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| United States<br>Environmental Protection<br>Agency | Region 7<br>726 Minnesota Ave.<br>Kansas City, KS 66101 | Missouri<br>Iowa<br>Kansas<br>Nebraska |
| Water Division | Office of<br>Groundwater Protection | December 1992 |

EPA

# DECISION SUPPORT DOCUMENT

## Big Spring Recharge Area Sole Source Aquifer Petition

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# THE BIG SPRING RECHARGE AREA
# SOLE SOURCE AQUIFER PETITION

PREPARED BY THE OFFICE OF GROUNDWATER PROTECTION
U.S. ENVIRONMENTAL PROTECTION AGENCY, REGION VII
KANSAS CITY, KANSAS

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# DECISION SUPPORT DOCUMENT FOR THE BIG SPRING RECHARGE AREA SOLE SOURCE AQUIFER PETITION

## INTRODUCTION

### Purpose

This document summarizes available information about the Big Spring Recharge Area in south-central Missouri, and serves as the basis for the U.S. Environmental Protection Agency's (EPA) determination whether to designate the Ozark Aquifer within the Big Spring Recharge Area as a sole source aquifer. Those interested in more detailed information may consult the references listed at the end of the report.

### Sole Source Aquifer Program

The Sole Source Aquifer (SSA) Program is authorized by the Safe Drinking Water Act of 1974 (Public Law 93-52342 U.S.C. 300 et. seq.). Section 1424(e) of the Act states:

> "If the Administrator determines, on his own initiative or upon petition, that an area has an aquifer which is the sole or principal drinking water source for the area and which, if contaminated, would create a significant hazard to public health, he shall publish notice of that determination in the Federal Register. After the publication of any such notice, no commitment for Federal financial assistance (through a grant, contract, loan guarantee, or otherwise) may be entered into for any project which the Administrator determines may contaminate such aquifer through a recharge zone so as to create a significant hazard to public health; but a commitment for Federal assistance may, if authorized under another provision of law, be entered into to plan or

design the project to assure that it will not so contaminate the aquifer."

EPA defines a sole or principal source aquifer as one which currently supplies 50 percent or more of the drinking water for persons in a given aquifer service area and for which there are no reasonably available alternative sources of drinking water should the aquifer become contaminated

## Petition History

On December 5, 1989, the National Park Service (NPS), Ozark National Scenic Riverways (ONSR), in accordance with Section 1424(e) of the Safe Drinking Act (SDWA), presented a petition to the U.S. Environmental Protection Agency (EPA), Region VII, requesting designation of the Big Spring Recharge Area (BSRA) as a sole source aquifer (SSA).

The BSRA lies within a 967-square mile area of the Current River and Eleven Point River topographic basins which includes southern Shannon County, western Carter County, northern Oregon County, northeast Howell County, and a small portion of northwest Ripley County, all in Missouri (Figure 1). Approximately 52 percent (500 square miles) of the petitioned area is in the Mark Twain National Forest, an area administered by the U.S. Department of Agriculture, Forest Service.

On December 12, 1989, EPA Region VII sent a letter to the NPS acknowledging receipt of the petition. On December 28, 1989, EPA Region VII asked the Missouri Department of Natural Resources/Division of Geology and Land Survey (DGLS), Rolla, Missouri, to conduct a detailed technical review of the petition. DGLS responded by providing EPA Region VII with technical comments on the petition on March 1, 1990. The review conducted by DGLS

did not include the petition addendum that was later submitted by the NPS.

On January 17, 1990, EPA Region VII provided written comments to the NPS regarding the completeness of the petition. In response to EPA's comments, the NPS submitted a petition addendum to EPA Region 7 on May 29, 1990. On June 20, 1990, EPA Region VII sent a letter to the NPS informing them the SSA petition was sufficiently complete to allow EPA Region VII to proceed with a detailed technical review.

On July 20, 1990, EPA requested the U.S. Geological Survey (USGS), Water Resources Division, Rolla, Missouri, to conduct a detailed technical review of the petition to help verify: (1) the accuracy of the proposed SSA boundary; and, (2) that the aquifer is the sole or principal source of drinking water for the public in the defined aquifer service area. On September 6, 1990, the USGS entered into an Interagency Agreement with EPA Region VII to review of the SSA petition and addendum. On November 29, 1990, USGS submitted an official report of its findings to EPA Region VII.

On October 16, 1991, EPA Region VII published a legal notice in six local newspapers soliciting written public comments and announcing both a public hearing and the availability of a SSA petition public information package at public libraries throughout the area. A public hearing was held at the Winona public high school gymnasium, Winona, Missouri on November 14, 1991. The purpose of the hearing was to seek public input regarding EPA's consideration of the petition, as well as to gather additional information which would be helpful in making the designation determination.

The public comment period was to close on December 6, 1991. However, at the request of Congressman Bill Emerson, the comment

period was extended 30 days. The public comment period closed on January 6, 1992.

EPA Region VII received 124 comment letters during the public comment period and 26 statements at the public hearing. EPA Region VII has prepared a Responsiveness Summary of the written and verbal comments received during the public comment period and the Public Hearing.

## GENERAL DESCRIPTION OF THE BIG SPRING RECHARGE AREA

### Geography

The BSRA is located within the Salem Plateau Physiographic Subprovince of the Ozark Plateau (Figure 2). The Salem Plateau represents a landform developed by prolonged weathering of moderately soluble carbonate (dolomite) bedrock (Gott, 1975). The Salem Plateau is characterized by broad, rolling uplands separated by entrenched, meandering streams in deep, narrow valleys. Karst features such as caves, sinkholes, and springs are found throughout this predominately forested and hilly area. Approximately 75 percent of the petitioned area is upland and rolling hills. The dissected land zone, which distinguishes the remaining 25% of the petitioned area, is typified by abundant rock outcrops, topographic relief in excess of 100 feet, and frequently 200 feet or more, and some small sinkholes. The uplands and rolling hills zone is characterized by a lack of outcrops because of residuum 60 or more feet deep, topographic relief of less than 100 feet, and abundant large sinkholes.

## Soils

The predominant parent material for soil (i.e., residuum) on the uplands is from the Roubidoux Formation. This residuum is a red clay containing contains blocks of sandstone and chert fragments. The bottomlands contain alluvial and colluvial soils from eroded residuum of the Roubidoux and Gasconade Formations (U.S. Dept. of Interior, 1987).

The broad relatively flat ridges have soils consisting of deep loam and clays capped with loess. They are moderately well-drained, moderately to slowly permeable and low in fertility. They are highly erodible and compact easily in wet weather. They are slow to recover after being disturbed because of their low nutrient content and because of the dense, clayey subsoil.

The narrow ridge tops and steep side slopes have soils developed from cherty dolomite and sandstone residuum. They are excessively drained, rapidly permeable and have low fertility. Because of the high chert content, they are only moderately erosive and are difficult to compact.

There are several different types of bottom land soils. Those formed on silty alluvium and sink bottoms are poorly drained, moderately permeable, moderate to high in water capacity, moderately erosive, and highly compactable when wet. Those occupying narrow stream bottoms are deep and cherty, excessively drained, highly permeable, low in available water capacity, slightly erosive, and moderately resistent to compaction. The soils in the wide bottom lands form low stream terraces, are well drained, are the best for cultivation, and contain high-value tree species. They are easily compacted when wet.

## Climate

The BSRA has a continental climate characterized by frequent and sometimes extreme changes in weather. The summers can be hot and humid and winters have periods of cold, severe weather.

