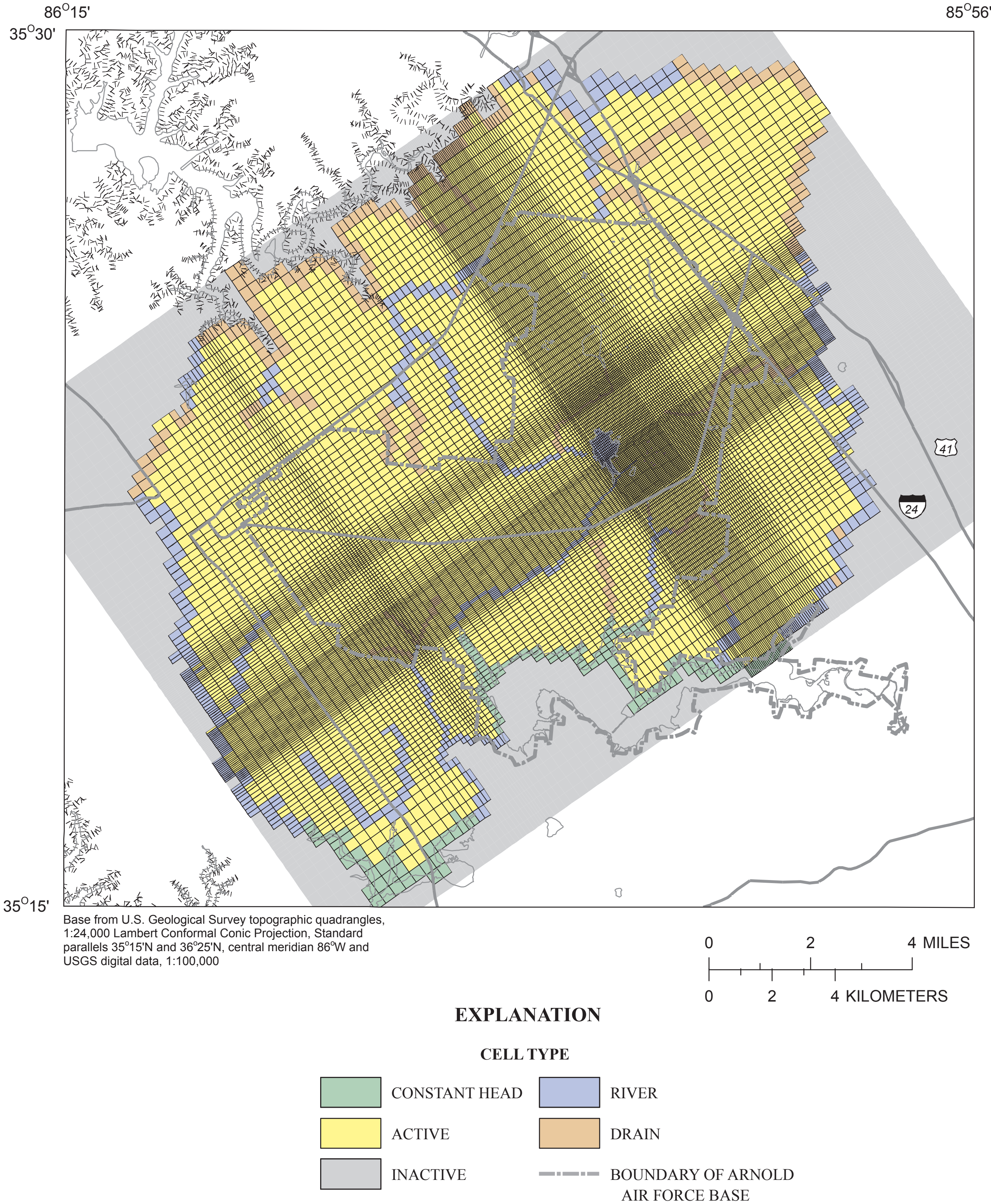
