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A Method for Estimating Groundwater Contribution Areas for Illinois Nature Preserves and Other Natural Areas

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Prepared for the
Illinois Nature Preserves Commission

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Illinois State Water Survey
Center for Groundwater Science

Illinois State Geological Survey
Wetlands Geology Section

Champaign, Illinois

A Division of the Illinois Department of Natural Resources

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Contents

Abstract

A new method for estimating the groundwater contribution area (GCA) for Illinois nature preserves was demonstrated using 12 test sites (Bluff Springs Fen, Braidwood Dunes and Savanna, Elizabeth Lake, George B. Fell, Goose Lake, Illinois Beach, Lake in the Hills Fen, Lockport Prairie, Parker Fen, Romeoville Prairie, Spring Grove Fen, and Volo Bog). The sites were selected for their varied hydrogeologic settings and available hydrogeologic data. None of the sites had sufficient local groundwater studies available to identify an entire GCA. Regional studies available for six preserves readily could be used to identify a regional GCA.

The amount of hydrogeologic data available for any given preserve will vary, but for most Illinois nature preserves groundwater studies are not available to evaluate groundwater flow conditions. Because contribution areas must be determined to address site management issues, this new method accommodates those sites by identifying GCAs using available information. In particular, it uses published hydrologic and geologic data, if available, as well as uncompiled water-level data, and proxy data adjusted by best professional judgment to account for significant features affecting shallow, unconfined groundwater flow.

Surface watersheds were delineated and adjusted based on significant hydrologic features (e.g., water elevations in ponds, streams, and wetlands; infrastructure such as ditches, sewers, and roadways) to develop adjusted surface watershed areas (ASWAs) for all 12 sites. These ASWAs and regional GCAs were compared to determine the viability of substituting ASWAs for regional GCAs at preserves lacking groundwater-level data. The ASWAs identified between 7 and 68 percent of the regional GCAs. More importantly, the ASWAs included the most hydrologically significant locations directly upgradient of each preserve. Use of an ASWA to estimate groundwater flow will not be effective in some hydrogeologic settings, including those where confined groundwater sources, karst terrains, and significant groundwater withdrawals may be a factor.

Regional GCAs and ASWAs were combined at each site to create final GCAs that attempt to identify all areas that could contribute groundwater to a nature preserve. Final GCA estimates presented in this report will be useful to determine areas where a Class III (also known as Special Resource) groundwater designation could be applied under Title 35 Section 620.230(b) of the Illinois Administrative Code. They also identify areas of important groundwater resources where it may be most effective to focus management or acquisition efforts to ensure preserve integrity.

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The authors sincerely appreciate the efforts of all who have added their time and insights to improve this study. The views expressed in this report are those of the authors and do not necessarily reflect the views of the sponsor, the ISWS, or ISGS.

Introduction

Scope

This report presents a new method developed by the Illinois State Water Survey (ISWS) and the Illinois State Geological Survey (ISGS) for use in estimating areas that contribute groundwater to Illinois nature preserves. The method was developed to determine areas where a Class III (also known as Special Resource) groundwater designation could be applied under the Illinois Administrative Code. In addition, these areas identify important groundwater resources of nature preserves where it may be most effective to focus management or acquisition efforts.

Because resources were not available to collect new hydrogeologic data at each nature preserve, the method for determining groundwater contribution areas (GCAs) outlined in this report uses only available information. The method was tested by estimating GCAs for 12 Illinois nature preserves, and the results identified issues that likely will be encountered when using the method for other Illinois nature preserves and natural areas.

Purpose

Studies have shown that alterations to groundwater quality and quantity can contribute to unwanted changes in natural communities that receive groundwater discharge (e.g., Verhoeven et al. 1983, Schot and Wassen 1993, Boeye et al. 1994, Panno et al. 1999). In order to maintain the biotic quality of some nature preserves, it is crucial to maintain the quality and quantity of groundwater discharge there.

In 1991, groundwater quality standards (35 Ill. Admin. Code 620) were adopted that established a groundwater classification system with four classes. Of most relevance to this report is Class III (also known as Special Resource) groundwater. Groundwater "*that contributes to a dedicated nature preserve...*" or that is determined by the Illinois Pollution Control Board (IPCB) to be either "*demonstrably unique...*," or "*vital for a particularly sensitive ecological system...*" (35 Ill. Admin. Code 620.230) can be considered for Class III designation. The most applicable definition for sites contained in this report is that of Section 620.230b, groundwater that contributes to a dedicated nature preserve.

A petition for designation of Class III groundwater to the Illinois Environmental Protection Agency (IEPA) must include a minimum set of information. As outlined in Section 620.230b, the five minimum components are:

1) a general description of the site and the surrounding land use,
2) a topographic map or other map of suitable scale denoting the location of the dedicated nature preserve,
3) a general description of the existing groundwater quality at and surrounding the dedicated nature preserve,
4) a general geologic profile of the dedicated nature preserve based upon the most reasonably available information, including but not limited to geologic maps and subsurface groundwater flow directions, and
5) a description of the interrelationship between groundwater and the nature of the site.

In addition to that information, the IEPA has required that each petition include a GCA estimate and full documentation of the estimate describing data and methods used. While not specifically called for under Section 620.230b, a GCA estimate is necessary to identify where Class III groundwater quality standards would be implemented. To develop GCA estimates, the INPC contracted with the ISWS and ISGS to assess data availability and determine an estimation method. This report documents the method used to develop GCAs for 12 Illinois nature preserves that can be used in Class III groundwater petitions.

Upon Class III designation, an area automatically is subject to water quality standards designed for Class I (also known as potable) groundwater. An estimated 80 percent of groundwater in Illinois already falls into Class I. However, an important distinction of the Class III designation is that it allows an area to be subject to adjusted water quality standards. The adjusted standards could be tailored to species or ecosystem requirements, if known.

In order to adjust Class III groundwater standards, it will be necessary to evaluate relationships between the concentrations of groundwater constituents and the health of ecosystems or indicator species. The first constituents likely to be evaluated for an adjusted standard are those that have been shown to affect ecological communities adversely at levels lower than those allowable by Class I groundwater standards. For example, chloride has an allowable concentration of 250 milligrams per liter under Class I standards, but can have negative effects on some plant species at concentrations as low as 40 milligrams per liter (Panno et al. 1999). Therefore, lower maximum concentrations may be warranted. It also will be important to assess the role of other constituents such as calcium and magnesium whose presence may be required to sustain highly adapted ecosystems (e.g., calcareous fens). For those constituents, minimum concentrations may be warranted. Further discussion of groundwater standard adjustments are outside the scope of this report.

Limits on the Use of GCAs

Although determinations of GCAs are necessary for each Illinois nature preserve, it is important to understand potential limitations of such estimates. Given the lack of resources available for additional field data collection, GCAs must be estimated from available information. While it is the intent of this report to provide the best method for each level of available data, it is ultimately the user's responsibility to determine that the accuracy of each GCA estimate is sufficient to meet his/her needs. If an estimate is insufficient and greater accuracy is needed, then additional field data collection would be necessary, and the GCA should be revised as appropriate. Similarly, if additional data or improved methods become available in the future, existing GCAs should be evaluated and revised as needed.

The accuracies of GCA boundaries presented in this report have not been determined. Several factors make it difficult to assess their accuracy. First, no standard exists with which to compare GCA quality. It is assumed a GCA prepared using all local groundwater-level data would be the most accurate, but no field examples exist in Illinois for verification. Second, historical potentiometric maps like Meyer (1998) and Roadcap et al. (1993) typically do not have assessments of mapping uncertainty. Despite their unknown accuracies, they represent the best available groundwater-level data. Third, while surface drainage patterns are often mimicked by unconfined groundwater flow patterns, topographic data may not always be an optimal proxy for groundwater-level data in characterizing groundwater flow. The appropriateness of using proxy data and the accuracy of GCAs based on proxy data will depend on hydrologic conditions present at individual sites.

Because GCAs are dynamic, estimates should be considered approximations regardless of the method or data used. A GCA is expected to fluctuate constantly in response to changes in groundwater recharge and discharge (e.g., variations in climatic conditions, alterations to surface permeability, increased or decreased pumping, etc.). Estimates based on historic data will have unknown accuracies unless they can be compared with current hydrologic conditions.

Similarly, a GCA must not be considered an outer limit of potential impacts to a preserve. Activities proposed both inside and outside a GCA must continue to be evaluated by resource and planning agencies for their potential to change groundwater flow conditions. For example, withdrawals from wells (especially those pumping greater than 100,000 gallons per day) in close proximity but outside a GCA may change groundwater flow patterns. Such hydraulic changes may affect GCA size and location and thus quantity and/or quality of water available for discharge to a preserve.

Data Types

Hydrogeologic data available for many Illinois nature preserves were collected and summarized in Locke et al. (1997a and 1997b), which included then current datasets and research projects of the ISWS, ISGS, and other agencies. Significant data sources and data qualities are described below.

Groundwater-Level Data

Groundwater investigations have been conducted on both local and regional scales in selected areas of Illinois. These studies rely on the measurement of groundwater levels as the basis for determining prevailing hydraulic gradients. The studies develop a conceptual framework in which the geologic units of the study area are identified and described, and water levels in each aquifer are measured and interpreted, allowing groundwater flow directions to be determined. Water-level data commonly are summarized in maps showing groundwater elevations, also known as a potentiometric surface maps. By design, data are collected from a large geographic area over a short time period and are used to show regional trends. All local hydrologic conditions may not be accounted for because data points may not be of sufficient density.

Six of the 12 preserves considered in this report were within areas of previous regional investigations. Key studies used in the preparation of this report were those of McHenry County by Meyer (1998) and Will and southern Cook Counties by Roadcap et al. (1993). These and other ISWS reports of groundwater investigations are listed on line at the ISWS publications search page (http://www.sws.uiuc.edu/pubs/isearch.asp).

Local studies can provide a greater density of data and more detailed description of the local groundwater-flow system, but few such studies are available, and they generally are not large enough to define entire GCAs. Six of the 12 preserves had available local hydrogeologic data: three published and three unpublished. The published studies include: Illinois Beach (Visocky 1977), Spring Grove Fen (Locke et al. 1997a), and Volo Bog (McComas et al. 1972). The unpublished studies pertain to Lake in the Hills Fen, Parker Fen, and Bluff Springs Fen. None of the noted studies encompass the full extent of a GCA at their respective preserves.

Uncompiled groundwater-level data are also available from drillers' logs and well completion reports on file at the ISWS and ISGS. The amount of data available in the vicinity of each preserve varies widely. In addition, these raw (i.e., uninterpreted) groundwater-level data have not been put in an appropriate hydrogeologic context. Because the identity and extent of the source aquifer may not be known, data interpretation is often difficult. It also should be recognized that these data often span seasons, years, and decades, which limits their applicability in determining current site-specific hydrologic conditions. Generalizations about groundwater levels and flow directions can be made from drillers' logs, but the accuracy of those interpretations is often ambiguous. Consequently, those records usually serve as supplementary, but not primary, data to estimate groundwater gradients and flow directions.

Geologic Data

Available maps were used to determine the three-dimensional arrangement of geologic deposits in the vicinity of each preserve. As with the water-level data, the density and scale of available geologic data strongly affect the detail discernable at each preserve. Regional and statewide mapping usually provides a starting point in interpreting site geology. Where site-specific studies have been conducted, interpretations can be refined extensively. Drillers' logs from the vicinity also can be used to confirm or refine expected conditions, although reliability of those records varies greatly as noted above.

Some sources of geologic information are identified in the *Index of Publications of the Illinois State Geological Survey* available through the ISGS. Geologic information also can be found by searching GeoRef (http://www.agiweb.org/georef/) or similar indexes on the Internet. Other statewide data used in this study include: Quaternary geology (Lineback 1979), bedrock lithology (Willman et al. 1967), bedrock topography (Herzog et al. 1994), stack-unit surficial geology (Berg and Kempton 1988), and information presented in county soil surveys. These resources, along with regional studies (e.g., Curry et al. 1997), drillers' logs, and other information gathered for selected preserves by Locke et al. (1997b), were used to evaluate the extent of geologic deposits in the vicinity of the 12 preserves.

Nature Preserve Boundaries and Base Maps

In 2003, nature preserve boundaries were obtained from the Illinois Department of Natural Resources (IDNR) in a geographic information system (GIS) format. Base maps for each preserve were constructed by superimposing the preserve boundaries on digital 7.5-minute U.S. Geological Survey (USGS) topographic maps. Topographic maps were obtained as digital raster graphics (DRG) files from the ISGS Geospatial Data Clearinghouse (http://www.isgs.uiuc.edu/nsdihome/ ISGSindex.html).

Digital Topographic Data

Digital elevation models (DEMs) available for the entire state can be used to show the topography and delineate surface watersheds for preserves. A DEM is composed of terrain elevations for ground positions at regularly spaced horizontal intervals (USGS 1997). The models have been available at three quality levels based partly on product accuracy. The Level 2 Illinois statewide DEM mosaic compiled by Don Luman, ISGS, is the highest quality available for Illinois, and was used for computer generation of surface watersheds for each of the 12 preserves.

Other Data Types

Other data types were used to identify natural (e.g., streams, lakes, and wetlands) or anthropogenic features (e.g., ditches, mines, and infrastructure) that may indicate or influence groundwater recharge and discharge. In particular, topographic maps, aerial photographs, and previous knowledge of the preserve from site visits were useful. In several instances described later, the GCA was altered based on features that suggested drainage away from the preserve.

Method

Data Availability

Twelve Illinois nature preserves (Figure 1) were selected as test sites for this study. Available and relevant hydrogeologic data for those sites summarized in Locke et al. (1997a) were examined.

Three of the preserves had some on-site groundwater-level data available, but none had site-specific hydrogeologic studies that encompassed the entire area that would be considered for a GCA. Furthermore, no Illinois nature preserve has enough groundwater-level data available to make such a determination based solely on local data. The regional hydrologic studies most relevant to this report are available for surficial and shallow aquifers in Will, southern Cook, and McHenry Counties. Regional hydrologic studies are available for other counties (e.g., Piatt and DeWitt), but they often do not deal with aquifers that discharge groundwater to the land surface. Most Illinois nature preserves lack both local and regional hydrogeologic studies for GCA estimates.

Because there are more than 300 Illinois nature preserves, cost and time prohibit the collection of sufficient field data to map head surfaces at all preserves with high resolution. Therefore, estimating GCAs for most Illinois preserves will require the use of proxy data (e.g., topography and surface watersheds), indicators (e.g., groundwater discharge and geologic deposits), uncompiled water-level data when available, and best professional judgment. While not readily quantifiable, a reduction in accuracy should be expected when proxy data are used.

The 12 test sites were divided into three cases based on the data availability discussed above. A short discussion of each case and specific steps to determine a GCA follow. The quality of each GCA derived from these methods will depend on the quantity and quality of the available groundwater data.

Case 1 - Local Hydrogeologic Studies Available

If a local hydrogeologic study with sufficient groundwater elevation data is available, then a fairly precise GCA for each contributing aquifer may be estimated. This can be done with flow net analyses of potentiometric surface maps using techniques described in Freeze and Cherry (1979) and Fetter (2001). Local hydrogeologic studies should provide sufficient information so groundwater levels and flow directions in each aquifer in the vicinity of the preserve can be interpreted with respect to local topography, geology, and surface water hydrology. Data density may be an issue, but it is assumed that data are sufficiently dense to draw local conclusions.

Case 1 is expected to be the most definitive, but no local studies cover sufficient areas to define entire GCAs. This case may be relevant in the future and is still considered. Additionally, the portions of a preserve that are well described by local studies or data can be estimated using Case 1 steps, then combined with the area estimated for the remainder of the preserve using steps described for other cases.