Summer temperatures range from the 60s to the 90s (degrees Fahrenheit). The daily average summer temperature is 76 degrees Fahrenheit. During the winter months, temperatures can range from the 20's to low 60's (degrees Fahrenheit). The daily average winter temperature is 41 degrees Fahrenheit. In an area that has such diverse terrain, nighttime temperatures can vary considerably from one location to another.

Snow fall averages less than seven inches per year and usually falls only three or four times a season, and then it quickly melts. Precipitation averages around 45 inches per year. Precipitation is mostly the result of fluctuating thunderstorm activity which is at a maximum in the spring and minimum in the fall. The average length of the growing season is about 175 days (Gott, 1975).

## Demographics

Approximately 12,686 people live in the BSRA (U.S. Dept. of Commerce, 1990). Of that total, 1,386 persons are farm residents and 11,300 are non-farm residents. The petitioned area is one of the least populated in the State with an overall density of 10 persons per square mile. A significant portion of the BSRA is located within Shannon County with a population density of 0-10 people per square mile. Carter County also has 0-10 people per square mile. Oregon, Howell, and Ripley Counties, portions of which constitute the BSRA have 10-20 people per square mile (Rafferty, 1970).

The main population centers within the Aquifer Recharge Area/Aquifer Service Area are Birch Tree (Pop. 600), Mountain View (Pop. 2,036), and Winona (Pop. 1,081), all located along U.S. Highway 60. In addition, there are other small communities or areas of concentrated rural settlement located along Highway 60 within the petitioned area. These communities include Chicopee (pop. 70), Freemont (pop. 160), Low Wassie (pop. 30), Bartlett (pop. 30), Montier (pop. 200), and Teresita (pop. 100). Other small communities located along State and county roads branching off Highway 60 in the petitioned area include Eastwood (pop. 40), Peace Valley (pop. 150), Thomasville (pop. 75), Wilderness (pop. 25), and Handy (pop. 30). Communities located within the Streamflow Source Area include Olden (pop. < 15), Pomona (pop. 200), White Church (pop. 75), and Willow Springs (pop. 2,045). Population figures for these small communities were obtained from 1990 U.S. census data, Rand McNally (1991), and U.S. Postal Service branches in Birch Tree and Winona.

1990 average annual household income in the petitioned area is approximately $20,000.

## Economy

Historically, wood products manufacturing has been extremely important to the local economy, and the growth of many towns in and around the BSRA, can be traced to the establishment of sawmills. Some of the major products currently manufactured in the area include dimension lumber, hardwood flooring, charcoal, pallets, poles, stave bolts, wooden handles, furniture, gunstocks, plaques, and trophies (U.S. Dept. of Interior, 1987).

In addition to wood products, there is a wide variety of other items being manufactured at different locations in and around the BSRA. There are meat packing and poultry dressing

plants, along with facilities producing breakfast cereals and animal feed. A significant number of people are also employed in the production of apparel (e.g., caps, uniforms, jackets, lingerie and shoes), truck bodies and trailers, electric motors, and fiberglass boats (U.S. Dept. of Interior, 1987).

The retail trade and service industries which support recreational pursuits are very important to the five counties wherein the BSRA is located. The five-county area has long been a popular recreation area for residents and nonresidents alike. Among the favorite activities are fishing, hunting, camping, floating, and picnicking. The affected retail trade industries includes sporting goods stores, gasoline stations, restaurants, and boats and camper sales. Canoe rentals and lodging are prominent recreation-related service industries in the area (U.S. Dept. of Interior, 1987).

## HYDROGEOLOGY OF THE BIG SPRING RECHARGE AREA

### Stratigraphy

Sedimentary rocks were deposited in Missouri throughout much of the Paleozoic era between 225 and 600 million years ago, when relatively shallow seas repeatedly covered part and at times all of the State. Mild vertical movements modified the environment from time to time; uplift with local or regional emergence resulted in discontinuous sedimentation (pinchouts) and unconformities; downwarping favored the continuity but not necessarily the thickness of sediments. Intermittent uplift and long-continued post-Paleozoic erosion brought the older rocks to the surface near the center of the Ozark Dome, with progressively younger rocks cropping out around its flanks. Upper Cambrian strata lie uncomfortably on the Precambrian surface in Missouri,

as in the St. Francois Mountains, where relief was locally as much as 2,000 feet around the Precambrian knobs when Paleozoic sedimentation began (U.S. Geological Survey, 1967).

Exposed rocks in the BSRA are confined to the Potosi, Emminence, Gasconade, Roubidoux and Jefferson City Formations. The Potosi and Eminence Formations are of Late Cambrian age and the Gasconade, Roubidoux, and Jefferson City Formations are Early Ordovician age. Outcroppings of the Potosi, Eminence, and Gasconade Formations are limited to the lowest elevations along major drainage valleys, while the Roubidoux and Jefferson City Formations are exposed elsewhere in the area. In fact streams and orifices of large springs in the Ozark National Scenic Riverways are in the Gasconade, Eminence, and Potosi Dolomites (Barks, 1978). The stratigraphic succession beneath the Gasconade Formation consist of approximately 1500 feet of sedimentary carbonates, shales and sandstones lying on an erosional surface of Precambrian crystalline rock.

The vertical succession of stratigraphic units underlying the BSRA (Figure 3) are generally described as follows, going from bottom to top:

* The Precambrian formations of southeast Missouri are composed of a variety of igneous rocks. The surface was subjected to intense erosion prior to the deposition of the upper Cambrian sediments resulting in a paleotopography of pronounced ridges, isolated peaks, broad basins and steep-walled valleys.

* The lower Cambrian Lamotte sandstone is the basal formation overlying the Precambrian surface except in areas where knobs rising from the basement have caused it to thin and pinch out. The Lamotte Sandstone is a quartzose sandstone, typically white or light gray. The lowermost section generally consists as a conglomerate of weathered Precambrian material and boulders.

The cement is highly siliceous. The formation is well-bedded with conspicuous crossbedding. The uppermost part is a transition zone into the overlying Bonneterre. Regional thickness ranges from 0 to 500 feet (U.S. Dept. of Interior, 1987). Geologically, the Lamotte Sandstone is the oldest aquifer in the state. In the eastern Ozark area, water from the Lamotte is used by municipalities. The Lamotte Sandstone is generally a low-yield aquifer with an average yield of up to 75 gallons per minute. Imes (1989) reports well yields from 100 to 500 gallons per minute. At Salem in Dent County, wells drilled into the Lamotte Sandstone produced approximately 125 gallons per minute. At Farmington and Bismark in the St. Francois Mountains the Lamotte yields 200 to 250 gallons per minute per well (U.S. Geological Survey, 1967).

* The Bonneterre Formation is the host rock for the major lead-zinc deposits of southeast Missouri. The Bonneterre is primarily a dolomite with some limestone. The transition between the Lamotte and the Bonneterre consists of alternating beds of sandstone, very sandy dolomite, and nearly pure dolomite with localized area of calcareous shale. Like the Lamotte sandstone, the Bonneterre can be absent from areas around the Precambrian topographic highs (U.S. Dept. of Interior, 1987). The regional thickness of the Bonneterre ranges from 0 feet to approximately 150 feet over the Precambrian knobs to approximately 400 feet in the basins. Generally, the Bonneterre is capable of providing water adequate for domestic use.

* The St. Francois Confining Unit consists of the Derby-Doe Run and Davis Formations (a.k.a., Elvins Group). The Derby-Doe Run Formation is a fine to medium crystalline dolomite with many shale partings. The Davis Formation is frequently referred to as the Davis Shale because it is the only notable shale horizon of the Cambro-Ordovician sequence of the Ozark region. However, besides shale, it is also composed of siltstone, fine-grained

sandstone and carbonates. The Derby-Doe Run and Davis Formations are not productive with typical well yields being near zero.