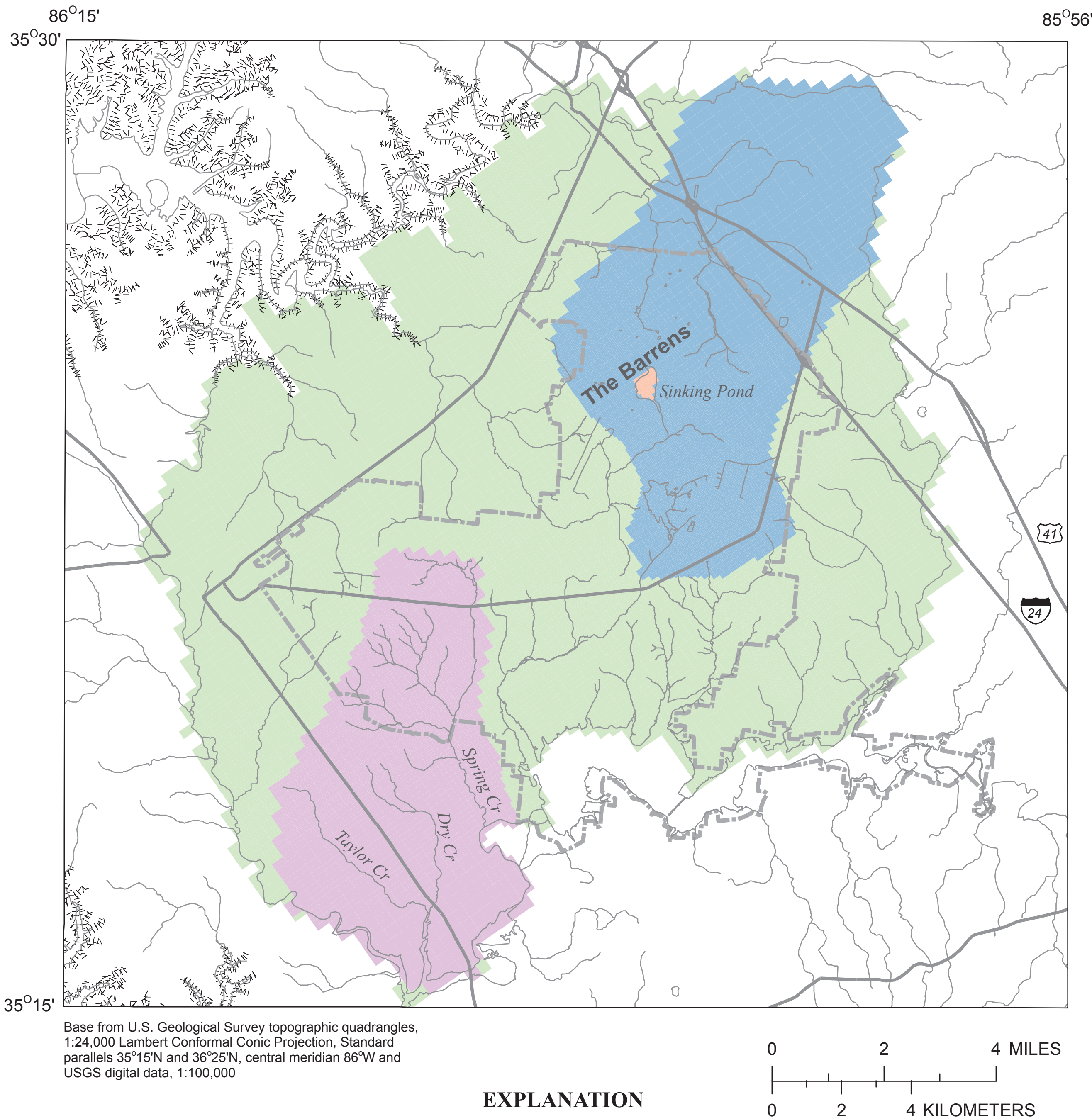