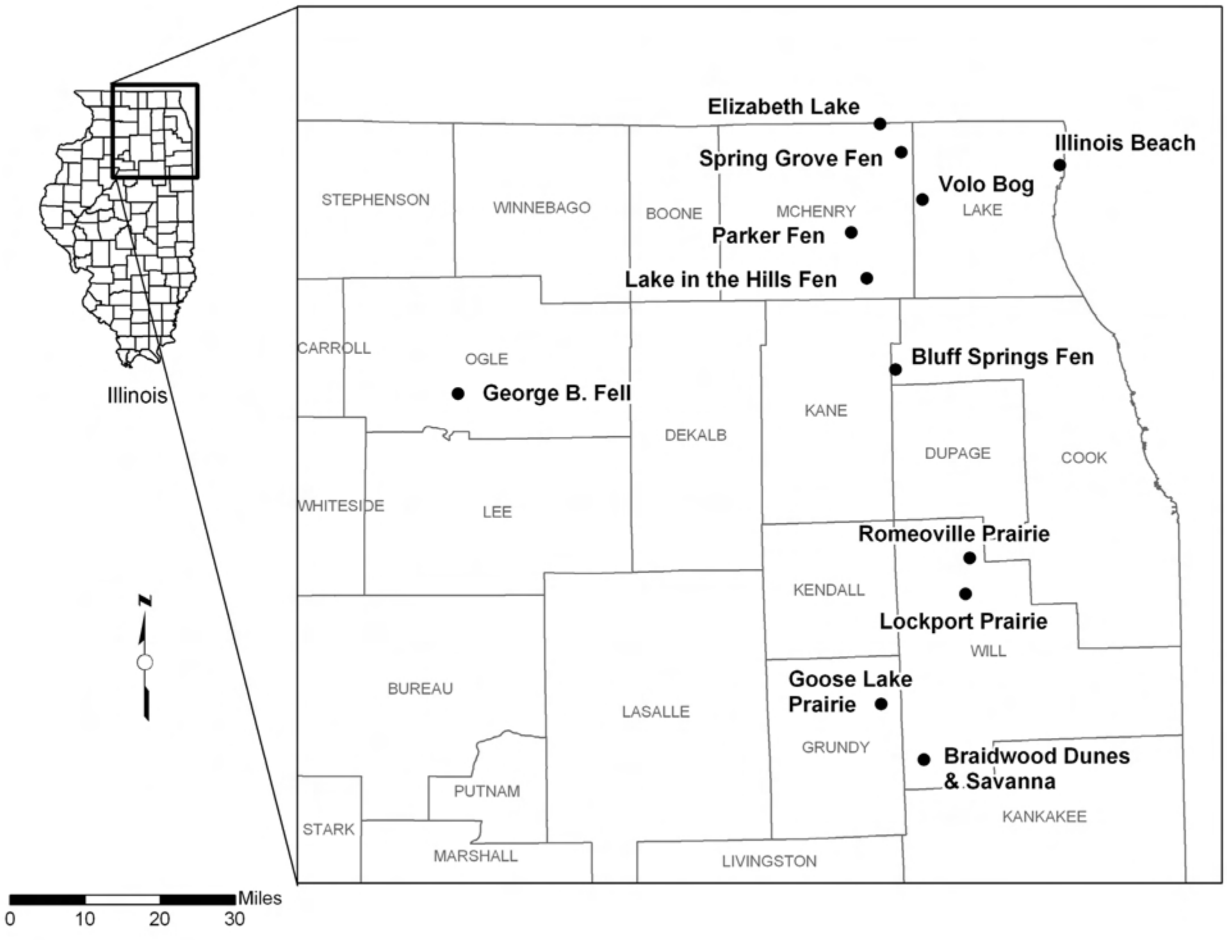

Figure 1. Locations of 12 nature preserves used in the study.

Case 2 - Regional Hydrogeologic Studies Available

The second case includes preserves for which regional hydrogeologic studies but no local studies exist and few, if any, local data are available. Areas estimated for Case 2 sites are conservatively inclusive to identify all potentially contributing areas. Six of the preserves addressed in this report fall into Case 2, and estimating their GCAs requires slightly different steps than those described for Case 1. Some data used have similar forms (i.e., a potentiometric map), but the main difference is the scale at which the data can be used.

For parts of a GCA for which local studies are available, flow net techniques can be applied to the potentiometric maps for each aquifer that contributes to the preserve. Flow net techniques also can be applied to regional potentiometric maps for each contributing aquifer. The total GCA then is constructed by combining all individually estimated areas.

Data scale and density should be considered carefully when using maps from a regional hydrogeologic study. In particular, data from these studies may be sparse when considered on a local scale. If possible, the original data used to prepare the regional potentiometric maps should be examined. Because data density may be insufficient to account for all hydrologic features that are significant locally (e.g., topography, surface water bodies, and local geologic units), adjustments to the regional GCAs may be necessary using best professional judgment. Some specific considerations and guidelines are discussed later.

For confined aquifers, additions to or subtractions from a regional GCA may be appropriate to account for the presence or absence of local geologic units. This should be done by examining local geologic maps or uncompiled geologic data (e.g., drillers' logs). In this context, the term "confined aquifer" indicates an aquifer that is hydrologically connected and significant to the preserve, but may be confined at some distance away from the preserve. It is not intended to mean an aquifer that is not in hydrologic connection with the nature preserve.

For unconfined aquifers, in addition to the adjustments described for confined aquifers, adjustments to the regional GCA may be necessary to account for topography, surface water or other hydrologically significant surficial features. Because unconfined groundwater flow generally mimics surface drainage, the final GCAs should be consistent with local topography. Local features such as surface water bodies and infrastructure (e.g., sewers) also may have significant effects. Areas also can be added or subtracted based on the local presence or absence of geologic units.

As discussed above, the GCA associated with an unconfined aquifer is often similar to the surface watershed because topography strongly influences both. Using best professional judgment, an adjusted surface watershed area (ASWA) can be constructed based on the surface watershed. The ASWA can be constructed to conform with features that would affect unconfined groundwater flow.

Case 3 - No Hydrogeologic Studies Available

If no groundwater-level studies were available at regional or local scales, as is true for the majority of Illinois nature preserves, then an ASWA may be an acceptable proxy for the GCA of an unconfined aquifer. Use of the ASWA as a proxy will not be optimal in all hydrogeologic settings. In particular, it will not be effective in identifying GCAs for which confined groundwater flow, karst, or groundwater withdrawal are significant factors. Adjustments to an ASWA could be made for confined aquifers if sufficient geologic and water-level data are available to suggest additional contributing areas, but this should be done only when the data clearly support such an adjustment. In addition, uncompiled geologic and water-level data may provide some indication of local conditions, but should be used carefully.

Despite these limitations, the areas hydraulically upgradient and in the immediate vicinity of the preserve generally will be included in an ASWA and therefore a Case 3 GCA. Those proximal and most critical areas can be identified. A Case 3 GCA will be useful for the protection of the preserve, even if it is does not optimally identify all areas of groundwater contribution.

GCA Estimation Method

The following method is suggested for estimating GCAs in all three cases. The method is presented as a series of steps to follow until an acceptable GCA is achieved. The following steps were used in estimating the GCA for each test site, and are suggested for future estimates:

Step 1. Use interpreted groundwater-level data from local (also known as site-specific) studies (Case 1) to estimate the GCA.

A. Superimpose the preserve boundary using GIS or other techniques on a base map showing interpreted local groundwater-level data (e.g., potentiometric surface contours) at the largest appropriate scale for each relevant aquifer. Estimate a GCA for each aquifer by identifying areas hydraulically upgradient of the site using flow net analysis. Compare the potentiometric surface to land-surface elevations to ensure that discharge to land surface is possible. If no discharge is possible at or near land surface at the preserve, do not include the aquifer. Similarly, if a major aquitard occurs above an aquifer, do not include that aquifer if best professional judgment suggests it does not contribute to discharge at or near land surface at the preserve.

B. If more than one aquifer contributes groundwater, combine the individual contribution areas into a composite area. This completes the GCA estimation process for Case 1.

Step 2. Where local hydrogeologic studies are not available or sufficiently comprehensive (Case 2), use available local groundwater-level data, regional studies, and adjusted proxy data to estimate the GCA. Where local groundwater studies are available, use Step 1 for those areas and combine any estimated contribution area with that produced using the steps below.

A. Superimpose the preserve boundary on the interpreted regional groundwater-level data (e.g., potentiometric surface contours) at the largest appropriate scale for each relevant aquifer. Estimate a GCA for each aquifer by identifying areas hydraulically upgradient of the site using flow net techniques. Assess each aquifer's ability to discharge water at or near land surface as discussed in Step 1A.

B. If more than one aquifer contributes groundwater, combine the individual contribution areas into a composite contribution area shown by one polygon as in Step 1B.

To improve the estimation, determine the ASWA using Steps 2C-2E below.

C. Estimate the surface watershed.

i. To estimate by hand, delineate an area on a 1:24,000 scale (or larger) topographic map using flow net techniques.

ii. To estimate by computer, use watershedding tools such as those available in ArcGIS™ software. Examine the resulting boundaries and verify that they are consistent with published topography (e.g., 1:24,000 scale DRGs).

iii. Adjust inappropriate or ambiguous areas.

a. Exclude portions of the surface watershed of any stream where groundwater is expected to discharge to the stream prior to the stream entering the preserve.

b. Individually evaluate closed or nearly closed depressions, which may be mishandled by computer routines. Include or exclude the depressions based on slope, hydraulic gradients, surficial drainage patterns, or any other features useful to infer groundwater flow.

D. Use best professional judgment to determine if additional adjustments are warranted. As appropriate, use natural hydrologic features (e.g., elevations of streams, lakes, and wetlands), constructed features (e.g., ditches, sewers, paved areas, and other infrastructure) and uncompiled hydrogeologic data (e.g., drillers' logs) where appropriate. Determine if these data fit the existing conceptual hydrogeologic framework and are consistent with the surface watershed boundary. Make adjustments to the ASWA as warranted. Assess aquifers for discharge to land surface using criteria listed in Step 1A.

E. Examine the regional and local geology to find the character, extent, elevation, and hydraulic conditions (if known) of each mapped geologic unit, and include or exclude areas as appropriate. Some guidelines include:

i. Units with moderate to high permeability (i.e., aquifers) may suggest additional sources of groundwater that may interact with the nature preserve.

ii. Units with low permeability (i.e., aquitards) tend to restrict groundwater movement and may prevent discharge from adjacent aquifers.

iii. Elevation of the top of the uppermost aquitard may suggest the extent of unconfined flow toward the preserve in a manner analogous to using land-surface elevation in determining a surface watershed.

iv. Peat mounds, hydric soils, bluffs, and other indicators may suggest groundwater discharge and/or artesian conditions. Geologic discontinuities may induce groundwater discharge.

v. Unsaturated coarse-grained materials should not automatically be eliminated from consideration as part of a GCA. These materials should be considered on a case-by-case basis, because infiltration (and therefore recharge) likely still occurs through them.

F. Combine the GCA determined using regional groundwater-level data in Steps 2A-2B with the ASWA determined in Steps 2C-2E to identify all areas of potential groundwater contribution. The combined area is the final GCA for Case 2.

Step 3. In Case 3, when no compiled hydrogeologic data are available, use proxy data discussed above and best professional judgment to estimate GCAs. Follow Steps 2C-2F above to determine a final GCA for Case 3 based solely on the ASWA.

Results and Discussion

The method was tested at 12 preserves to evaluate its possible use for all Illinois nature preserves. The final GCA boundaries presented are appropriate for use in Class III groundwater petitions to the IEPA. Geologic nomenclature follows Hansel and Johnson (1996), and older names are reclassified accordingly. Aquifer nomenclature for sites in McHenry County follows Meyer (1998).

Test Sites

The 12 test sites selected represent a variety of geologic and hydrologic conditions. Data availability also was considered. None of the 12 sites had sufficient data to be representative of Case 1. Six sites (Lake in the Hills Fen, Spring Grove Fen, Parker Fen, Lockport Prairie, Romeoville Prairie, and Elizabeth Lake) with regional groundwater-level data are representative of Case 2. The remaining six sites (Bluff Springs Fen, George B. Fell, Illinois Beach, Volo Bog, Goose Lake Prairie, and Braidwood Dunes and Savanna) with very limited or no compiled groundwater-level data available are representative of Case 3. For brevity, only one detailed example of Case 2 and 3 is shown below. Appendices A and B include descriptions and associated figures for the other ten sites. For all sites, significant considerations in the estimation process are noted, and specific steps of the method are referenced where appropriate.

Case 2 - Lake in the Hills Fen

Lake in the Hills Fen in southeastern McHenry County west of the Fox River has unconsolidated deposits up to 300 feet thick above bedrock. Regional groundwater-level studies are available for this area, along with limited data from site-specific studies. Meyer (1998) mapped groundwater levels for five shallow aquifers of the county, including two at the site above an extensive aquitard of glacial till; aquifers below that till are not expected to discharge to the land surface in the preserve. Aquifer 1 is mostly sands and gravels of the Henry Formation and the Haeger Member, a moderately permeable diamicton of the Lemont Formation. These deposits are at or near the land surface on the east side of the preserve. Aquifer 2 is mostly sand and gravel underlying or within the Yorkville Member of the Lemont Formation and is at or near land surface to the west of the preserve. Aquifer 1 appears to overlie Aquifer 2 in areas northwest of the preserve. The water levels in each aquifer suggest that discharge to the land surface in the preserve is possible. Both aquifers are expected to be water sources for the calcareous seeps and fens. The Tiskilwa Formation, a thick, clay-rich diamicton that effectively prevents upward flow from deeper aquifers and bedrock, underlies both aquifers.

The potentiometric surface maps of Aquifers 1 and 2 (Plate 1 and Plate 2, respectively, from Meyer 1998) were composited and used to estimate a regional GCA. Following Step 2A, the regional GCA determined from the composite map by flow net analysis represents flow conditions in the fall of 1994. Figure 2 shows a portion of the composite potentiometric surface map and the regional GCA, which covers 6.7 square miles (mi^2) or 4263 acres (ac)

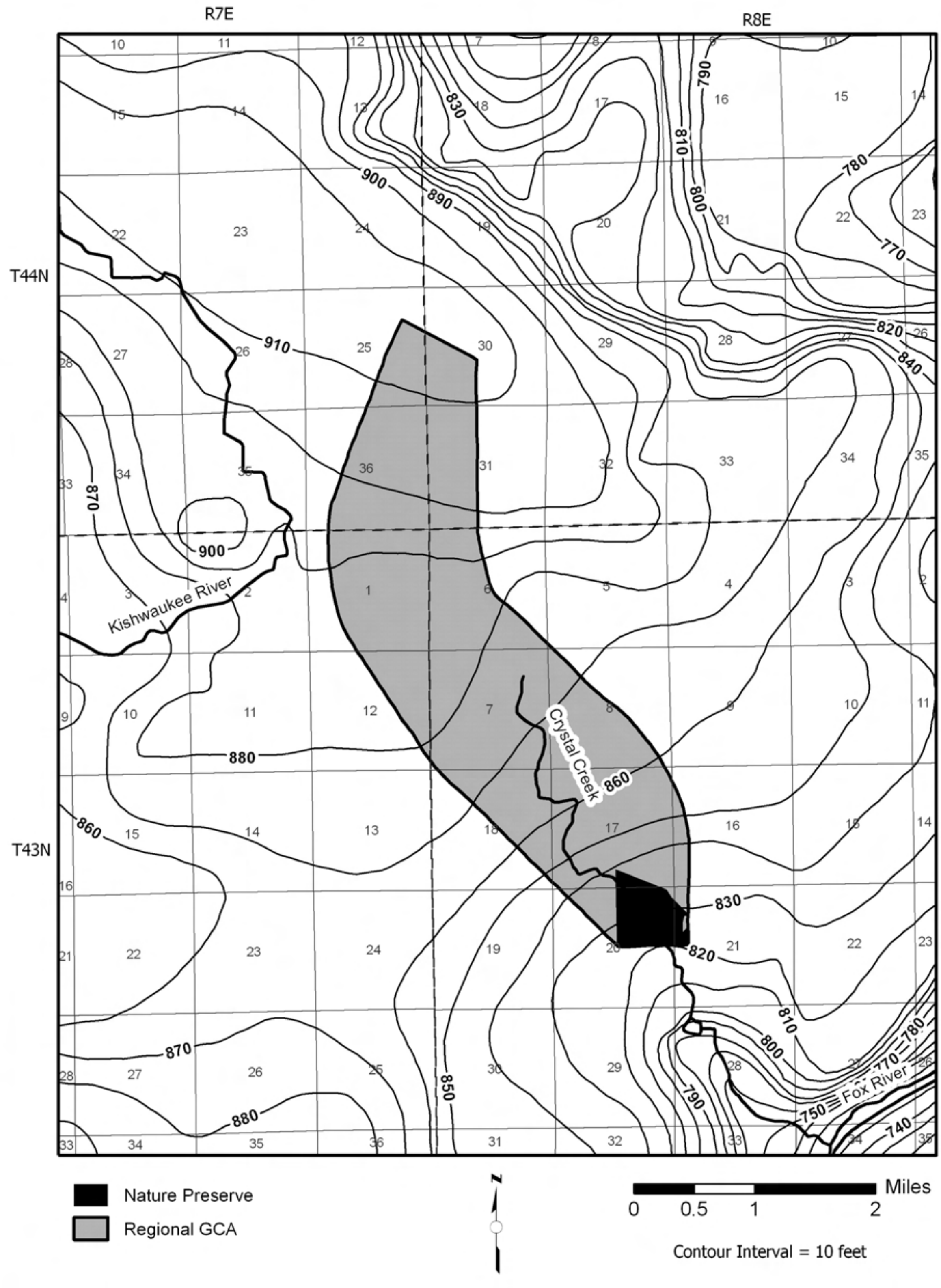

Figure 2. Groundwater elevation contours and regional GCA for Lake in the Hills Fen Nature Preserve based on data modified from Meyer (1998).

and extends north and west of the site toward the groundwater high near Township 44 North (T44N), Range 7 East (R7E), Section 25. Water-level elevations from unpublished local hydrologic studies conducted by the Surveys were examined and are consistent with the regional GCA.

To estimate surface watershed boundaries for Step 2C(ii) at this preserve, computerized methods were expected to be an efficient way to generate reproducible and accurate results. However, it became clear early in this study that the computer-generated boundaries were not sufficiently accurate due to the scale of the available DEMs. Boundaries were redigitized by hand according to topography shown on USGS 1:24,000 scale DRGs. Figure 3 shows the boundaries of the original computer-generated and adjusted watersheds for Lake in the Hills Fen. A primary difference between the two is the exclusion of areas from the ASWA because groundwater discharges to Crystal Creek before entering the preserve (Step 2C(iii)(a)).