* The Potosi Formation is a massively bedded, tan dolomite with abundant quartz crystals in holes or cavities in the upper part. The lowermost section of the Potosi is transitional with the underlying Derby-Doe Run and is often silica free (U.S. Dept. of Interior, 1987). The Potosi is a highly productive aquifer capable of yielding, on average, 500 gallons per minute, and is a favored source of municipal drinking water in the Ozark region.

* The Eminence Formation is the youngest unit of the upper Cambrian in southeast Missouri. The Eminence is a massively bedded, medium to course-grained gray dolomite containing abundant chert (U.S. Dept. of Interior, 1987). This formation is increasingly being used for small industry and municipalities. The Eminence and underlying Potosi Formations are the source of many large springs in the Current River valley (U.S. Geological Survey, 1967).

* The lower Ordivician Gasconade Formation is a massively bedded cherty dolomite with a 25 to 30 foot thick sandstone (Gunter member) near the base overlying in erosional unconformity representing the division between the Cambrian and the Ordovician. The overlying dolomites are light gray and argillaceous with the chert content increasing upward. The bedrock thickness of the dolomite member of the Gasconade varies from 50 to 100 feet. Certain zones within the Gasconade Formation yield a sufficient quantity of water for farm and domestic use. The Gunter member, for example, produces 40 to 50 gallons per minute on average and in some areas as much as 100 gallons per minute.

* The Roubidoux Formation sits unconformably on the Gasconade Formation and is composed of interbedded sandstone and sandy dolomite in the lower portion and sandy dolomite in the

upper portion. The sandstone is thin-to medium-bedded with abundant crossbedding and ripple marks as the dominant lithology. Some dense or oolitic cherts may be present. The Roubidoux is a very reliable aquifer for farm wells in the Ozarks. Yields average 15 to 20 gallons per minute, but in the northern and western part of the Ozarks, this aquifer is capable of yielding up to 300 gallons per minute (U.S. Geological Survey, 1967).

* The Jefferson City-Cotter Formation is light brown to brown, medium to finely crystalline dolomite and clayey dolomite usually ranging in thickness from 200 to 300 feet (Aley, 1975). The average water yield of the Jefferson City-Cotter Formation is 20 gallons per minute, which is sufficient for domestic supplies (U.S. Geological Survey, 1967).

The deep weathering of the outcropping Roubidoux is responsible for the deep residuum covering most of the BSRA. The residuum is composed of red clay containing blocks of sandstone and chert fragments. The depth of residuum in the petitioned area ranges 0 to 200 feet (Aley, 1975).

## Structure

The aspects of regional geology most effecting the hydrology of the aquifer are the sequence and composition of the stratigraphic units and the structure.

The dominant structural feature of the region is the Ozark Uplift which trends through southeast Missouri in a south-southeasterly direction. The St. Francois Mountains, lying approximately 50 miles to the northeast of the BSRA, are highland masses of Precambrian igneous rocks which form part of the core of the Ozark Uplift. The St. Francois Mountains cause overlying formations on its flanks to dip away concentrically from it.

Consequently, formational dips within the BSRA trend south-southwest (U.S. Dept. of Commerce, 1987).

There is a general lack of available data regarding faulting, if any, in the petitioned area and concurrent effects on the Davis Formation. Aley (1989) deduces that faults are at depth within the petitioned area because lineaments (any reasonably straight alignment of topographic features) identified by Aley (1975) in the petitioned area and faults mapped by Anderson (1979) north of and just within the northeast boundary of the petitioned area are similarly aligned. While the presence of faulting at depth is inferred from such alignment, the evidence is not conclusive.

A detailed mapping of the orientation of joints (geological fractures along which movement has been negligible or absent) was conducted within the Hurricane Creek Basin by Henry Hillard in 1967 (unpublished) while employed by the Forest Service. Hurricane Creek lies near the center of the petitioned area. The attitude of 168 joint planes was measure on 22 outcrops of the Gasconade and Roubidoux formations. Almost all the joints measured were vertical or nearly vertical with major joint sets occurring at N60E, N78E and N10W (Aley, 1989). Aley (1975) concluded from a detailed analysis of lineaments and the orientation of joint sets that both lineaments and joints are important in controlling the location and number of sinkholes and the orientation of subsurface solution cavities in the petitioned area.

## Hydrology

According to Imes (1990c), the Ozark Aquifer (which includes the Jefferson City, Roubidoux, Gasconade, Eminence, and Potosi formations) ranges in thickness from 1,000 to 1,600 feet. The St. Francois Aquifer (consisting of the Bonneterre and Lamotte

formations) ranges in thickness from 400 to 800 feet (Imes, 1990a). The individual thicknesses of the Bonneterre and Lamotte Formations may be highly variable within the petitioned area. Log data from wells in Shannon County and West Plains indicate the Bonneterre and Lamotte Formations range in thickness from 60 feet to 380 feet and 30 to 262 feet respectively. (Telephone Communication with Mike Kleeschulte, USGS, June 17, 1992).

The Ozark and St. Francois Aquifers are separated by the St. Francois Confining Unit (composed of the Derby-Doe Run and Davis Formations) which varies in thickness from 200 to 400 feet (Imes, 1990b). The Derby-Doe Run and Davis Formations are not productive and are less permeable than the over- and underlying formations that constitute the Ozark and St. Francois aquifers. Regionally, the St. Francois Confining Unit has the ability to restrict flow between the St. Francois and Ozark Aquifers (Barks & Kleeschulte, 1990). Harvey (1980) discusses how the confining ability of the Davis Formation inhibits downward movement of groundwater, thus restricting the major solution activity of meteoric water to the dolomites above it (Barks & Kleeschulte, 1990). According to Imes and Emmett (in press), significant secondary porosity and permeability have not been developed in the St. Francois Confining Unit, and the fine-grained nature of the dolostones in the confining unit indicates that the unit has a low permeability even in areas containing little or no shale (Barks & Kleeschulte, 1990). According to Imes (1990b), however, the percent shale of the St. Francois Confining Unit in the petitioned area is 20-30 percent which is comparable (as is the unit's thickness) to what is found in the New Lead Belt (Figure 2). Fletcher (1974) reported that large groundwater withdrawals in the St. Francois aquifer by lead mining companies working the New Lead Belt, did not seem to substantially affect water levels in the Ozark Aquifer. Fletcher concluded that the Davis Formation forms an effective confining unit in the New Lead Belt area. However, Fletcher did report that groundwater levels were affected by

pumping near major fracture zones that penetrate the confining unit in the New Lead Belt. If the presence of faulting of the confining unit in the petitioned area was confirmed, groundwater levels in the Ozark Aquifer also could be locally affected by large groundwater withdrawals from the St. Francois Aquifer; however, there is no conclusive evidence supporting the presence of faulting in the petitioned area.

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Based on the previous discussion, EPA concludes the Ozark Aquifer and St. Francois Aquifer are hydrologically separate aquifers and not a single unit as proposed by the NPS.

Depending on the thickness of the overlying residuum, the depth to the top of the Ozark Aquifer ranges from 0 to 200 feet. The depth to the top of the St. Francois Confining Unit ranges from 1000 to 1800 feet. The depth to the top of the St. Francois Aquifer ranges from 1200 to 2200 feet. The depth to the more productive formation within the St. Francois Aquifer (i.e., the Lamotte (sandstone) Formation ranges from 1260 to 2600 feet.