Figure 17. Model grid and cell types for the ground-water flow model of the Arnold Air Force Base area.

Table 3. Recharge and hydraulic-conductivity parameters defined in the Arnold Air Force Base area ground-water flow model.

Model parameter	Description	Initial estimates	Calibrated value
RCH_base	Recharge rate from direct infiltration of precipitation for most of the study area.	5 to 8 inches per year	4.2 inches per year
RCH_divide	Recharge rate from direct infiltration of precipitation in The Barrens area of the divide.	7 to 10 inches per year	7.8 inches per year
RCH_spcr	Recharge rate from direct infiltration of precipitation for Spring, Taylor, and Dry Creek drainage areas.	13 to 18 inches per year	17.7 inches per year
RCH_sp	Recharge rate from water that drains through the bottom of Sinking Pond.	110 inches per year	110 inches per year
HK_1	Hydraulic conductivity for all of layers 1 and 4 and a small part of layers 2 and 3.	0.3 to 6 feet per day	1.5 feet per day
HK_2	Hydraulic conductivity for parts of layers 2 and 3 where data suggest hydraulic conductivity is lower than average of the layer.	0.08 to 4 feet per day	0.2 foot per day
HK_3	Hydraulic conductivity for most of layers 2 and 3.	1 to 390 feet per day	21 feet per day
HK_4	Hydraulic conductivity for part of layer 3 near the J4 test cell.	500 to 1,000 feet per day	1,000 feet per day
HK_5	Hydraulic conductivity for parts of layers 2 and 3 where data suggest hydraulic conductivity is higher than average of the layer.	20 to 2,000 feet per day	1,900 feet per day
HK_7	Hydraulic conductivity for layers 2 and 3 in the area of the Crumpton Creek ground-water trough.	500 to 5,000 feet per day	6,500 feet per day
HK_9	Hydraulic conductivity for layers 2 and 3 in the areas of the Spring Creek and Short Springs ground-water troughs.	500 to 5,000 feet per day	5,900 feet per day
VANI_1	Ratio of horizontal to vertical hydraulic conductivity for most of layer 1.	10:1 to 100:1	21:1
VANI_1a	Ratio of horizontal to vertical hydraulic conductivity for part of layer 1 where water-level data show vertical gradient greater than 5 feet.	100:1 to 1,000:1	440:1
VANI_2	Ratio of horizontal to vertical hydraulic conductivity in layer 2.	10:1	10:1
VANI_3	Ratio of horizontal to vertical hydraulic conductivity in layer 3.	10:1	10:1
VANI_4	Ratio of horizontal to vertical hydraulic conductivity in layer 4.	1,000:1	1,000:1
Horizontal anisotropy (layers 1 and 2)	Ratio of hydraulic conductivity along column to hydraulic conductivity along row.	1:1	1:1
Horizontal anisotropy (layers 3 and 4)	Ratio of hydraulic conductivity along column to hydraulic conductivity along row.	1:1 to 2:1	1.5:1



Base from U.S. Geological Survey topographic quadrangles, 1:24,000 Lambert Conformal Conic Projection, Standard parallels 35°15'N and 36°25'N, central meridian 86°W and USGS digital data, 1:100,000

EXPLANATION

RECHARGE ZONE

- RCH_BASE—Recharge rate from direct infiltration of precipitation for most of the study area
- RCH_DIVIDE—Recharge rate from direct infiltration of precipitation in The Barrens area of the divide
- RCH_SPCR—Recharge rate from direct infiltration of precipitation for Spring, Taylor, and Dry Creek drainage areas
- RCH_SP—Recharge rate from water that drains through the bottom of Sinking Pond

Figure 18. Distribution of simulated recharge zones for the ground-water flow model of the Arnold Air Force Base area.