Figure 4 shows the regional GCA and ASWA for Lake in the Hills Fen. A combination of the two areas (Step 2F) represents the final GCA (Figure 5) and includes 6.8 mi^2 (4339 ac).

Case 3 - Bluff Springs Fen

Bluff Springs Fen is located in northwestern Cook County in an east-west trending valley underlain by Henry Formation sand and gravel (Berg and Kempton 1988) and formed by glacial meltwater. Uplands to the north and south also are Henry Formation sand and gravel at the land surface. To the south, multiple units of glacial till of the Wedron Group and earlier formations underlie the sand and gravel in the uplands. Silurian dolomite exists at a depth of about 70 to 100 feet. North of the preserve, the till units are generally absent.

No published regional groundwater-level studies are available for this preserve. Site-specific studies have been performed in and around the preserve, including those by Patrick Engineering, Inc. (1988 and 2003), but they concentrate primarily on an area south of the preserve and do not include the entire contribution area. Following the method, the final GCA will be based largely on an ASWA.

The initial computer-generated watershed (Figure 6) included more than 40 mi^2 of the Poplar Creek watershed upstream of the preserve. In consideration of Step 2C (iii)(a), much of the Poplar Creek watershed was excluded because groundwater discharges to Poplar Creek before entering the preserve. Significant alterations to the land surface have occurred in the area, including sand-and-gravel excavation south and east of the preserve. The mined area to the south contains altered topography with a less distinct surface watershed boundary. However, the entire mined area was included in the ASWA because data from Patrick Engineering, Inc. (1988) and current knowledge of the site indicate local groundwater flow originates from areas south and east of the preserve. Surface water flow directions outside the mining area were used to estimate the ASWA boundary south of the preserve and mined areas.

A local topographic high exists approximately 1.0 to 1.5 miles east of the preserve in T41N, R9E, Sections 20, 21, and 28. East of that local high, a large, nearly closed depression is bounded by a larger and broader topographic high about 3 miles east of the preserve. In Step 2C(iii)(b), the large depression was excluded from the ASWA based on surface water elevations

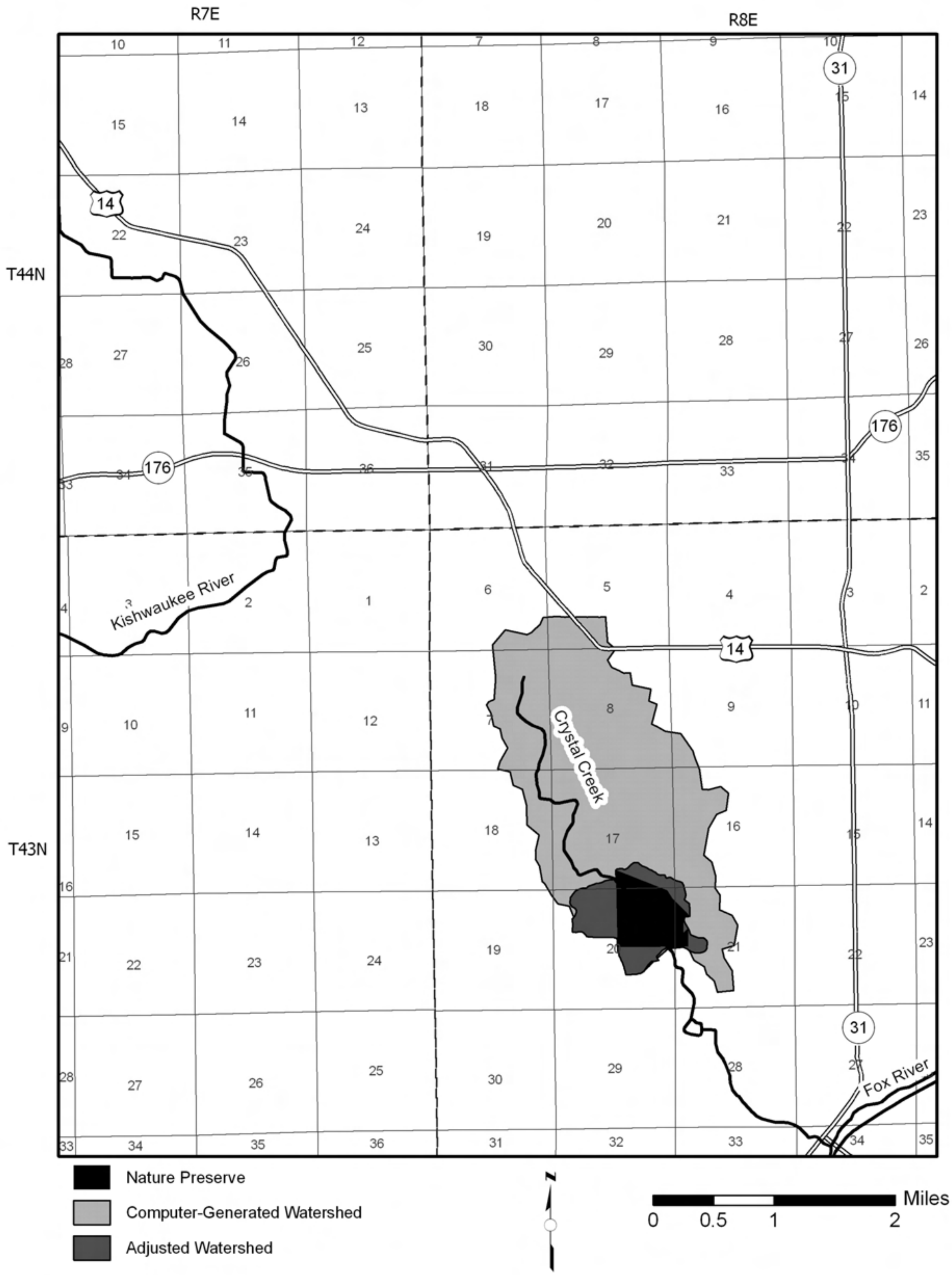

Figure 3. Comparison of computer-generated and adjusted watersheds for Lake in the Hills Fen Nature Preserve.

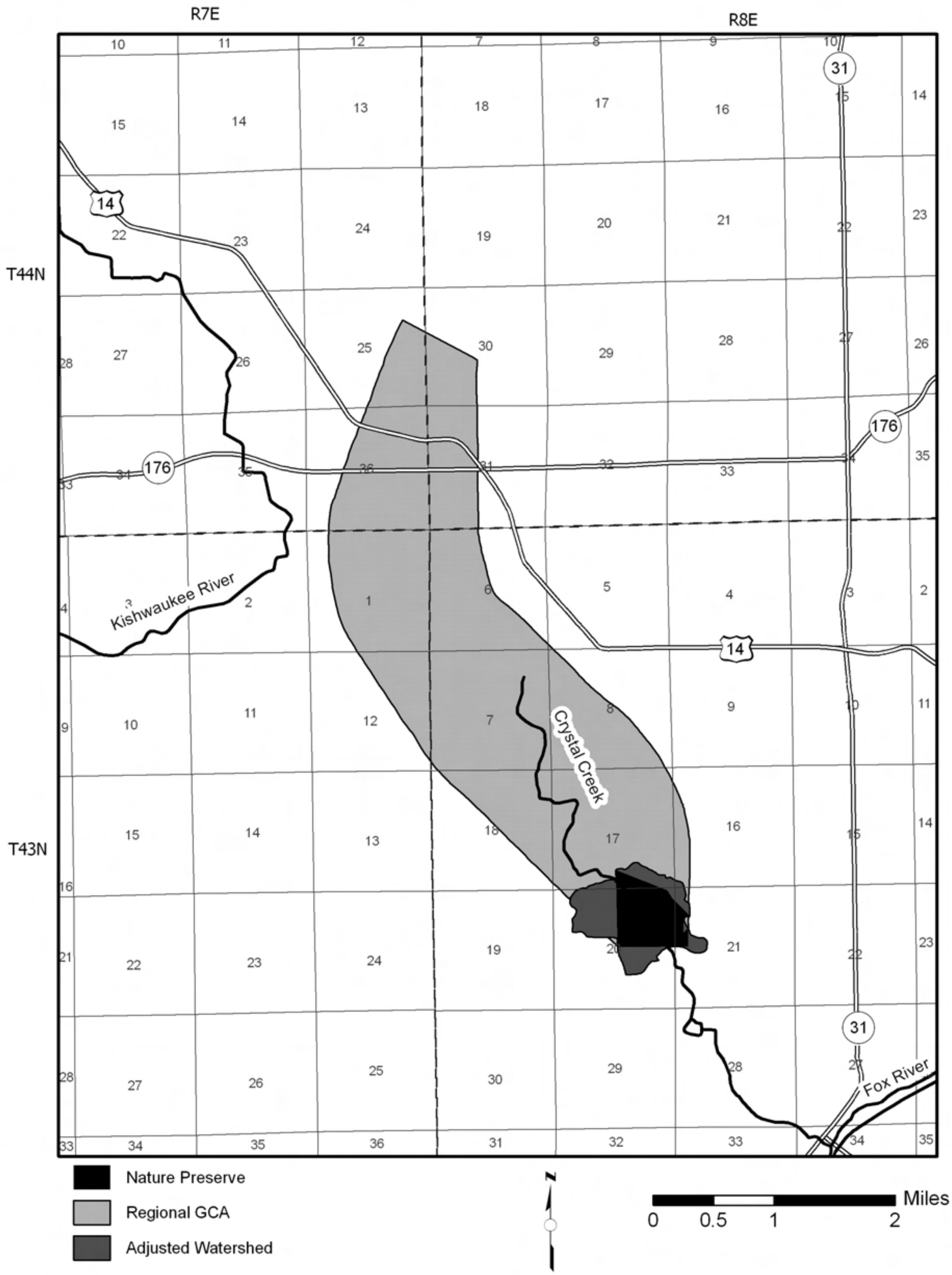

Figure 4. Comparison of regional GCA and ASWA for Lake in the Hills Fen Nature Preserve.

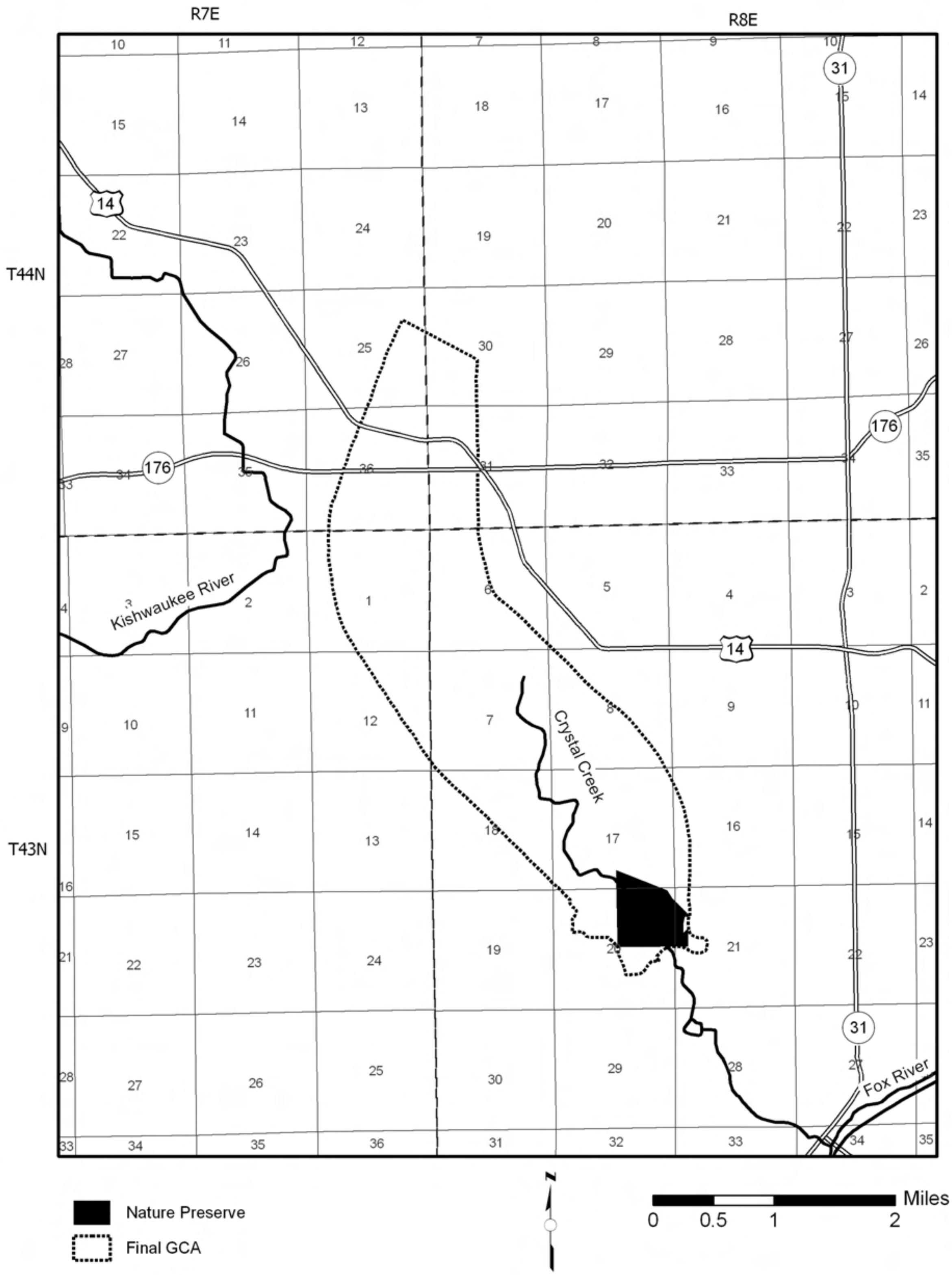

Figure 5. Final GCA for Lake in the Hills Fen Nature Preserve.

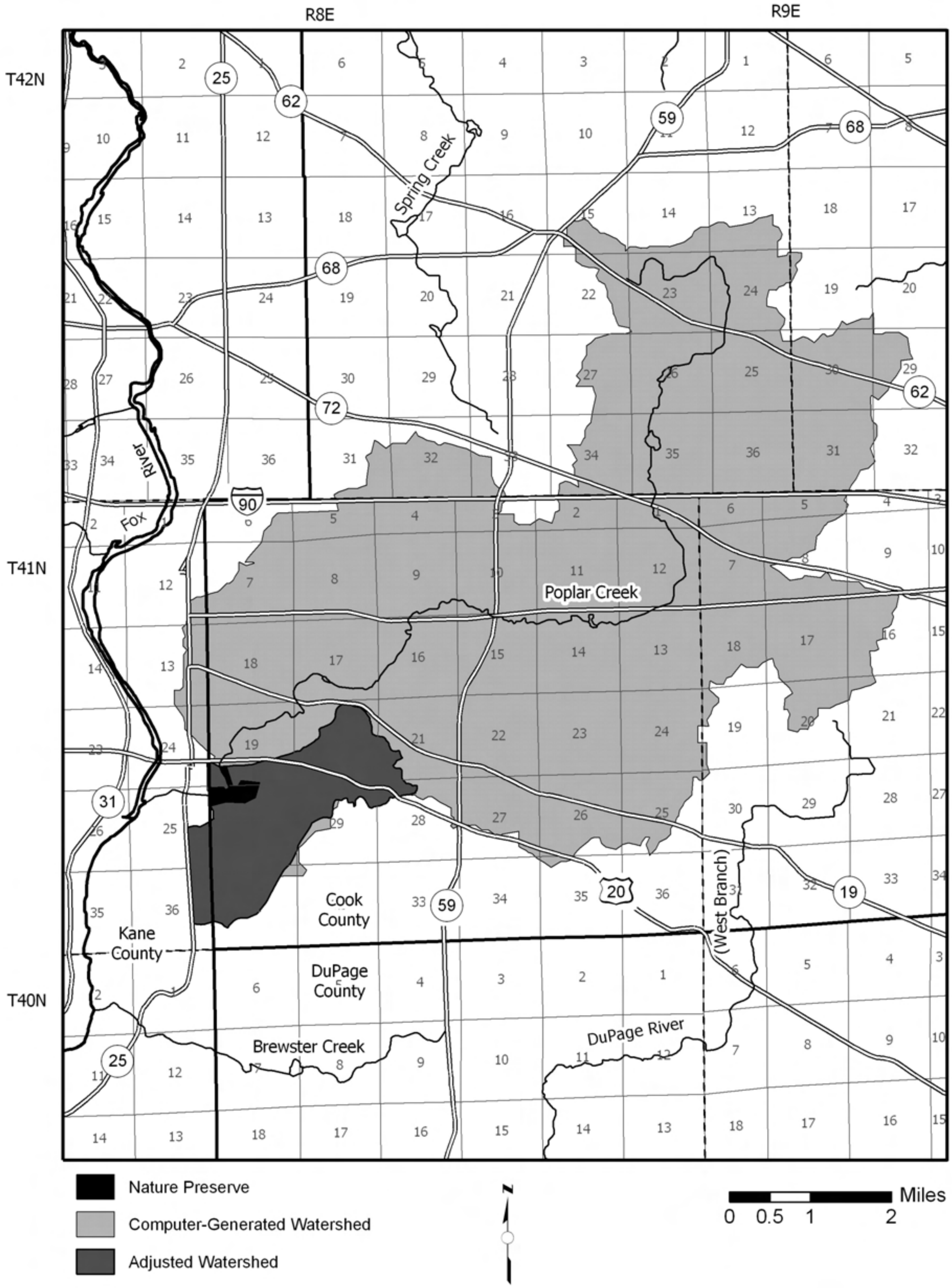

Figure 6. Comparison of computer-generated and adjusted watersheds for Bluff Springs Fen Nature Preserve.

that suggest a divide near the local topographic high. In addition, a ditch system that drains the depression to the southwest away from the preserve is further evidence for excluding the area.