The total groundwater system just described underlies the Salem Plateau, but only a limited geographic portion of the total system, the Big Spring Recharge Area, is the subject of this petition.

The Eleven Point River, originating near Willow Springs, is the only major river within the petitioned area. The Eleven Point River is protected under the Wild and Scenic Rivers Act and managed by the U.S. Forest Service. A small portion of the Current River forms the eastern boundary of the area; however, the Current River receives water from the Ozark Aquifer rather than contributing to it. A small portion of the Jacks Fork River flows along the northern boundary of the petitioned area. The Current and Jacks Fork rivers comprise the Ozark National Scenic Riverways which is administered by the National Park Service. Water quality

data from a monitoring point on the Current River below Hawes Campground, 15 miles downstream of Big Spring, is presented in Table 1 and is reflective of surface water quality in this spring-fed river.

The high rate of stream loss to the subsurface in the BSRA is substantiated by the similarity between the flow characteristics of the streams and springs. Storms producing high flows in the streams produce high flows in the springs. In addition to losing streams, which recharge groundwater supplies, water also moves freely to aquifers and springs via sinkholes and solution openings, and the groundwater levels in such areas fluctuate in response to precipitation events.

Table 2 displays Aley's (1975) estimated mean annual recharge through both discrete and diffuse recharge zones within the petitioned area.

Figure 4 depicts and compares the estimates of storage water and transit water for five area springs for Water Years 1967-1973. The mean annual transit water discharge from the smaller springs (Falling, McCormack, and Turner Mill) is about 62 percent of their total discharge. Big Spring is characterized by a mean annual transit water discharge of about 22 percent of its total discharge. These data indicate that the percentage of total discharge that is transit water is 2.8 times greater for the smaller springs than for the larger springs. Storage water discharges about 78 percent of mean annual discharge for the larger springs while it is about 38 percent for the smaller springs. Thus, the percentage of mean annual discharge that is storage water is about twice as great for the larger springs than for the smaller springs.

## Groundwater Quantity and Quality

The principal freshwater aquifers most likely to yield a dependable supply of water in the proposed SSA are the Lamotte Formation which is part of the St. Francois Aquifer, and the Potosi Formation, Gunter member of the Gasconade Formation, and the Roubidoux Formation which are part of the Ozark Aquifer system. However, owing to the soluble character of the rock sequence as a whole and the development of openings along bedding planes and joints, other intervals may contain a bountiful supply of water in one place or another (U.S. Geological Survey, 1967). Figure 5 displays typical well yields from various geologic units in the Ozark Plateau.

In general, groundwater from Paleozoic aquifers in the Ozarks is of excellent quality. Fresh water within the Salem Plateau is typically a hard calcium-magnesium bicarbonate water derived from the dolomite of the Cambrian and Ordovician rocks. Water quality data for selected wells and springs in and near the BSRA are presented in Tables 3 and 4. Big Spring is the largest groundwater discharge point in the petitioned area. Water quality data for Big Spring are presented in Table 1.

Water-quality determinations for <u>individual</u> aquifers are generally unavailable in the Ozarks. Below the point at which the casing is set, all aquifers penetrated may contribute to the well so that the water is a mixture from all water bearing units below the casings (U.S. Geological Survey, 1967).

## Potential for Contamination

The groundwater system in the petitioned area is recharged both discretely (i.e., water conducted freely to aquifers and

springs by losing streams, sinkholes, and solution openings) and diffusely. Discrete recharge plays a dominant role in replenishment of water in transit (i.e., conduit flow) and diffuse recharge plays a more important role in recharging water in storage.

The Ozark Aquifer is vulnerable to contamination because activities which produce contaminants or pollutants could be conducted freely to aquifers and springs by losing streams, sinkholes, and solution openings. Water in transit is much more subject to contamination and pollution hazards than water in storage because: (1) effective filtration and adsorption within conduits transporting waters in transit are undependable and unlikely; and, (2) travel rates are more rapid, thus allowing less time for bacterial and viral decay.

Conversely, once the source of pollution is corrected, pollutants can be expected to flush through the groundwater system in a relatively short time and not affect a wide portion of the aquifer. Further, a pollutant spilled into a sinkhole or losing stream is very unlikely to affect a properly constructed well (public or private) in the petitioned area; unless drilled into, or immediately adjacent to, a conduit, wells are unlikely to be affected because the contaminated water would follow well-defined flow paths, and would not travel in a plume throughout a wide portion of the aquifer (Vandike, 1990). But a well in that path is still out of service

Those pollutants that enter the water in storage component will take longer to appear but will effect water quality for a prolonged period of time until pollutant sources are removed and natural cleansing takes place. diffuse recharge

Figure 6 is a map of the dye traces conducted in the area. Dye tracing studies conducted by Aley and others demonstrate the rapid horizontal movement of water in this aquifer system.

Tracing data (Table 5) indicates subsurface movement of water for distances as great as 40 miles at velocities ranging from less 0.1 to 3.2 miles per day.

## DESCRIPTION OF BOUNDARIES

The areal boundary of the SSA approximates the recharge area for Big Spring based on the predevelopment potentiometric map (i.e., water table map) for the Ozark Aquifer (Imes, 1990c) and available dye-trace data for the area. All known areas of recharge for Big Spring as defined by dye tracing were located, then the boundary was moved back to the nearest ground-water divide (recharge area) or drain (discharge area) (Figure 7).

Vertically, the petitioned area extends from the land surface through the entire thickness of the Ozark Aquifer system and the St. Francois confining unit. However, because the Ozark Aquifer is the only groundwater source within the Big Spring Recharge Area currently used for drinking water, and because it is hydrologically separate from the St. Francois Aquifer (which is <u>not</u> currently used as a drinking water source in the petitioned area), EPA excluded the St. Francois Aquifer from consideration as a sole source aquifer and focused only on the Ozark Aquifer in terms of SSA designation potential.

The petitioned area encompasses the following sub-units: (1) the Aquifer; (2) the Aquifer Recharge Area; and, (3) the Aquifer Service Area. The Aquifer represents the actual geologic formation, group of formations, or part of formations which is capable of yielding a significant amount of water to a well or spring; the Aquifer Service Area represents the areal extent above the aquifer and including those lands where the entire population served by the aquifer reside. Collectively, these three areas, in fact, share the same boundary. Contiguous to these three areas is

the Streamflow Source Area which coincides with the topographic drainage divide that delineates the western part of the Eleven Point River watershed. The Streamflow Source Area boundary encompasses the drainage area that contributes surface and groundwater recharge to the BSRA. Contaminated recharge water originating in the Streamflow Source Area could adversely effect groundwater quality of the Big Spring Recharge Area. Therefore, reviews of Federal financially assisted projects in the petitioned area would also include the Streamflow Source Area.

## DRINKING WATER USE

Based on 1990 Census Bureau household data, at least 90 percent (11,417) of the total population in the petitioned area depend on groundwater as a drinking water source. Currently, all public and private water supplies in the petitioned area are derived from the Ozark Aquifer. Out of a total population of 12,686 in the petitioned area, approximately 40 percent (5,074) are served by either publicly or privately owned public water supply systems drawing water from the Ozark Aquifer; 50 percent (6,343) rely on private drilled or dug wells for drinking water; and 10 percent (1,269) use an "unspecified source" of drinking water. Census data do not define "unspecified sources" but it is assumed these include surface water, springs, cisterns, and even bottled water.