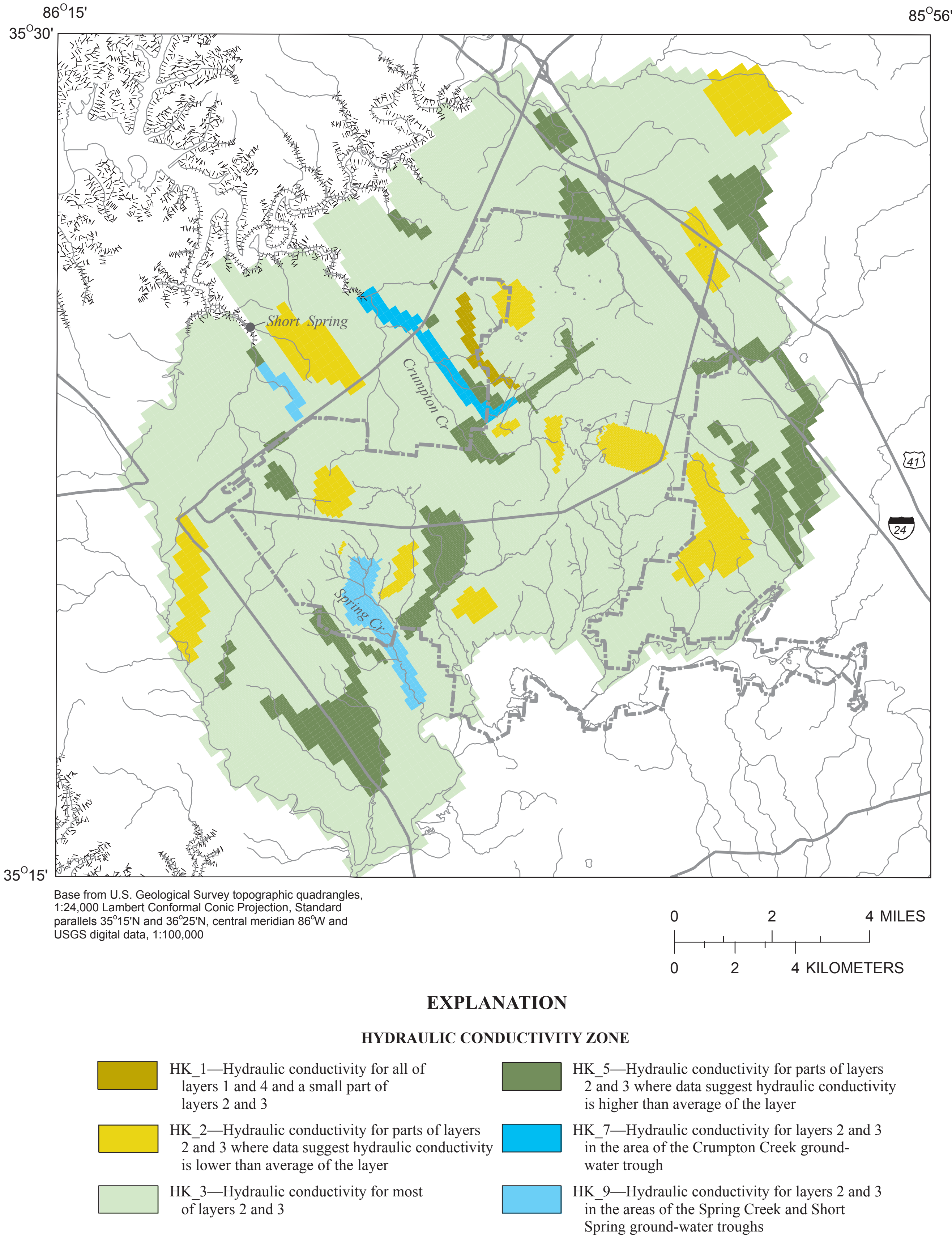


Figure 19. Hydraulic-conductivity zones for model layer 2 of the Arnold Air Force Base area.