Geologic materials at the land surface within the surface watershed are dominantly sand and gravel of the Henry Formation (Berg and Kempton 1988) and topography is expected to strongly influence unconfined groundwater flow. Glacial till of the Wedron Group is at the land surface in a small eastern portion of the surface watershed. Glacial till is expected to have reduced infiltration in comparison to sand and gravel, but the area was not excluded because infiltration and groundwater flow toward the preserve still will occur.

Reports by Patrick Engineering, Inc. (1988 and 2003) and other uncompiled data suggest that bedrock directly underlies the Henry Formation sand-and-gravel deposits below the preserve, such that upward discharge from bedrock to the preserve is possible. However, sufficient vertical hydraulic gradient data were not available to include the Silurian dolomite as a major groundwater source. Groundwater flow from the dolomite was not considered in constructing the ASWA (Figure 6), which covers 3.49 mi^2 (2235 ac). Because no other relevant groundwater information is available for the site, the ASWA serves as the final GCA (Figure 7). Should the dolomite be determined to be a significant water source for the preserve in the future, the final GCA should be adjusted accordingly.

Summary Information

Table 1 summarizes information presented for the preceding test cases and those presented in Appendices A and B. It includes the approximate nature preserve acreage, GCA acreage based on regional data (regional GCA), ASWA acreage, and final GCA acreage. The smallest site, Parker Fen, has the smallest regional GCA, ASWA, and final GCA. The seventh largest site, Lake in the Hills Fen, has the largest regional GCA. In contrast, the fourth largest site, Braidwood Dunes and Savanna, is 75 percent larger than Lake in the Hills Fen, but has a final GCA nearly 90 percent smaller. This suggests that preserve size alone is not indicative of the expected size of the final GCA.

Comparison of Regional GCAs and ASWAs

Regional GCAs and ASWAs can be compared to determine their relative extent. Expressed as a percentage of the regional GCA, the *percent overlap* ranges from 7 percent at Lake in the Hills Fen to 68 percent at Romeoville Prairie with a mean value of 28 percent. As seen in the figures for each site, regional GCAs almost always extended beyond ASWAs. The largest differences were noted if the preserves were small or located on a strong slope. At all test sites, the ASWAs and regional GCAs included common areas immediately upgradient of the preserves. Those areas are often the most hydrologically important from management and protection perspectives.

Another statistic, the *regional GCA to ASWA ratio*, was determined to compare relative sizes of regional GCAs and ASWAs. With the exception of Elizabeth Lake, the ratios show that ASWAs were from 24 to 91 percent smaller than corresponding regional GCAs. At Elizabeth Lake, the ASWA was 59 percent larger.

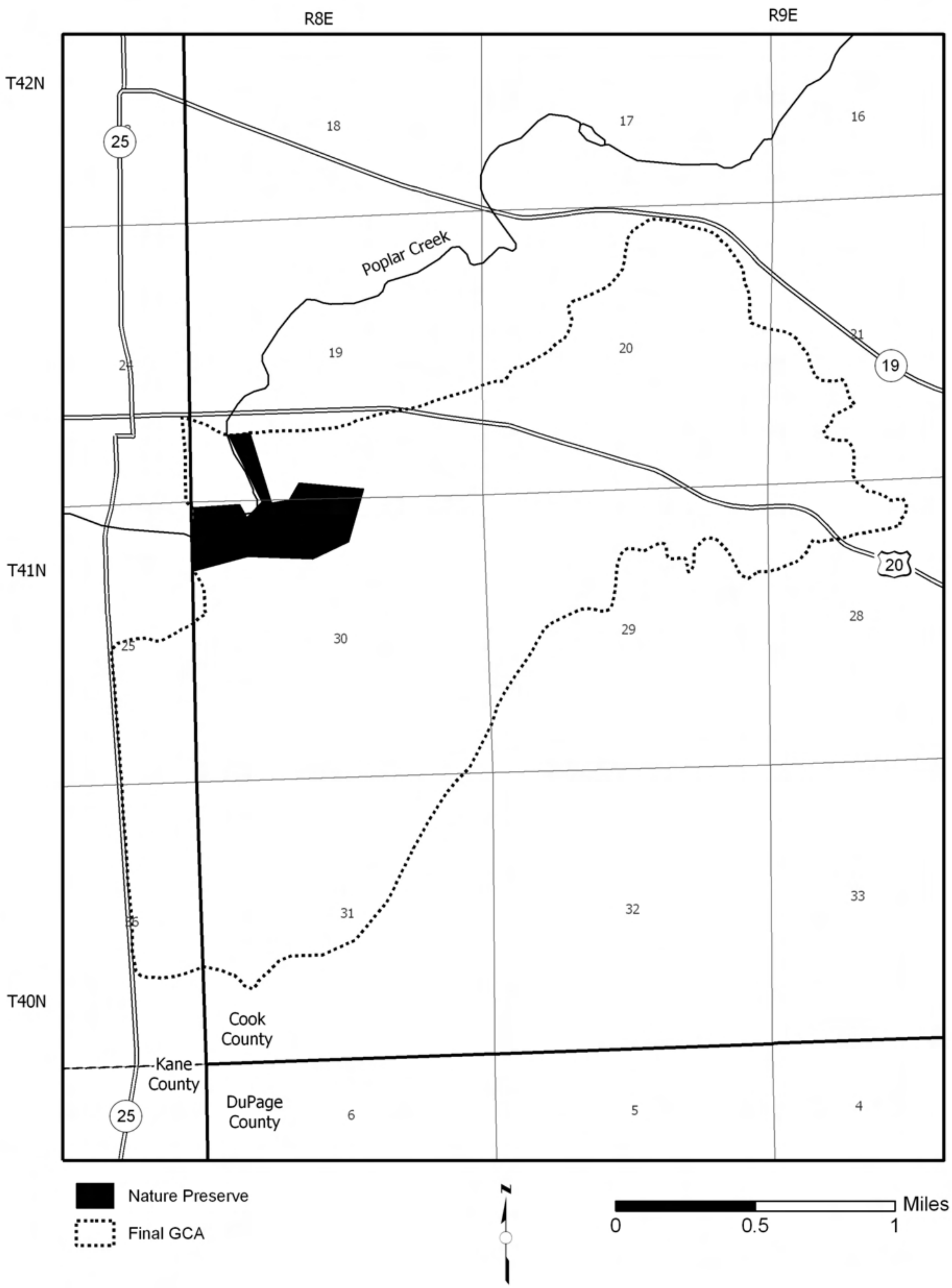

Figure 7. Final GCA for Bluff Springs Fen Nature Preserve.

Table 1. Summary Information for Groundwater Contribution Area (GCA) and Adjusted Surface Watershed Area (ASWA) Estimates (in acres) for 12 Test Sites.

Preserve	County	Preserve area [a]	Regional GCA[b]	ASWA[b]	Percent overlap	Final GCA[b]	Regional GCA to ASWA ratio
Bluff Springs Fen	Cook	94.5	-	2235	-	2235	-
Braidwood Dunes	Will	330.6	-	443	-	443	-
Elizabeth Lake	McHenry	218.7	897[c]	1427	59[c]	1799[c]	1 : 1.59[c]
George B. Fell	Ogle	681.3	-	1057	-	1057	-
Goose Lake Prairie	Grundy	1649.4	-	3665	-	3665	-
Illinois Beach	Lake	1089.3	-	1691	-	1691	-
Lake in the Hills Fen	McHenry	188.0	4263	380	7	4339	1 : 0.09
Lockport Prairie	Will	222.3	3381	1054	31	3382	1 : 0.31
Parker Fen	McHenry	13.3	136	103	21	211	1 : 0.76
Romeoville Prairie	Will	156.3	1692	1234	68	1781	1 : 0.73
Spring Grove Fen	McHenry	32.1	1547	238	15	1550	1 : 0.15
Volo Bog	Lake	150.3	-	657	-	657	-
	Min	13.3	136	103	7	211	1 : 0.09
	Max	1649.4	4263	3665	68	4339	1 : 1.59
	Mean	402.2	1986	1182	28	1901	1 : 0.60

Notes:

[a]Approximate acreages are based on 2003 ArcGIS data from IDNR (Personal Communication with T. Gibbs-Kieninger, IDNR, June 2003).
[b]Calculated areas include the approximate preserve acreage.
[c]Contribution areas for Aquifers 4 and 5 were not estimated and therefore not included in these descriptive statistics.

For the purposes of groundwater protection for a preserve, a final GCA based solely on an ASWA appears to identify significant areas for groundwater protection even though it does not strictly match the the regional GCA. In addition, ASWAs did not usually include large areas outside the regional GCA. This suggests the inclusion of little extraneous area in a final GCA based on an ASWA. Because Class III areas can be adjusted after initial designation, use of ASWAs for Class III areas appears to be a good first step. Review of Class III areas produced from ASWAs is recommended each time new site-specific or regional data become available.

Conclusions

Establishing Class III groundwater protection for Illinois nature preserves requires a GCA estimate for each site. A method was presented, and the GCAs for 12 nature preserves were estimated to evaluate the method. The test sites were selected for their varied hydrogeologic settings and available data. The accuracy of the results obtained from this method will vary according to data quality and availability and the experience of the person preparing the GCA. The following conclusions were drawn from working with the test sites.

Sufficient groundwater studies for GCA estimates are not available for much of the state, thus requiring use of alternative data and methods. Regional groundwater-level data were unavailable for half of the test group, and none of the sites had sufficient local data to estimate an entire GCA. Most Illinois nature preserves are expected to lack sufficient groundwater-level data for GCA estimates. Because there are more than 300 Illinois nature preserves, cost and time prohibit the collection of sufficient field data to map head surfaces at all preserves with high resolution. Therefore, estimating GCAs for most preserves in the state will require the use of proxy data (e.g., topography and surface watersheds), indicators (e.g., groundwater discharge and geologic deposits), uncompiled data when available, and best professional judgment. While not readily quantifiable, a reduction in GCA accuracy should be expected when proxy data are used.

Existing regional groundwater studies may not allow a GCA to be estimated accurately at a local scale, although estimates can be improved by evaluating multiple data sources. Studies at a regional scale may or may not fully depict local groundwater-flow conditions. Therefore, even when regional groundwater-level data are available, it is best to use multiple data sources to verify and improve estimates of groundwater sources.

An ASWA can provide an estimate of the unconfined GCA. As a starting point, the GCA of the unconfined aquifer can be approximated by a surface watershed that is adjusted to conform to any uncompiled groundwater-level data pertaining to surficial aquifers and local hydrogeologic conditions. The ASWAs identified between 7 and 68 percent of the regional GCAs. More importantly, the most hydrologically significant areas immediately upgradient of the preserves were identified more consistently. For the purposes of groundwater protection when no groundwater-level data are available, a final GCA created from the ASWA provides significant protection for a preserve even though it may not entirely correlate with a GCA estimated using regional groundwater-level data.

Some hydrogeologic conditions may be represented poorly when an ASWA is used to estimate a GCA. The GCAs should address both confined and unconfined groundwater sources. Because ASWAs are based mostly on topography and other near surface features, they may not adequately address confined sources. Other hydrogeologic conditions poorly represented include karstic terrain and areas influenced by development or groundwater pumping. Best professional judgment needs to be applied in these cases.

The uncertainties of the GCA estimates in this report have not been determined. Each dataset used to estimate GCAs has inherent uncertainties, whether local groundwater-level data, regional groundwater-level data, or proxy data were used. Historical potentiometric maps typically do not have assessments of mapping uncertainty. Despite their unknown accuracies, they represent the best available groundwater-level data.

Contribution areas are dynamic. A GCA changes constantly as a result of fluctuations in recharge and water usage (e.g., variations in climatic conditions, alterations to surface permeability, and increased or decreased pumping). Estimates based on historic data may be inaccurate unless a comparison is made with current hydraulic conditions. In addition, resource and planning agencies must continue to evaluate activities (e.g., pumping from water-supply wells or other development) proposed within and near the GCA for their potential to change groundwater-flow conditions and thus GCAs.

Using the method described in this report, GCAs were determined for 12 test sites. Those areas are the most applicable to be proposed for Class III groundwater protection, given current data availability, funding, and technology. As additional groundwater-level data are available, Class III areas can be amended. As appropriate, this method also may be used to determine GCAs at other Illinois nature preserves and natural areas.

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Appendix A. Additional Case 2 Test Sites

Spring Grove Fen

Spring Grove Fen is located in northeastern McHenry County in the Nippersink Creek Valley. Geologic data (Curry et al. 1997) show the site has sand and gravel of the Henry Formation at land surface. Uplands to the south of the preserve are comprised of the Haeger Member of the Lemont Formation, a coarse-grained diamicton, which overlies a thick sequence of Henry Formation sand and gravel. Meyer (1998) grouped both of these units as Aquifer 1. They are underlain by Tiskilwa Formation till, which contains sand-and-gravel bodies that are mapped as Aquifer 3. Aquifer 2 is not present at this location. Tiskilwa till is expected to prevent aquifers below Aquifer 3 from contributing groundwater to the preserve. Unconsolidated deposits can exceed thicknesses of 250 feet in some areas. For a more detailed description of site geology, refer to Locke et al. (1997a).

Potentiometric surface maps (Meyer 1998) indicate that Aquifer 3 is connected to Aquifer 1 in the vicinity of the site, and is capable of discharge to the land surface in the preserve. Following Step 2A of the GCA estimation method, flow net analysis of the potentiometric surfaces for Aquifer 1 (Figure A1) and Aquifer 3 (Figure A2) was used to estimate two regional GCAs to the south and west that partially overlap. Following Step 2B, the combined contribution area (Figure A3) for Aquifers 1 and 3 is 2.4 mi^2 (1547 ac). Site-specific data (Locke et al. 1997a) also were examined and were consistent with Meyer (1998).

The preserve is directly adjacent to Nippersink Creek. Originally, the entire 117 mi^2 watershed of Nippersink Creek upstream of the preserve was identified by the watershedding process in Step 2C(ii). Following Step 2C(iii)(a), the surface watershed boundary was adjusted to remove areas where groundwater would be expected to discharge into Nippersink Creek before entering the preserve. The resulting ASWA (Figure A3) included only 0.4 mi^2 (238 ac).

The regional GCA is significantly larger than the ASWA. Only about 15 percent of the regional GCA would have been identified by use of the ASWA alone at this site, although both include the most hydrologically significant areas directly upgradient of the preserve. For Step 2F, the final GCA (Figure A3) was produced by combining the ASWA with the regional GCA. The final GCA includes 2.4 mi^2 (1550 ac).

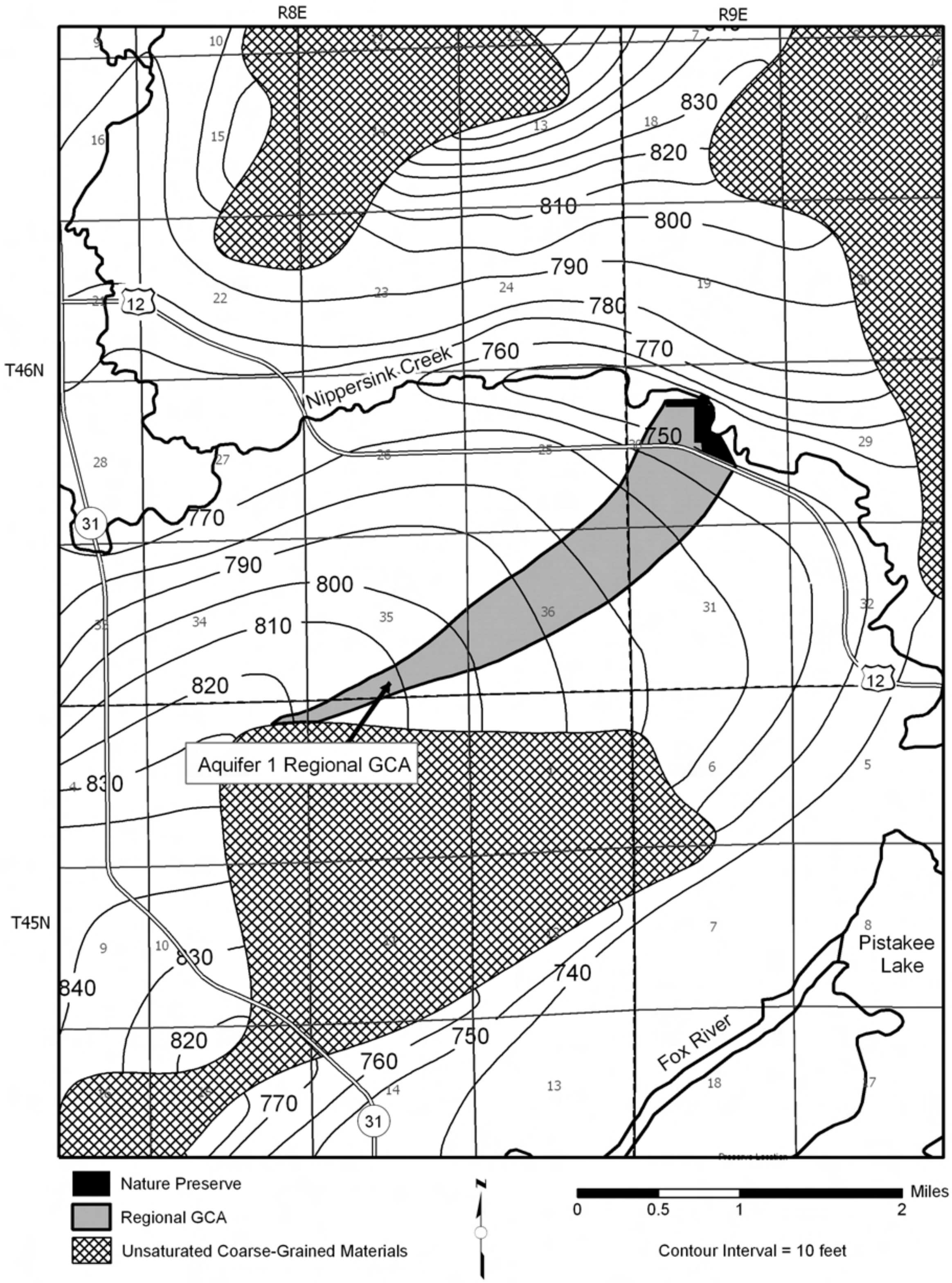

Figure A1. Aquifer 1 regional GCA for Spring Grove Fen Nature Preserve with groundwater contours modified from Meyer (1998).