Consumptive water use in the entire area is approximately 1.9 million gallons per day (based on per capita water use of 150 gallons/day).

## ALTERNATIVE DRINKING WATER SOURCES

An alternative source of drinking water is any surface water or groundwater, or combination thereof, near or in the petitioned area which is currently used, or has the potential to be used, as a drinking water supply. If an alternative source of drinking water is available, then the petitioned aquifer is not considered a "sole or principal" source of drinking water.

Although the Ozark Aquifer is the principal source of drinking water in the petitioned area, there are both surface water and groundwater sources available to provide alternate water supplies to residents in the petitioned area.

### Groundwater

EPA has determined that the St. Francois Aquifer is of comparable quality to the Ozark Aquifer; and that the St. Francois Aquifer can provide sufficient yield to meet current drinking water demands from residents in the petitioned area.

The most productive zone of the St. Francois Aquifer is the Lamotte (sandstone) Formation which is capable of yielding 100 to 500 gallons of water per minute (Imes, 1990a). To extract water from the St. Francois Aquifer (i.e., the Lamotte Formation) would entail drilling through and casing out the entire thickness of the Ozark Aquifer, drilling through the St. Francois Confining Unit, and drilling through the St. Francois Aquifer to the Lamotte Formation. Casing the Ozark would prevent vertical leakage or mixing of waters from the Ozark Aquifer to the St. Francois Aquifer; furthermore, casing in the Ozark Aquifer would extend only a short distance into the top of the St. Francois before being firmly seated. The entire St. Francois Confining Unit would not need casing because of it naturally inhibits movement of water

between the Ozark and St. Francois Aquifers. From below the casing, open hole drilling would continue on through the St. Francois Confining Unit on into the St. Francois Aquifer.

Cost estimates for completing a typical 6-inch well were obtained from drillers serving the petitioned area. These estimates varied depending on what a driller charges for each foot of drilling, casing diameter and length, pump installation, and any special problems or conditions encountered during drilling. For example, our survey indicated that one driller charges $6 for each foot of drilling and $6 for each foot of 6-inch casing; another driller charges $4 for each foot of drilling and $12.50 for each foot of 8-inch casing; and still another driller charges $7 or $10 for each foot of drilling (6-inch hole and 10-inch hole respectively) and $7 for each foot of 8-inch casing. Based on these various combinations, the cost for an alternate drinking water well which extracts water from the St. Francois Aquifer would range from $13,560 to $36,200. The added cost to purchase and install a pump would range from $1100 to $1500. By adding the cost of a pump, the estimated cost of completing a six-inch water well to the St. Francois Aquifer would range from $14,660 to $37,700.

These estimates do not include ancillary costs such as a wellhouse, steel water storage standpipe, and water distribution lines which a new central water supply system would need to acquire. For an existing system, however, such capital cost improvements may not be necessary.

With respect to legal availability of groundwater, Missouri categorizes groundwater as either (1) percolating groundwater, or (2) groundwater flowing in a well defined stream. Both of these categories are governed by the rule of reasonable use; that is, a landowner can make reasonable use of the groundwater under his

property so long as that use does not deprive other landowners of their co-equal rights to groundwater in its natural condition.

New wells, private or public, are subject to permit and certification requirements under the Missouri Water Well Drillers Law. Public water supply wells also must comply with the requirements of the State's drinking water regulations which are administered through the Missouri Public Drinking Water Program.

## Surface Water

Alternative surface water sources of drinking water which could serve the petitioned area include the Current, Jacks Fork, and Eleven Point Rivers. There are short reaches of the Current and Jacks Fork Rivers up and downstream of Van Buren and Eminence, Missouri which are not designated as part of the Ozark National Scenic Riverways. The existence of these undesignated reaches along the Current and Jacks Fork Rivers would facilitate any proposed diversion of water to communities needing an alternate source of drinking water. However, any proposal to divert this water may result in legal challenges by various groups, including the Federal government. Access to the Eleven Point River, a Federally designated Wild and Scenic River, is presumably limited because there are no unprotected reaches along the Eleven Point in or reasonably near the petitioned area from which water can more easily be diverted.

Based on a period of record from October 1921 to 1989, the mean annual flow of the Jacks Fork River at Eminence was 453 cubic feet per second (cfs). The lowest annual mean for that same period was 154 cfs, the lowest daily mean was 67 cfs., and the lowest instantaneous flow was 64 cfs (Water Resources Data for Missouri, 1989). EPA concludes that even at its lowest flow (64 cfs), the Jacks Fork River at Eminence could provide the public

with a greater volume of drinking water than is currently being used throughout the entire petitioned area (2.9 cfs). The Current River at Van Buren, Missouri, the closest surface water source for communities in the petitioned area, carries four times the mean annual flow of the Jacks Fork River (Water Resources Data for Missouri, 1989) and therefore also is capable of meeting or exceeding the drinking water demands of residents in the petitioned area.

According to the Missouri Water Resources Program, the ownership of riparian land carries with it a right to the continued flow of the stream and a right to make a reasonable use of the water so long as that use does not deprive other landowners of their co-equal rights to the stream in its natural condition. Resolution of water use conflicts has been a matter of judicial decision in litigation between private individuals. The existence of a riparian water right is dependent upon ownership of land actually touching on the water course. The right to the use of water is transferred upon a conveyance of the real property or purchase of easements through the real property to the water course. Federal reserved water rights takes precedence over all other riparian water rights if the Federal government believes proposed withdrawals from a stream source outside its jurisdiction would significantly impair downstream flow of a water course under its jurisdiction (e.g., Ozark National Scenic Riverways). As there are no major cities in the area which might cause large withdrawals, EPA has determined that diversion of water from the Current or Jacks Fork Rivers, if any, by small communities in the petitioned area would have a little or no impact on downstream flows of these rivers. Thus, Federal reserved water rights would not likely become an issue.

If a surface water source is used for a regional distribution system, a pipeline from the Current River (the most feasible source) connecting communities and settlements located along U.S.

Highway 60 and State/county road branches, would be approximately 95 miles long. To supply surface water to individual communities within the petitioned area would require pipelines ranging from 0.5 mile to 60 miles in length. Most communities in the petitioned area are, in fact, more than 10 miles from the nearest alternative surface water supply.

Based on information obtained from engineering firms serving the petitioned area, a surface water supply pipeline would begin as a 12-inch diameter pipe, and gradually would be reduced to a 6-inch pipe at the end of the system. The number of miles of twelve-inch versus six-inch pipe would vary according to final system design. Based on an average cost of $4/diameter-inch/foot, a twelve-inch diameter pipeline would cost an estimated $253,000 per mile, and a six-inch pipe would cost $127,000 per mile, exclusive of costs for such items as pumps, booster pumps, valves, distribution lines, meters, or a water treatment plant to remove possible impurities. The minimum estimated cost of constructing just ten miles of pipeline to provide a surface water supply to an individual community in the petitioned area would be approximately $1.3 million dollars. On the other hand, for a community to drill two wells to the St. Francois Aquifer, at a maximum cost of $37,700 per well, would cost $75,400 and be a considerably less expensive option to providing a surface water supply. Consequently, while surface water is available as an alternative water supply for the petitioned area, it is a more expensive alternative than is groundwater.

## DETERMINATIONS

To designate the Big Spring Recharge Area as a sole source aquifer, two questions must be answered. If the answer to either question is no, the area does not qualify as a sole source aquifer under the Safe Drinking Water Act.

**Question 1:** Does 50 percent or more of the population within the proposed SSA area depend on the Ozark Aquifer as its drinking water supply? The answer to the question is yes. At least 90 percent of the population within the proposed SSA area depends on the Ozark Aquifer for its drinking water supply.