downgradient end of the zone. The other zones (HK_1 and HK_2) are present where data indicate hydraulic conductivity is lower than the average of the unit. Layer 3 consists of seven hydraulic-conductivity zones (fig. 20). The distribution of hydraulic-conductivity zones in layer 3 is identical to layer 2 with the exception of an additional zone (HK_4) near the J4 test cell. The HK_4 zone is present where fractures create higher permeability as indicated by elongated water-level depressions around the J4 test cell (Haugh, 1996a). Layer 4 consists of a uniform hydraulic-conductivity value defined by parameter (HK_1). Horizontal anisotropy is not simulated within layers 1 and 2, which represent the regolith, but is simulated as a uniform value within layers 3 and 4, which represent the bedrock. Vertical anisotropy is assumed to be uniform within each layer except layer 1 where vertical anisotropy is divided into two zones. In layer 1, a second zone (VANI_1a) is present where water-level data indicate the difference in water levels is greater than 5 ft between the shallow aquifer and upper part of the Manchester aquifer (fig. 21).

Stream reaches with perennial flow were simulated as river nodes in layer 1 (fig. 17). Stream reaches that were dry under both high and low base-flow conditions measured in 2002 were not simulated (Robinson and Haugh, 2004). The remaining stream reaches, which had flow under high base-flow conditions but were dry under low base-flow conditions, were simulated as drain nodes in layer 1. Large regional springs were simulated as drain nodes. Woods Reservoir and Tims Ford Lake were simulated by constant-head cells using water-level altitudes of 960 and 888 ft, respectively (Flohr and others, 2003).

Model Calibration

The process of adjusting the model input variables to produce the best match between simulated and observed water levels and flows is referred to as calibration. The digital model developed for this study was calibrated to steady-state conditions as defined by averaging water-level and flow measurements from the spring and fall 2002 (Robinson and Haugh, 2004; Robinson and others, 2005). Precipitation during 2002 was near average, so these data should be representative of average annual conditions (table 2). The model was calibrated using a combination of parameter estimation and manual methods to minimize the difference between simulated and observed water levels, streamflows, and spring flows. Initial calibration was done by fixing recharge to initial estimates and using parameter estimation procedures to estimate the hydraulic conductivity. Additional parameter estimation calibrations were then used to further refine the recharge parameters. Final calibration runs estimated the recharge and hydraulic-conductivity parameters together. Vertical anisotropy parameters for layers 2, 3, and 4 (VANI_2, VANI_3, and VANI_4) were fixed during the calibration process because low sensitivities made them difficult to estimate.

Overall, simulated water levels agree reasonably well with observed water levels (appendix; figs. 22, 23, 24, 25, 26, and 27). Water-level data at 615 wells were available for comparison to simulated conditions (appendix). The root mean square error (RMSE) was calculated to compare simulated and measured water levels. The RMSE, in feet, is calculated by

$$RMSE = \sqrt{\left(\sum_{i=1}^{N}\left\langle h_i^m - h_i^c\right\rangle^2\right) / N},$$

where:

- N is the number of observations;
- h_i^m is the measured water level, in feet; and
- h_i^c is the simulated water level, in feet.

The RMSE for water levels is 9.8 ft. The average residual or difference between measured and simulated water levels is –0.47 ft. Seventy percent of the simulated water levels are within 10 ft of observed water levels, and 95 percent are within 20 ft. The range of residuals is similar in each layer. The residuals show a small positive bias in layer 1 and a small negative bias in layers 3 and 4 (fig. 27, appendix). The residuals show no significant spatial patterns (figs. 22, 23, 24, and 25). Simulated discharge fluxes to springs and streams are within ranges of base flow measured in spring and fall 2002 (table 4).

Table 4. Comparison of simulated and measured flows for the Arnold Air Force Base area ground-water flow model.

	Model-simulated streamflow, in cubic feet per second	Range of measured stream base flow from June and October 2002 (Robinson and Haugh, 2004), in cubic feet per second
Crumpton and Wiley Creeks	7.1	4.3 – 9.4
Big Spring at Rutledge Falls	3.3	3.1 – 3.5
Little Duck River	7.1	6.6 – 7.4
Bradley Creek	11.4	6.5 – 17.2
Spring Creek	10.3	8.5 – 10.8
Taylor and Dry Creeks	9.9	8.2 – 11.6
Rock Creek	5.3	6.7 – 9.5
J4	0.22	0.2 – 0.26