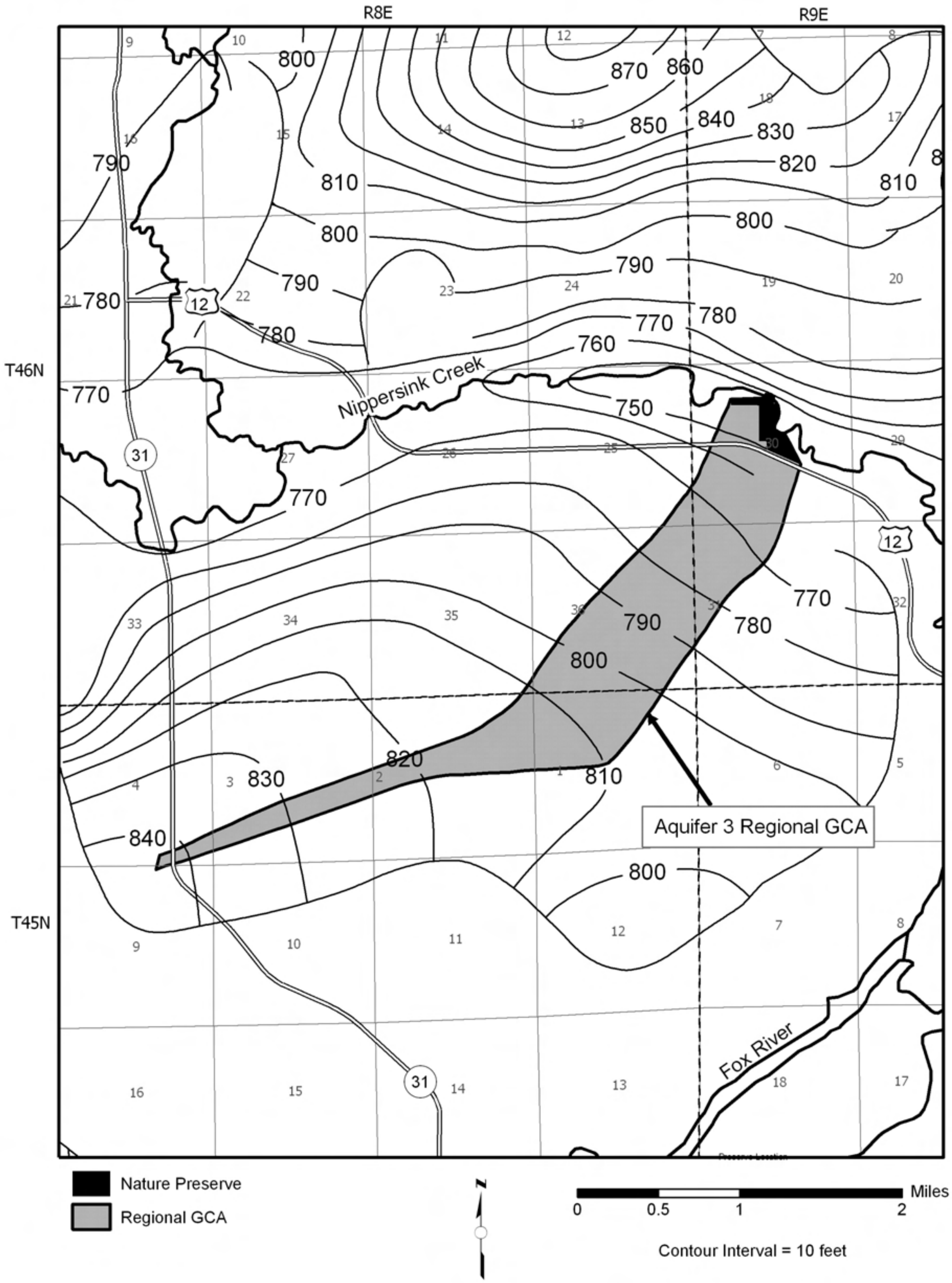

Figure A2. Aquifer 3 regional GCA for Spring Grove Fen Nature Preserve with groundwater contours modified from Meyer (1998).

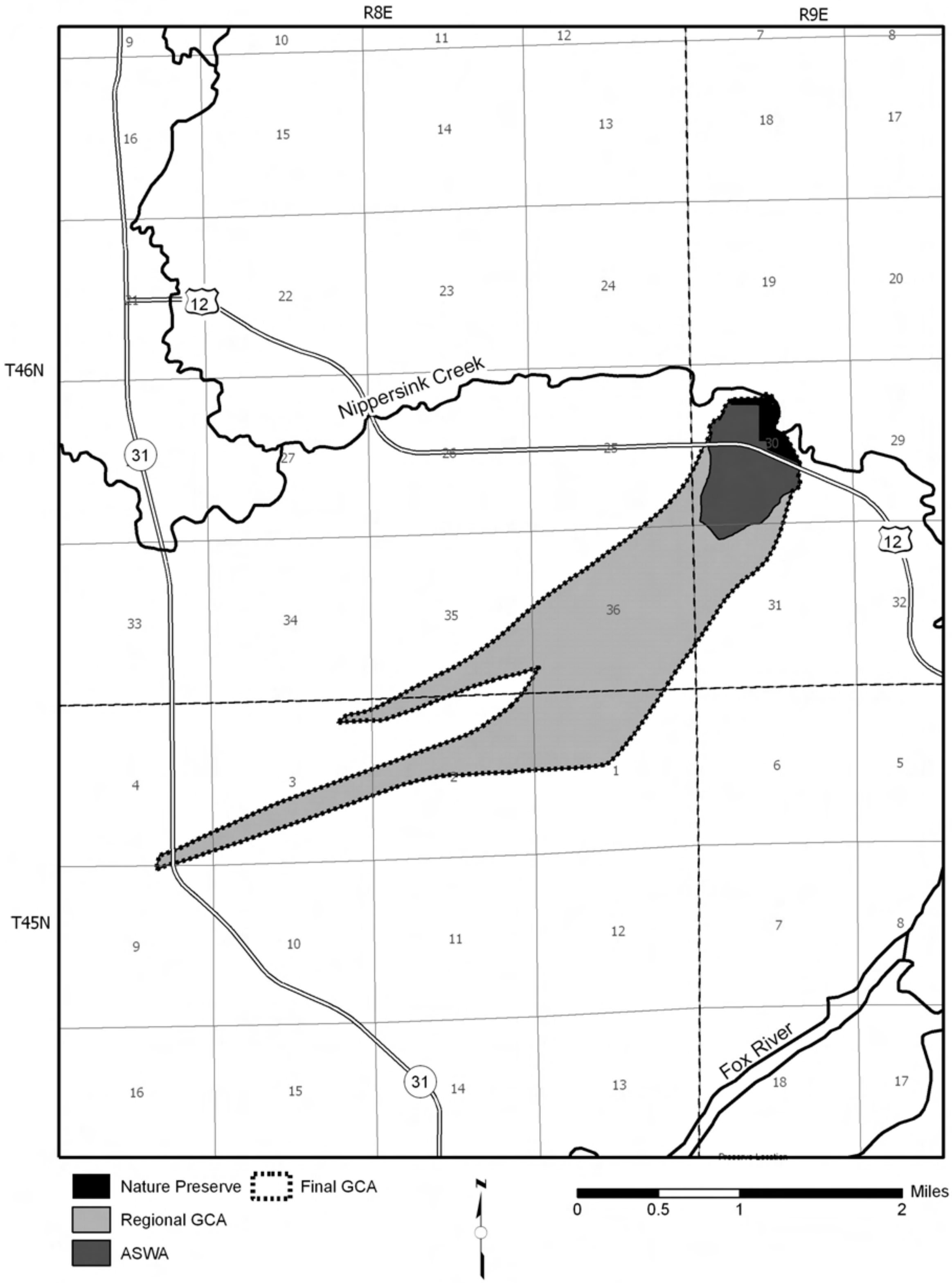

Figure A3. Regional GCA, ASWA, and final GCA for Spring Grove Fen Nature Preserve.

Parker Fen

Parker Fen is located in central McHenry County where unconsolidated sediments are up to 300 feet thick above bedrock. Lineback (1979) shows sand and gravel of the Henry Formation at the land surface adjacent to the preserve, underlain by till of the Yorkville Member, which locally includes related sand-and-gravel deposits. These two units form Aquifers 1 and 2 (Meyer 1998). They are predominantly unconfined, hydraulically connected, and underlain by glacial till of the Tiskilwa Formation, which likely prevents upward discharge from deeper aquifers. Following Step 2A, composited potentiometric surface maps from Aquifers 1 and 2 were used, and the regional GCA (Figure A4) was 0.21 mi^2 (136 ac). Following Steps 2C-2E, the ASWA (Figure A5) was 0.16 mi^2 (103 ac).

The ASWA and the regional GCA have relatively little overlap, with 21 percent of the regional GCA included in the ASWA. This is due in part to the preserve's relatively small size (13 ac) and its topographic position. The preserve is located on the convex face of a hill, so local topography is likely to be very influential in determining local groundwater flow, and may vary significantly from regional groundwater-level studies that were not interpreted for local conditions. It is not readily possible with the available data to determine which is more accurate. The final GCA (Figure A5), determined from Step 2F includes both the ASWA and the regional GCA, a total of 0.33 mi^2 (211 ac).

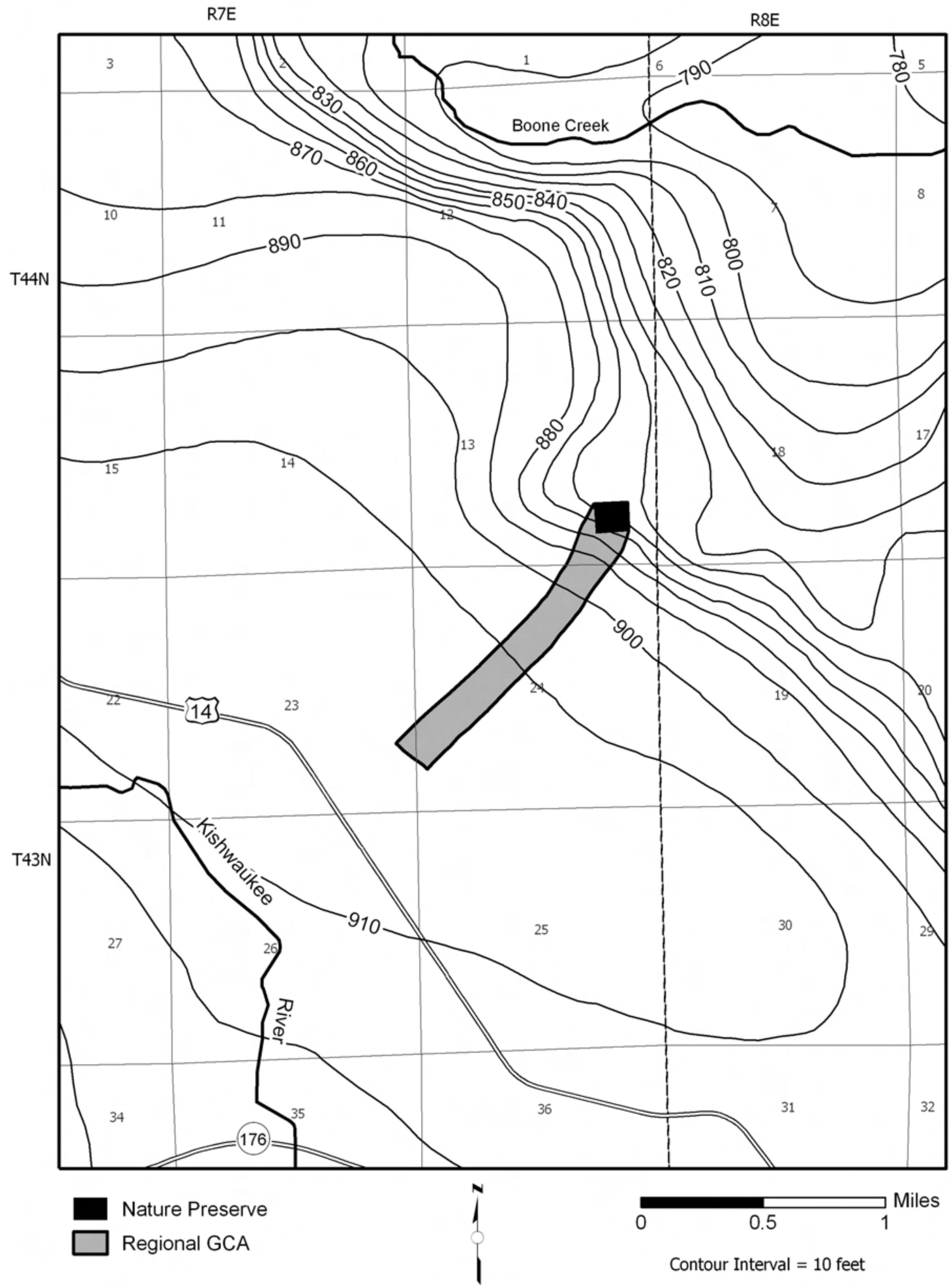

Figure A4. Regional GCA for Parker Fen Nature Preserve with groundwater contours modified from Meyer (1998).

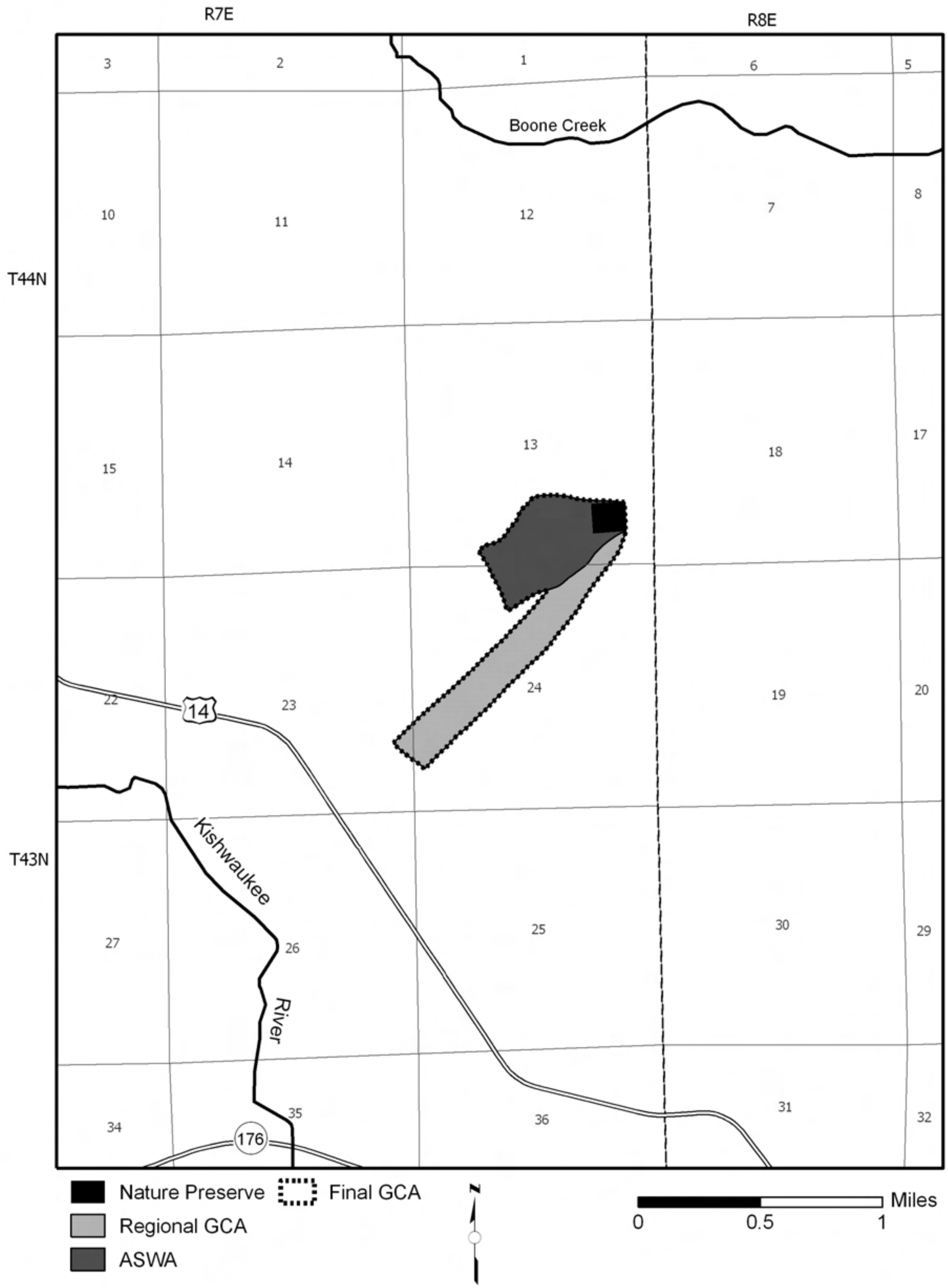

Figure A5. Regional GCA, ASWA, and final GCA for Parker Fen Nature Preserve.