**Question 2:** Is the Ozark Aquifer the only source of drinking water available? The answer to the question is no, based on the following:

* The Ozark Aquifer is not the only water supply source available to residents in the petitioned area. Alternative supplies are physically available from a groundwater source (the St. Francois Aquifer) and from surface water sources (the Current and Jacks Fork Rivers). These alternatives are of comparable quality to the Ozark Aquifer and are able to supply sufficient quantities to meet current demands of communities and individual households in the petitioned area.

* There are no known legal constraints for communities or individuals to develop drinking water wells to the St. Francois Aquifer. Legal access to surface water alternatives also is available but limited to unprotected reaches along the Current and Jacks Fork Rivers near Van Buren and Eminence, respectively.

* The cost of developing surface water supplies is prohibitive for any communities or settlements that are not adjacent to a surface water source. Most communities in the petitioned area are 10 miles or more from a surface water supply. The minimum cost to deliver surface water via a 6-inch pipeline to a community ten miles from the extraction point would be approximately $1.3 million. In contrast, the maximum cost of drilling a new well to the St. Francois Aquifer ($37,700), and assuming a community drills two water supply wells, the total cost would be approximately $75,400. These comparative costs indicate

the expense of obtaining surface water would be at least 17 times greater than obtaining drinking water from the St. Francois Aquifer. Therefore, EPA has determined that surface water cannot be considered an economically viable alternative drinking water source to communities and settlements in the petitioned area and the St. Francois Aquifer is the only economically viable water supply alternative to the Ozark Aquifer.

* EPA has determined that communities in the petitioned area already served by public water supplies could afford the cost of developing new wells to the St. Francois Aquifer. They may apply for financial support (i.e., Community Development Block Grants and loans) available through the Department of Housing and Urban Development (HUD), the U.S. Department of Agriculture/Farmers Home Administration (FmHA), the Department of Commerce/Economic Development Administration (EDA), and the State. These communities include 40% of the total population of the petitioned area.

* Small, unincorporated towns presently not having a public water supply system account for about 6.0 percent of the total population of the petitioned area. EPA has determined that these small communities and a significant percentage (unknown) of households in cluster settlements throughout the petitioned area, and also not served by water supply systems, may combine their resources to develop new wells to the St. Francois Aquifer. Loans and grants available to these small communities and cluster settlements through FmHA, HUD, EDA, and the State could support development of centralized water systems.

* EPA has determined that isolated households in the petitioned area which are not currently served by public water supplies may not be able to afford to drill a new well to the St. Francois Aquifer. EPA's draft "Guidelines for Groundwater Classification" suggest that an alternative source of water is not

economically feasible if the annual cost to a user exceeds one percent of their mean household income. Mean household income in the petitioned area is $20,000; thus, the annual cost to a household should not exceed one percent of this figure, or $200. Although individual households could take advantage of FmHA's Rural Housing Program of long-term, low interest loans, repayment of a loan on a $15,000 well would average about $1,080 per year.

## CONCLUSION

Based on the preceding determinations, EPA concludes the Ozark Aquifer is not the sole or principal source of drinking water for residents living in the petitioned area and therefore does not qualify for sole source aquifer designation.

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TABLES

Table 1

**WATER QUALITY IN THE BIG SPRING RECHARGE AREA**
**(1975 to 1984)**

| Parameter & Units | Big Spring | | | | Current River Below Hawes Campground | | | |
|---|---|---|---|---|---|---|---|---|
| | # of measurements | Max. | Min. | Mean | # of measurements | Max. | Min. | Mean |
| Specific conductance (umhos/cm) | 16 | 368 | 210 | 302 | 18 | 360 | 222 | 296 |
| pH (units) | 16 | 7.6 | 7.1 | 7.4* | 18 | 8.3 | 7.5 | 8.1 |
| Temperature (C) | 16 | 16.0 | 13.0 | 14.4 | 18 | 22.0 | 7.5 | 17.9 |
| Dissolved Oxygen (mg/l) | 16 | 9.6 | 8.0 | 8.8 | 18 | 11.2 | 7.7 | 9.2 |
| Fecal Coliform (colonies per 100 ml) | 15 | 580 | <1 | 13* | 18 | 230 | 1 | 13* |
| Fecal strep. (colonies per 100 ml) | 15 | 2100 | <1 | 17* | 17 | 440 | <1 | 17* |
| Alkalinity (mg/l) | 5 | 196 | 140 | 163 | 7 | 186 | 123 | 148 |
| Nitrite Nitrogen mg/l | 4 | <.020 | <.010 | -- | 4 | <.020 | <.010 | -- |

**WATER QUALITY IN THE BIG SPRING RECHARGE AREA** (Continued)
**(1975 to 1984)**

| | Big Spring | | | | Current River Below Hawes Campround | | | |
|---|---|---|---|---|---|---|---|---|
| Parameter & Units | # of measurements | Max. | Min. | Mean | # of measurements | Max. | Min. | Mean |
| Nitrite & Nitrate Nitrogen mg/l | 6 | .50 | .30 | .40 | 6 | .30 | .200 | 0.26 |
| Ammonia Nitrogen mg/l | 13 | .090 | .00 | .010* | 14 | .04 | .00 | 0.01* |
| Ammonia Nitrogen & Organic Nitrogen mg/l | 4 | .30 | <.20 | .25* | 4 | .50 | <.20 | .40* |
| Phosphorus total (mg/l as P) | 9 | .140 | .00 | .010* | 12 | .04 | .00 | .01 |
| Cadmium total recoverable ug/l as Cd | 8 | 8 | 0 | <1* | 10 | 10 | 0 | 0 |
| Pb total recoverable ug/l | 11 | 95 | <1 | 7* | 14 | 100 | <1 | 5* |
| Ag total recoverable ug/l | 11 | 1 | 0 | 1* | 14 | 10 | 0 | <1* |
| Zn total recoverable ug/l | 11 | 130 | 0 | 20* | 14 | 60 | 0 | 20* |

* Median Value

Source: USGS Annual Reports, 1975 thru 1984. Water Resources for Missouri

## Estimated Mean Annual Groundwater Recharge Through Discrete and Diffuse Recharge Zones in Petitioned Area (from: Aley, 1975)

| | |
|---|---|
| **Total Groundwater Recharge** (acre feet) | |
| Mean annual springflow | 720,000 |
| Mean annual well extraction | 1,500 * |
| Total | 718,500 |
| **Diffuse Recharge** (acre feet per year) | |
| Valleys | 200,000 |
| Hillsides and Uplands | 65,000 |
| Subtotal for diffuse recharge | 265,000 |
| **Discrete Recharge** (acre feet per year) | |
| Sinkholes | 75,000 |
| Losing streams including estavelles | 80,000 |
| Non-valley features with little or no surface expression | 300,000 |
| Subtotal for discrete recharge | 455,000 |
| **Summary** (acre feet per year) | |
| Diffuse recharge | 265,000 |
| Discrete recharge | 455,000 |
| Total recharge | 720,000 |

* Since all values are only general estimates, they are all rounded to the nearest 5,000 acre feet. The only exception is annual well extraction which is estimated at 1,500 feet per year.

# SELECTED WELL DATA

| Well Owner | National Park Service Austin House | National Park Service Cedar Grove |
|---|---|---|
| **Well location** | | |
| County | Carter | Shannon |
| **Well Characteristics** | | |
| Sampling depth or total depth (ft) | 250 | 500 |
| Depth of casing (ft) | 150 | 250 |
| System | Cambrian | Cambrian |
| Rate of pumping (gal/min) | 23 | 60 |
| Specific capacity (gal/min per feet of drawdown) | .5 | .3 |
| Date of collection | 8-19-69 | 9-24-71 |
| **Water Quality (Mg/l)** | | |
| Dissolved silica ($SiO2$) | 6.2 | 11 |
| Dissolved iron (Fe) | ... | .21 |
| Dissolved manganese (Mn) | ... | .01 |
| Dissolved calcium (Ca) | 73 | 58 |
| Dissolved magnesium (Mg) | 39 | 30 |
| Dissolved sodium (Na) | 3.7 | 1.2 |
| Dissolved potassium (K) | 2.0 | .6 |

SELECTED WELL DATA (Continued)

| Well Owner | National Park Service Austin House | National Park Service Cedar Grove |
|---|---|---|
| Water Quality (Mg/l) (Continued) | | |
| Bicarbonate ($HCO_3$) | 396 | 341 |
| Dissolved sulfate ($SO_4$) | 9.2 | 1.2 |
| Dissolved chloride (Cl) | 4.8 | 2.7 |
| Dissolved fluoride (F) | .1 | 0 |
| Dissolved nitrate ($NO_3$) | 4.1 | .3 |
| Dissolved solids (residue at 180°C) | 351 | 300 |
| Hardness as ($CaCO_3$): | | |
| Calcium magnesium | 343 | 268 |
| Noncarbonate | 18 | 0 |
| pH | 7.7 | 7.8 |

Source (Imes, 1990)

## SELECTED SPRING DATA
(Analyses by U.S. Geological Survey and Missouri Geological Survey and Water Resources)

| Location (County) | Carter | Oregon | Shannon | Shannon | Shannon |
|---|---|---|---|---|---|
| **Description** | | | | | |
| Spring name | Big | Greer | Alley | Blue | Welch |
| Geologic system | Є | O | O | Є | Є |
| Range of Observed discharges ($ft^3/s$) | 236-1,300 | 104-903 | 54-1,060 | 62-236 | 70-331 |
| **Water Analysis** | | | | | |
| Date of collection | 4-27-71 | 4-27-71 | 4-27-71 | 4-27-71 | 4-27-71 |
| Discharge ($ft^3/s$) | 493 | 387 | 119 | 122 | 169 |
| Temperature (°C) | 14.0 | 14.0 | 13.5 | 13.0 | 13.5 |
| Mg/l: | | | | | |
| Dissolved silica ($SiO_2$) | 8.7 | 9.2 | 8.0 | 6.9 | 9.5 |
| Dissolved Iron (Fe) | .110 | .130 | .270 | .060 | .050 |
| Dissolved calcium (Ca) | 40 | 40 | 31 | 29 | 35 |
| Dissolved magnesium (Mg) | 18 | 18 | 15 | 14 | 16 |
| Dissolved sodium (Na) | 1.3 | 1.1 | 1.2 | 4.3 | 1.4 |
| Dissolved potassium (K) | .7 | .9 | .7 | .7 | .6 |
| Bicarbonate ($HCO_3$) | 220 | 216 | 172 | 156 | 192 |
| Dissolved sulfate ($SO_4$) | 1.5 | 3.0 | 1.5 | 8.8 | 3.0 |
| Dissolved chloride (Cl) | 2.7 | 4.7 | 4.7 | 8.2 | 3.2 |

Є = Cambrian    O = Ordovician

SELECTED SPRING DATA (Continued)

| Location (County) | Carter | Oregon | Shannon | Shannon | Shannon |
|---|---|---|---|---|---|
| Mg/l (continued): | | | | | |
| Dissolved fluoride (F) | 0.0 | .0 | .0 | .0 | .0 |
| Dissolved nitrate ($NO_3$) | 1.0 | 1.8 | 2.4 | 1.1 | 2.7 |
| Dissolved solids (residue at 180°C) | 188 | 194 | 156 | 161 | 180 |
| Hardness as ($CaCO_3$): | | | | | |
| Calcium magnesium | 173 | 172 | 138 | 128 | 154 |
| Noncarbonate | 0 | 0 | 0 | 0 | 3 |
| Specific conductance (micromhos at 25°C) | 340 | 340 | 280 | 280 | 315 |
| pH | 7.5 | 7.6 | 7.4 | 7.7 | 7.5 |
| Colonies per 100 millilitres: | | | | | |
| Fecal coliform | <1 | 8 | 3 | <1 | <1 |
| Fecal streptococci | 5 | 8 | 10 | 6 | 8 |

Table 5

**SUMMARY OF GROUNDWATER TRACING EXPERIMENTS FOR BIG SPRING**

(Adapted from Aley, 1969 & 1972)

| Injection date | Injection site | Recovery site | Straight-line distance (miles) | Approximate elapsed time (days) | Approximate velocity (ft/min) |
|---|---|---|---|---|---|
| 6/11/68 | Blowing Spring Estavelle | Big Spring | 17.0 | 7 - 14 | 8.92 - 4.46 |
| 8/29/69 | Johnson Spring | Big Spring | 18.0 | 17 | 3.89 |
| 11/18/70 | Leslie Spring | Big Spring | 17.5 | 6 - 13 | 10.7 - 4.94 |
| 8/26/71 | Stillhouse Spring | Big Spring | 33.5 | 57 - 75 | 2.16 - 1.64 |
| 10/22/71 | Blowing Spring Estavelle | Big Spring | 17.0 | 11.2 - 13.0 | 5.59 - 4.81 |
| 12/10/71 | Paul Doweler Sinkhole | Big Spring | 25.3 | 7 - 14 | 13.3 - 6.64 |
| 1/18/72 | Middle Fork, Eleven Point River | Big Spring | 39.5 | 13 - 17 | 11.1 - 8.52 |
| 2/9/72 | Middle Fork, Eleven Point River | Big Spring | 39.5 | 5 - 14 | 29.0 - 10.4 |
| 4/17/72 | Jam Up Creek | Big Spring | 38.1 | 8 - 15 | 17.5 - 9.32 |