Lockport Prairie and Romeoville Prairie

Lockport Prairie and Romeoville Prairie are located in northern Will County west of the Lower Des Plaines River. The sites overlie Silurian dolomite of the Niagaran Series (Berg and Kempton 1988). The Silurian dolomite is a main groundwater source for Lockport Prairie, as is a terrace of Henry Formation sand and gravel adjoining the western boundary of the preserve. West of the sand-and-gravel terrace, the deposits on the uplands are dominantly glacial till up to 50 feet thick. Romeoville Prairie is in a similar hydrogeologic setting and is expected to have similar water sources. Infiltration through the glacial till varies and provides groundwater recharge for the bedrock in the county.

Roadcap et al. (1993) state that the shallow dolomite in Will County is under confined to semi-confined conditions, and local studies confirm this for the area west of the preserve. Regional GCAs for both sites were estimated in Step 2A using the potentiometric surface of the Silurian dolomite aquifer from the fall of 1990 (Roadcap et al. 1993). The regional GCAs (Figure A6) cover 5.3 mi^2 (3381 ac) for Lockport Prairie and 2.6 mi^2 (1692 ac) for Romeoville Prairie. Local water-level data are consistent with those areas.

Because of the local topography, the surface watersheds extend only a short distance to the west. No major adjustments were made to the surface watersheds. The ASWAs (Figure A7) for Lockport Prairie cover 1.65 mi^2 (1054 ac) and 1.93 mi^2 (1234 ac) for Romeoville Prairie.

The regional GCAs at these preserves generally extend beyond the surface watershed boundaries because the dolomite is at the land surface in the vicinity of the preserves, but it is confined in areas farther to the north and west. Thus, groundwater flow is less influenced by surface topography than an unconsolidated aquifer would be. The ASWAs include 31 percent and 68 percent of the estimated contribution areas for Lockport and Romeoville Prairies, respectively. However, both the ASWAs and the regional GCAs include the closest upgradient areas, which are likely to be the most critical hydrologically. The final GCAs (Figure A7) determined from Step 2F combine the ASWAs and the regional GCAs and include 5.3 mi^2 (3381 ac) for Lockport Prairie and 2.8 mi^2 (1781 ac) for Romeoville Prairie.

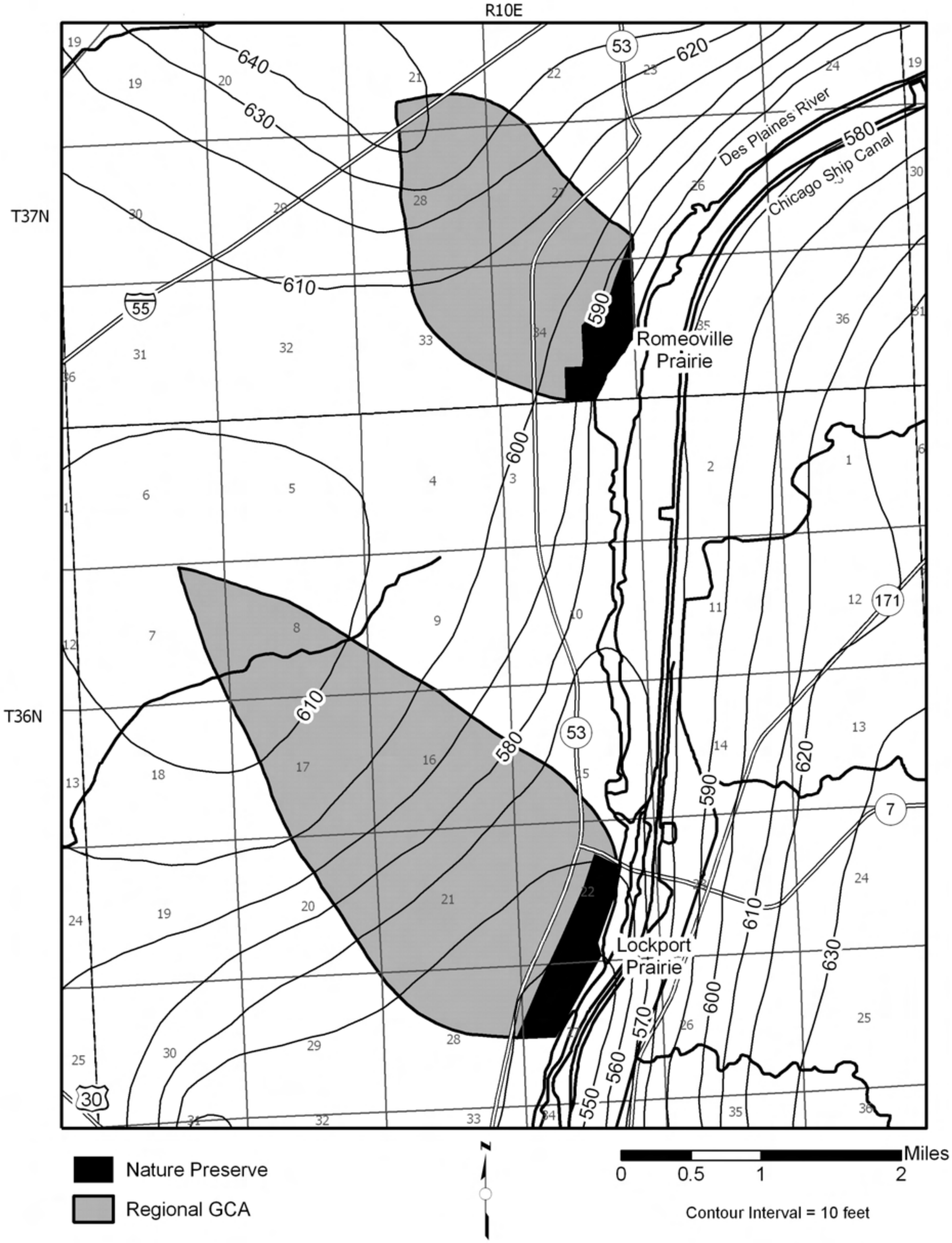

Figure A6. Regional GCAs for Lockport Prairie and Romeoville Prairie Nature Preserves with groundwater contours from Roadcap et al. (1993).

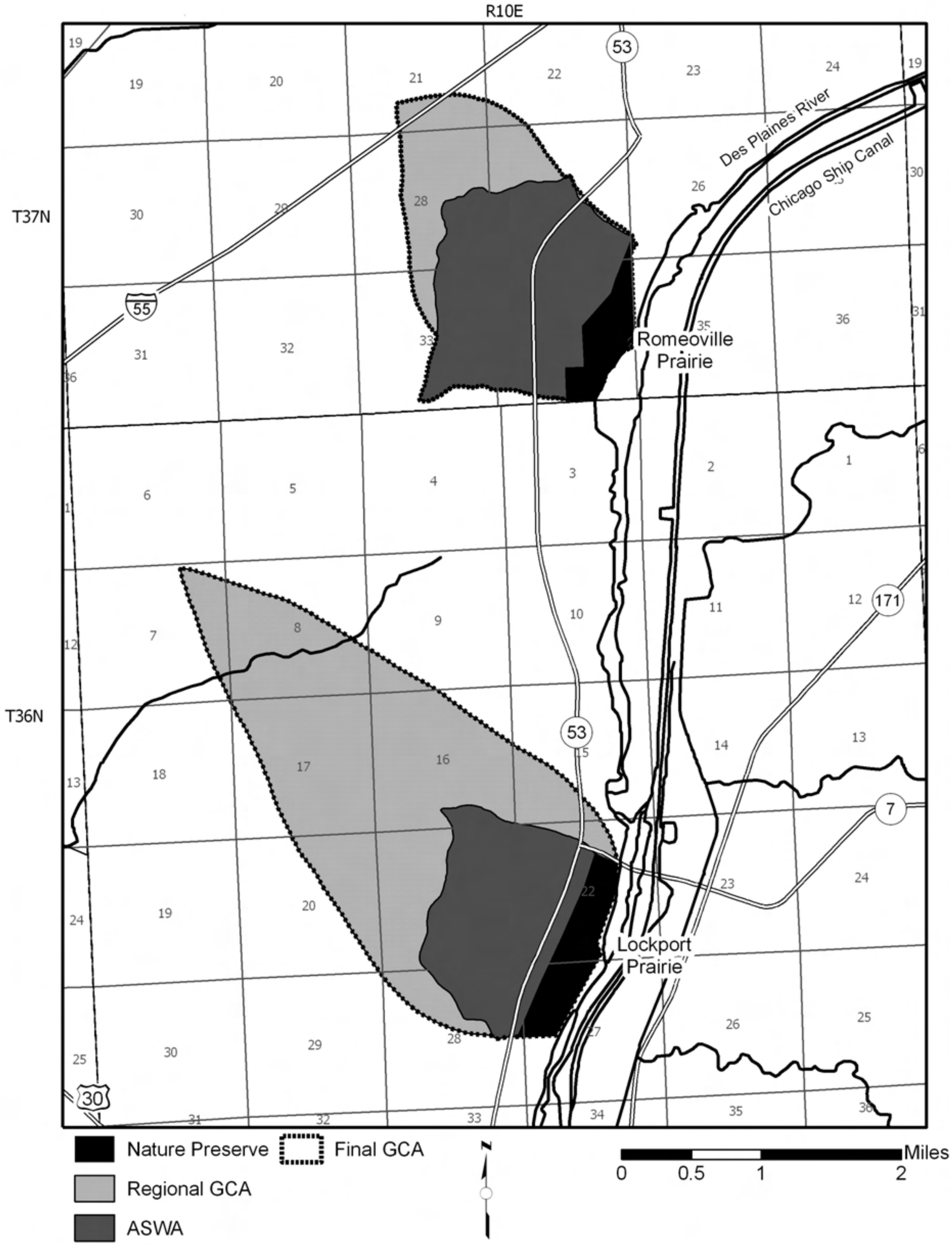

Figure A7. Regional GCAs, ASWAs, and final GCAs for Lockport Prairie and Romeoville Prairie Nature Preserves.

Elizabeth Lake

Elizabeth Lake Nature Preserve is located in northeastern McHenry County. Geologically, it is within the Wonder Lake Valley system, which is underlain by coarse-grained materials of the Henry Formation (Aquifer 1), although deposits of the Equality Formation, Cahokia Formation, and Grayslake Peat also exist at the land surface (Curry et al. 1997). Gravel lenses within the Tiskilwa Formation (Aquifer 3), Ashmore Tongue deposits (Aquifer 4), and Winnebago and Glasford Formations (Aquifer 5) are interconnected at depth in the valley (Curry et al. 1997). This connection allows groundwater input to Aquifer 1 from other aquifers. In the uplands adjacent to the valley, Henry Formation sand and gravel lap onto the adjacent slopes, but Wedron Group glacial till is present at the land surface at higher elevations.

Data from Meyer (1998) indicate Aquifer 1 is the main hydrologic unit controlling groundwater flow at the preserve. Because infiltration and recharge occur in areas shown by Meyer as unsaturated areas of Aquifer 1, the areas were considered part of the GCA (Figure A8). Aquifer 3 contributes additional flow to Aquifer 1 from the south and east (Figure A9). Aquifers 4 and 5 appear to be hydraulically connected to Aquifer 1 and also appear to be capable of discharge to the land surface at the preserve, but regional water-level data were insufficient to estimate entire GCAs for Aquifers 4 and 5 north and west of the preserve. Partial GCAs from Aquifers 4 and 5 may warrant inclusion and likely would extend to the north and west past the surface watershed. However, Aquifers 4 and 5 may have a minimal groundwater contribution to the preserve compared with Aquifers 1 and 3 because of their depth, and for that reason they were not included in this estimate of the GCA. Regional GCAs for Aquifers 1 and 3 were estimated and composited following Steps 2A and 2B. The resulting contribution area, 1.4 mi^2 (897 ac), extends mostly southeast of the preserve.

The surface watershed for the site includes flat areas and closed depressions south and east of the preserve in T46N, R8E, Section 12, as judged by local topography. The surface water divide was defined just above the 920-foot contour. Areas on the east side of the preserve were excluded from the watershed where groundwater would discharge to the surface water in Elizabeth Lake before reaching the preserve. Northwest of the preserve, the surface watershed includes areas across the Illinois-Wisconsin state line southwest of Twin Lakes, Wisconsin. With the above considerations, the ASWA (Figure A10) covers 2.23 mi^2 (1427 ac).

The ASWA and the regional GCA were combined to produce the final GCA (Figure A10), which includes 2.2 mi^2 (1427 ac).

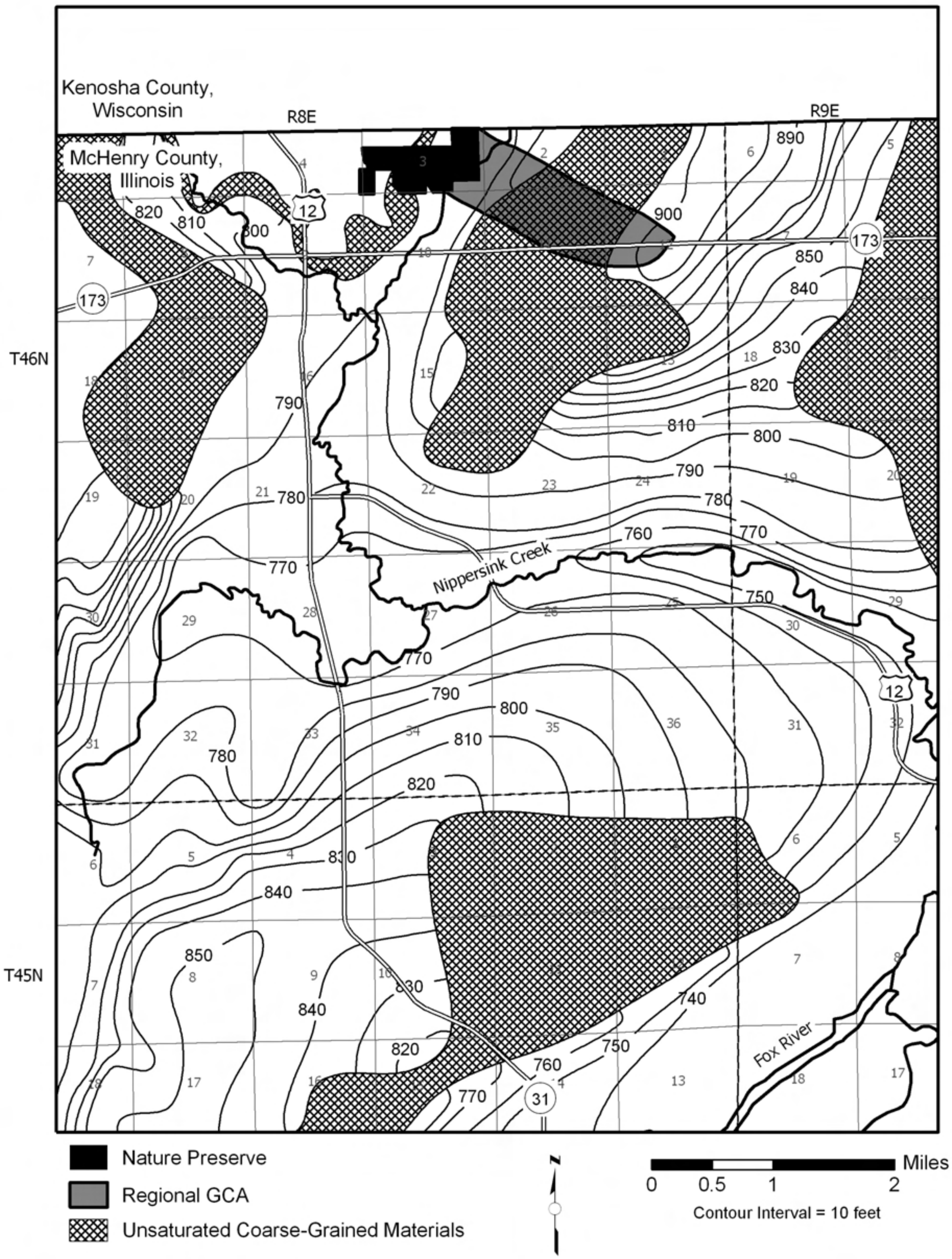

Figure A8. Aquifer 1 regional GCA for Elizabeth Lake Nature Preserve with groundwater contours modified from Meyer (1998).

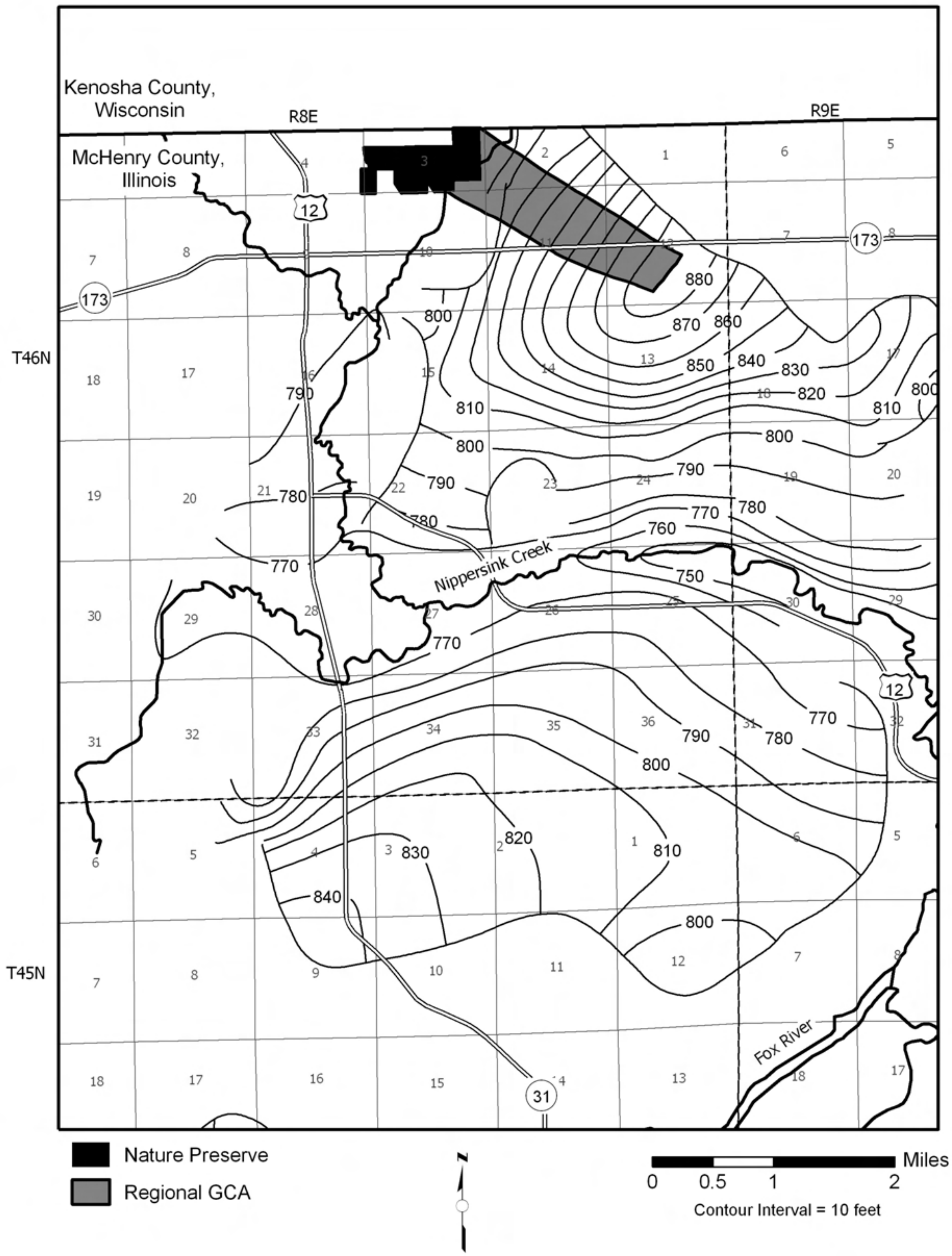

Figure A9. Aquifer 3 regional GCA for Elizabeth Lake Nature Preserve with groundwater contours modified from Meyer (1998).

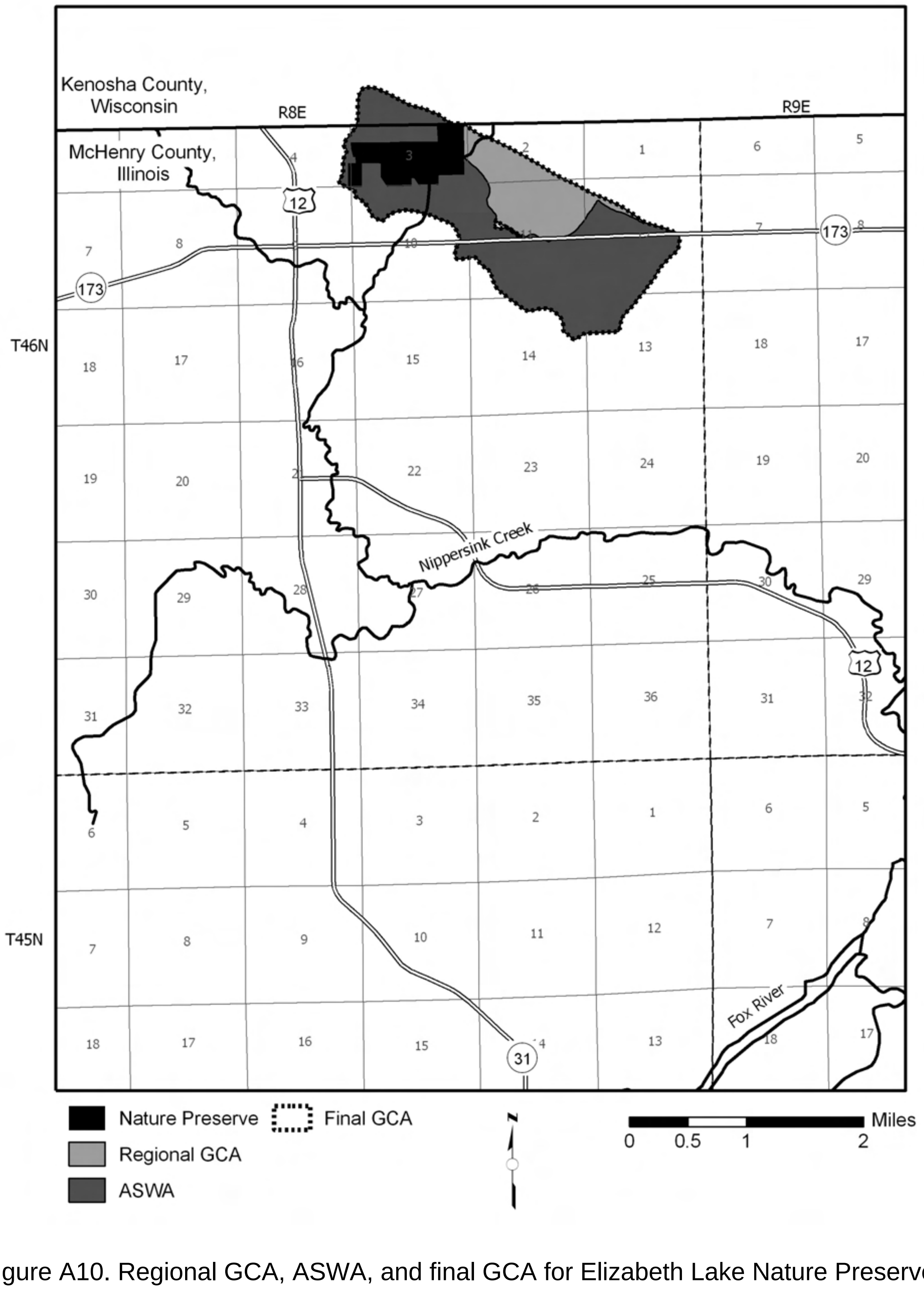

Figure A10. Regional GCA, ASWA, and final GCA for Elizabeth Lake Nature Preserve.

Appendix B. Additional Case 3 Test Sites

George B. Fell

George B. Fell Nature Preserve is located in south-central Ogle County. Bedrock at or near land surface in this area consists of the Ordovician Ancell and Galena-Platteville Groups (Berg and Kempton 1988), which are dominantly dolomites and sandstones. Some loess and Glasford Formation glacial till also may be present. Perennial and intermittent streams flow in deeply incised valleys toward the Rock River to the east. Available site-specific groundwater-level data are insufficient to determine the entire contribution area.

Because no groundwater studies are available for this preserve, an ASWA was prepared. Steep terrain at the preserve limits the extent of its surface watershed. Watershed boundaries were determined separately for the south and north parcels of the preserve. The boundary is generally no more than 0.25 miles from the edge of the preserve (south parcel) and 0.5 miles from the edge of the preserve (north parcel). Alterations to the watershed include significant mining in the vicinity. East of the north parcel and north of the south parcel, the ASWA boundaries were truncated at the edges of mined areas because of the lack of topographic data. No other adjustments to the ASWAs were made. The ASWA (Figure B1) covers 1.6 mi^2 (1057 ac) and is proposed for the final GCA. A larger area to the west and northwest may warrant inclusion later because of the expected regional groundwater gradient toward the Rock River.

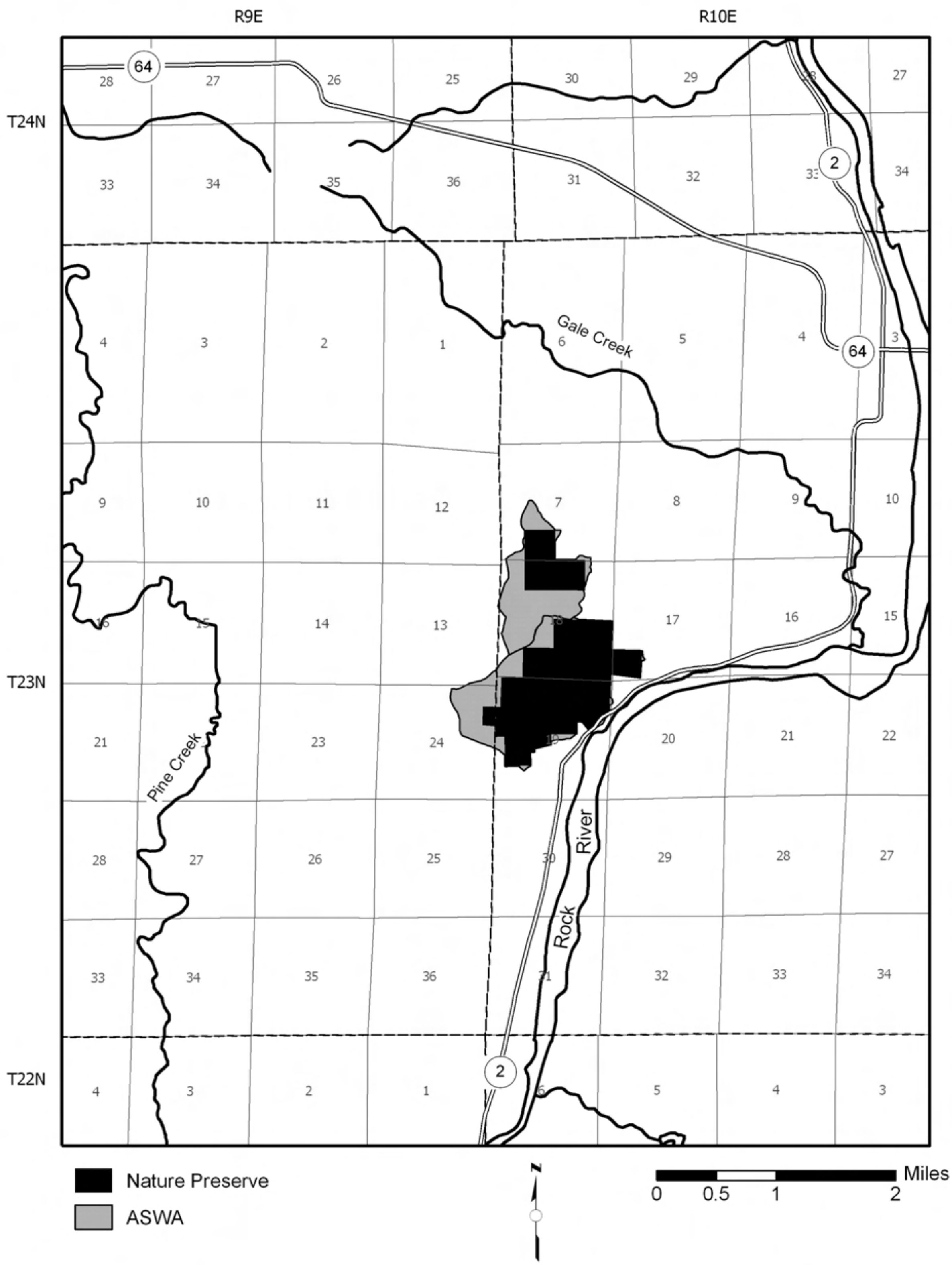

Figure B1. ASWA for George B. Fell Nature Preserve.

Illinois Beach

Illinois Beach Nature Preserve is located in northeastern Lake County directly west of Lake Michigan. Thick sand is mapped throughout the preserve, although discontinuous peat occurs at the land surface (Lineback 1979). Equality Formation silt underlies the sand at the surface of the preserve, and glacial till of the Wedron Group composes the bluffs to the west and underlies the Equality silt (Berg and Kempton 1988).

Because water-level data for the preserve are limited to local studies (Visocky 1977), which do not cover a sufficient geographic area to define the GCA, an ASWA (Figure B2) was developed following Steps 2C-2E.

Extensive development has obscured much of the natural topography, requiring that some of the surface watershed boundaries be inferred. No information was available regarding drainage from the large plateau to the west that contains the Waukegan Airport (T45N, R12E, Sections 31 and 32). The plateau was excluded because local topographic highs between it and the preserve form a surface water divide. South of the preserve, the natural topography is difficult to determine near the Waukegan Generating Station and the Johns-Manville Disposal Area, where, the surface watershed boundary follows the edge of the preserve and projects westward until it intersects the moraine bluffs. It is not expected that the preserve would receive groundwater discharge from areas to the south under typical flow conditions because groundwater flows southeast (Visocky 1977), but redevelopment of the Johns-Manville property could change groundwater flow patterns. The ASWA covers 2.6 mi^2 (1691 ac) and is proposed as the final GCA.

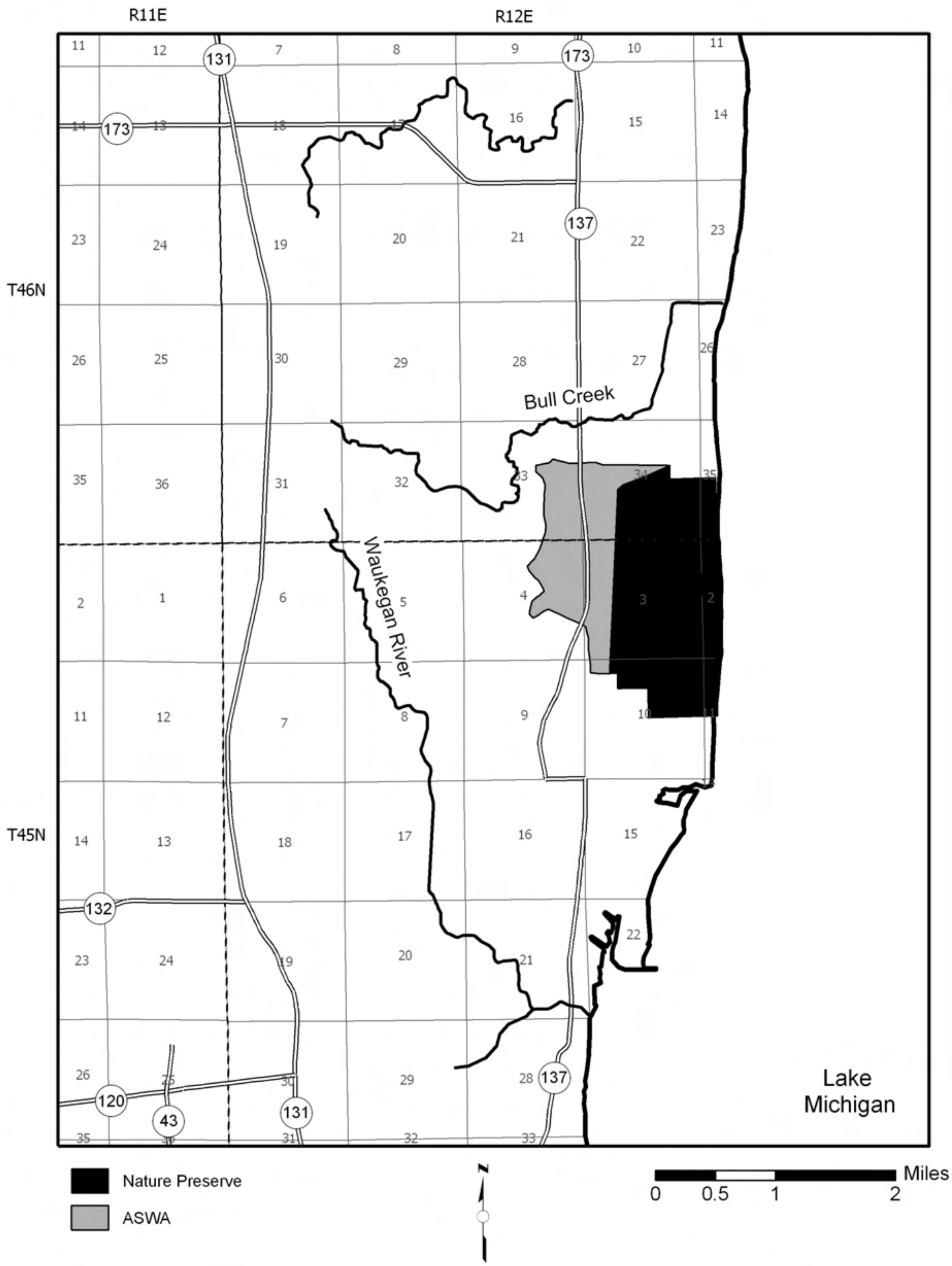

Figure B2. ASWA for Illinois Beach Nature Preserve.

Volo Bog

Volo Bog Nature Preserve is located in west-central Lake County. A site-specific study conducted by McComas et al. (1972) contains geologic information and limited hydrologic information. In addition, the authors have conducted limited geologic investigation and collected water levels surrounding the preserve. Stack-unit mapping (Berg and Kempton 1988) shows the bog and Sullivan Lake to the southwest are underlain by less than 6 meters of Grayslake Peat. Adjacent to the preserve, silty to gravelly sand deposits at the land surface would facilitate infiltration and groundwater flow toward the preserve. Below these coarse-grained surface deposits, fine-grained materials overlie additional sand and gravel at depth. At greater depths, well records suggest multiple clay units above bedrock.

No regional groundwater-level data were available for this site. Some limited water-level data collected in this region by the ISWS and ISGS were evaluated and suggest groundwater flow toward the bog on the east and west sides. The data show a local groundwater divide between the bog and the gravel pit to the east. Because the surface sands and sandy gravels are expected to be unconfined, the surface watershed likely would provide a sufficient estimate of their contribution area. However, McComas et al. (1972) also found an upward hydraulic gradient at the bog, suggesting that confined hydraulic conditions may exist in the aquifer below the fine-grained units, causing groundwater to flow upward and discharge in the bog. Because very limited groundwater-level data are available for the preserve, a GCA cannot be made for the confined aquifers. An examination of the uncompiled hydrogeologic data does not assist in determining the extent of the confined aquifers either. No adjustments were made to the surface watershed, but it likely will not estimate the entire area that belongs in the GCA. Future data collection would be desirable in this area.

The ASWA is limited to within about 0.75 miles from the preserve boundary (Figure B3). Except for areas south and east of the bog, the surrounding narrow band of uplands are the local topographic highs that limit the extent of the ASWA. Numerous closed depressions adjacent to the preserve and their water-level elevations were evaluated in Step 2C (iii)(b). Their relative elevations and other surface-water drainage patterns were used to estimate the location of surface water divides. The ASWA covers 1.0 mi^2 (657 ac) and is proposed as the final GCA.

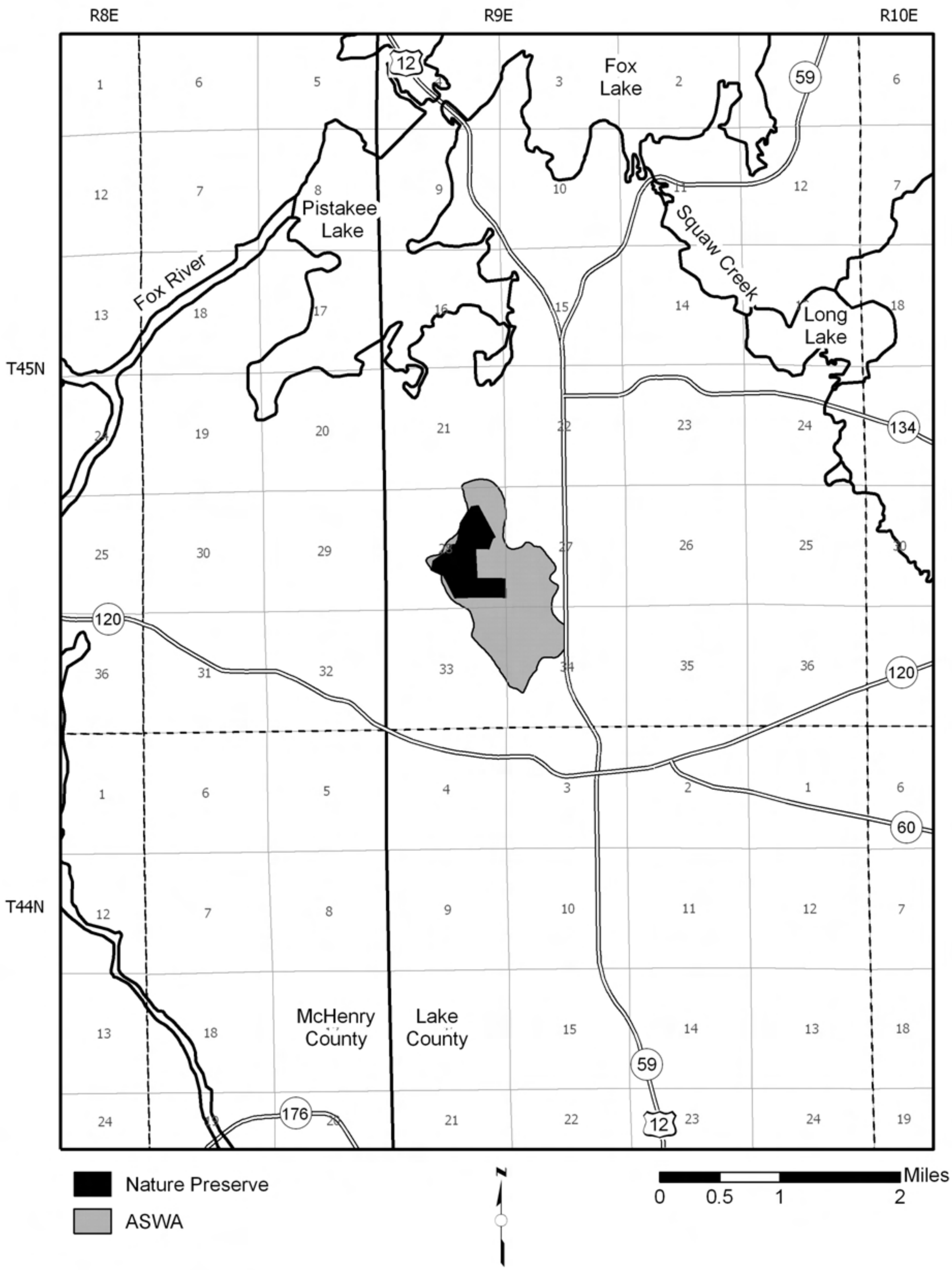

Figure B3. ASWA for Volo Bog Nature Preserve.

Goose Lake Prairie

Goose Lake Prairie Nature Preserve is located in northeastern Grundy County. Surficial geologic deposits at the preserve and surrounding areas are sand and gravel of the Henry Formation, although a small area west of the preserve is comprised of glacial till of the Wedron Group (Berg and Kempton 1988). On-site borings and other geologic maps indicate that bedrock very near land surface throughout the vicinity is shale from the Ordovician Maquoketa Formation to the north and the Pennsylvanian Spoon Formation to the south. The presence of bedrock that has low hydraulic conductivity is expected to limit the extent of the contribution area.

No groundwater-levels studies were available for this preserve, and local groundwater data were insufficient to determine a GCA. Along the northeast edge of the site, a wetland straddles the site boundary and was included in the adjusted watershed because it likely receives inputs from surrounding upland areas. This wetland was not contiguous with others nearby, and a groundwater divide was inferred between it and the nearest wetland to the east.

Strip mines east and south of the preserve significantly have altered the local topography. Therefore, the watershed boundary was drawn by connecting the nearest local topographic highs on either side of individual mines. The ASWA (Figure B4) covers 5.7 mi^2 (3665 ac) and is proposed as the final GCA.

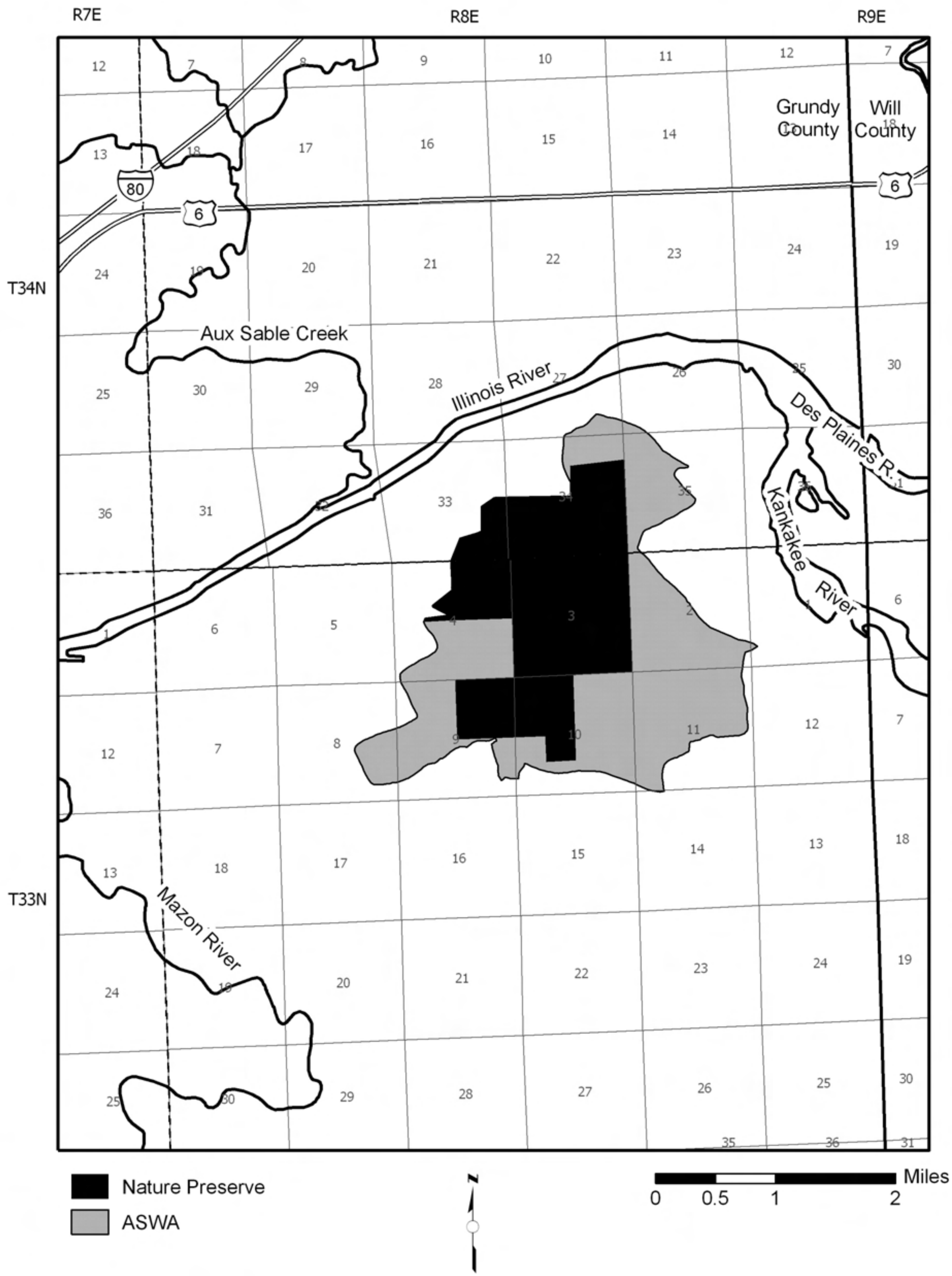

Figure B4. ASWA for Goose Lake Prairie Nature Preserve.

Braidwood Dunes and Savanna

Braidwood Dunes and Savanna Nature Preserve is located in southwestern Will County. Wascher et. al (1962) and Lineback (1979) indicate coarse-grained Parkland Sand deposits at the land surface in the area.

Regional groundwater-level data are not available for this preserve, and well records do not provide sufficient data to indicate groundwater levels and flow directions. Well records did not indicate an upward hydraulic gradient from bedrock sufficient for groundwater discharge to the preserve. The coarse-grained materials in and near the preserve appear to serve as an unconfined aquifer that supplies local groundwater flow to the preserve.

Surface water generally radiates away from the preserve. Boundaries of the surface watershed were adjusted to correspond with dune crests along the west, south, and east margins of the preserve. The surface mine at the northeast margin of the preserve was not included, because topography indicates that this area is downslope of the preserve. The ASWA (Figure B5) covers 0.7 mi^2 (443 ac) and is proposed as the final GCA.

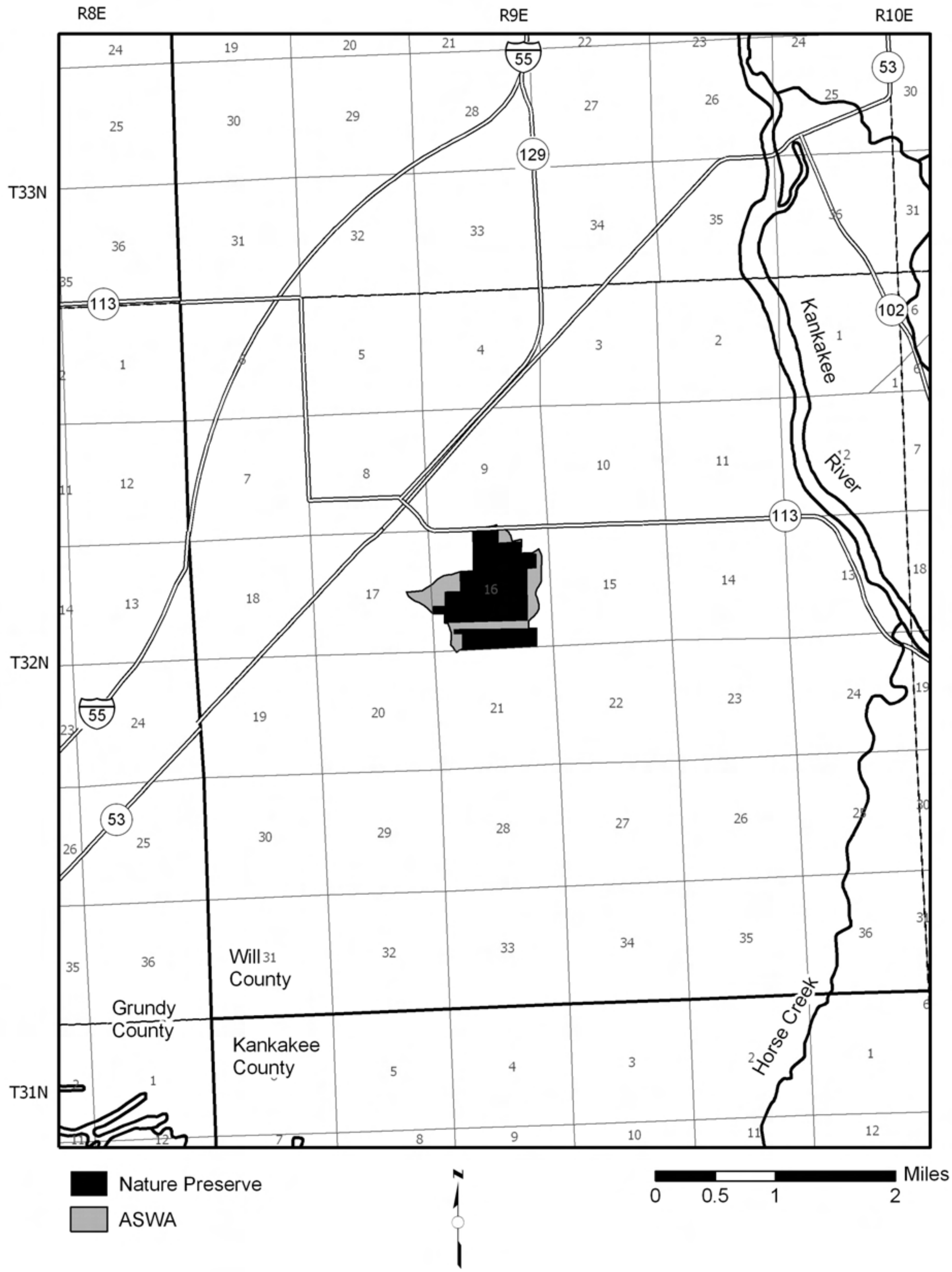

Figure B5. ASWA for Braidwood Dunes and Savanna Nature Preserve.

Illinois State WATER Survey (1895)

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