Figure 1

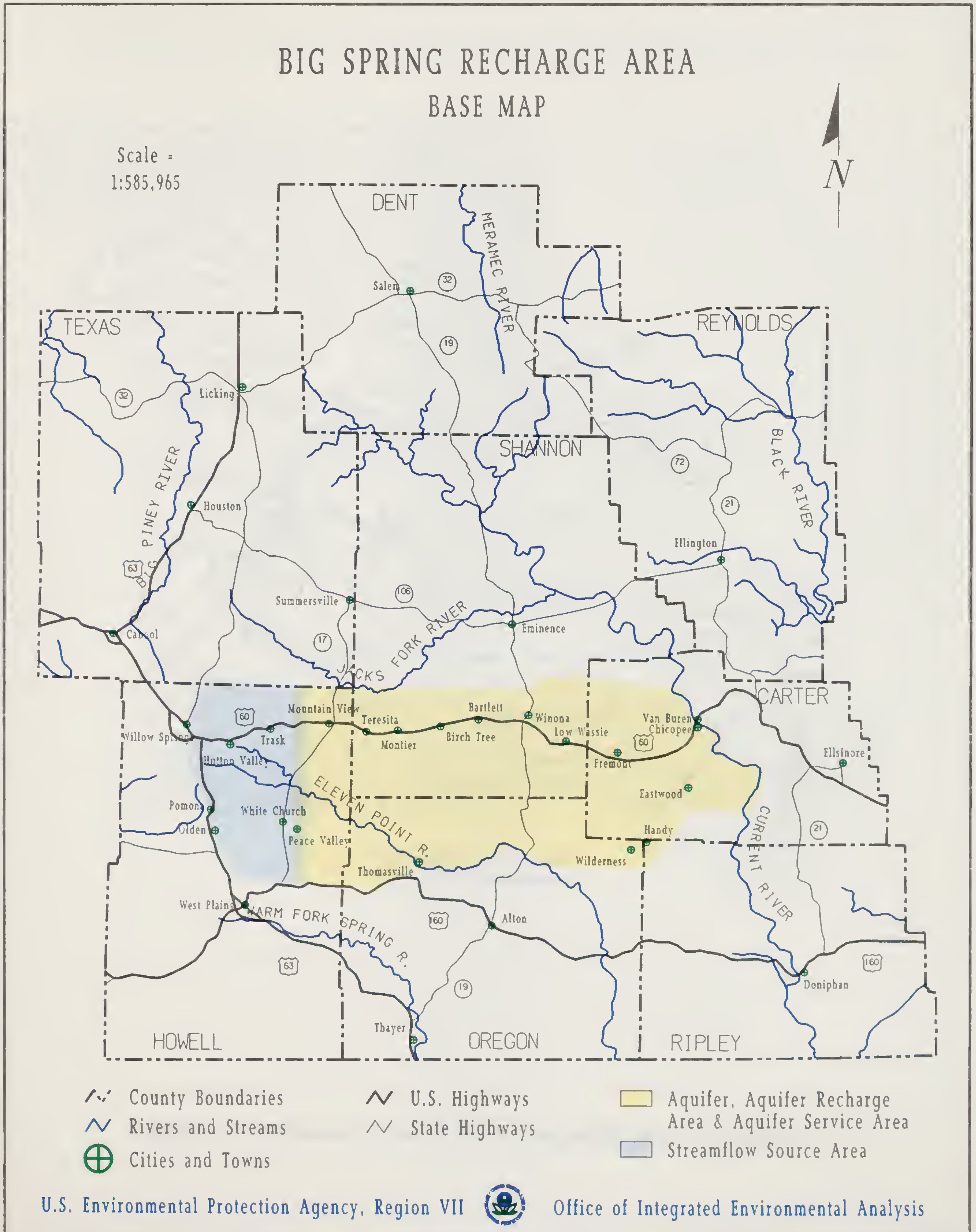
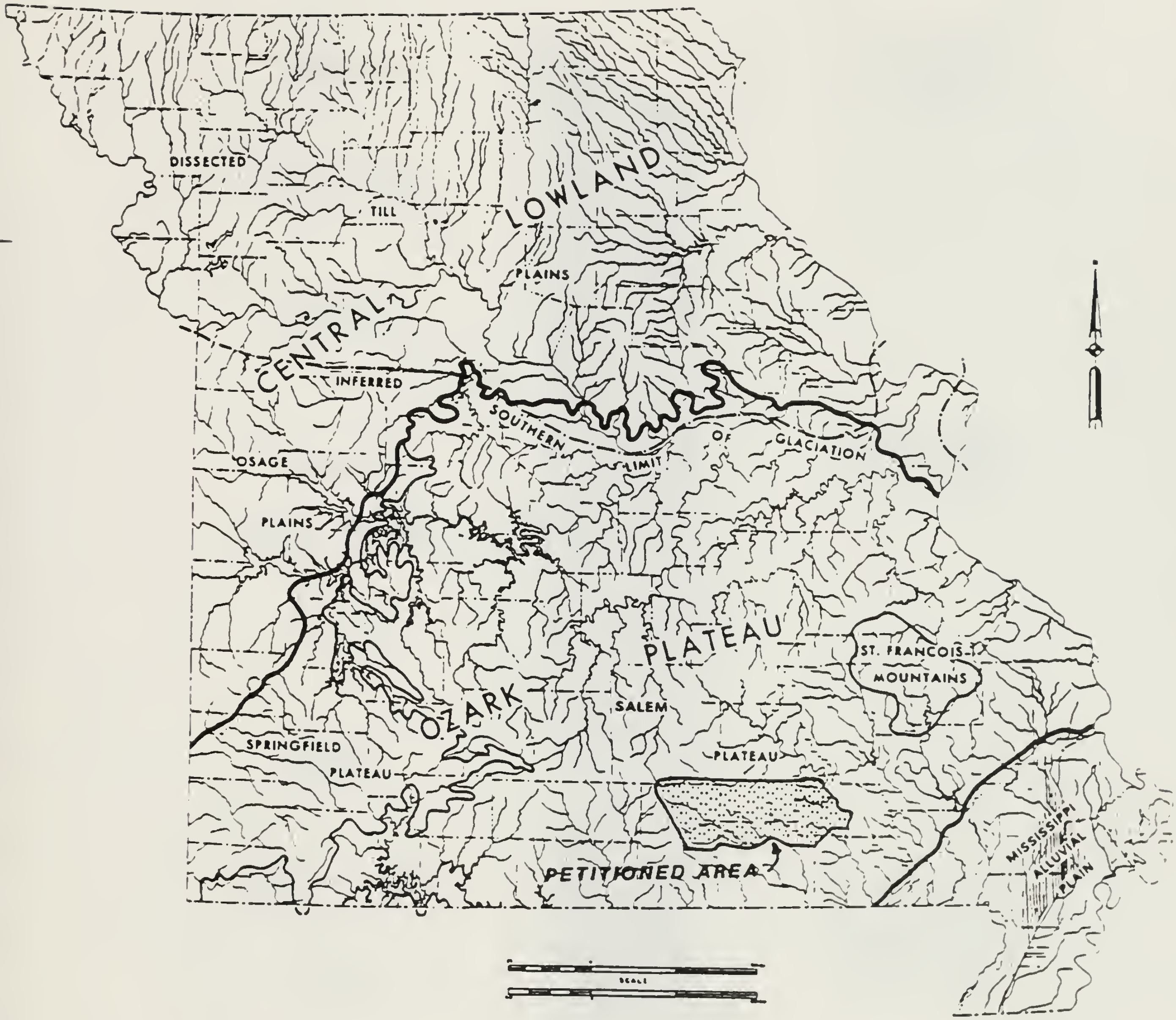

BIG SPRING RECHARGE AREA
BASE MAP
Scale = 1:585,965
N
DENT
TEXAS
REYNOLDS
SHANNON
CARTER
HOWELL
OREGON
RIPLEY
MERAMEC RIVER
PINEY RIVER
BIG PINEY RIVER
BLACK RIVER
JACKS FORK RIVER
ELEVEN POINT R.
CURRENT RIVER
WARM FORK SPRING R.
Salem
Licking
Houston
Summersville
Cabool
Eminence
Ellington
Willow Springs
Mountain View
Teresita
Bartlett
Winona
Trask
Montier
Birch Tree
Low Wassie
Van Buren
Chicopee
Hutton Valley
Fremont
Ellsinore
Eastwood
Pomona
White Church
Olden
Peace Valley
Handy
Thomasville
Wilderness
West Plains
Alton
Doniphan
Thayer
County Boundaries
Rivers and Streams
Cities and Towns
U.S. Highways
State Highways
Aquifer, Aquifer Recharge Area & Aquifer Service Area
Streamflow Source Area
U.S. Environmental Protection Agency, Region VII
Office of Integrated Environmental Analysis

Figure 2




Location of Petitioned Area on a Physiographic Map of Missouri

**Figure 3**

# Geologic Column of the Big Spring Recharge Area

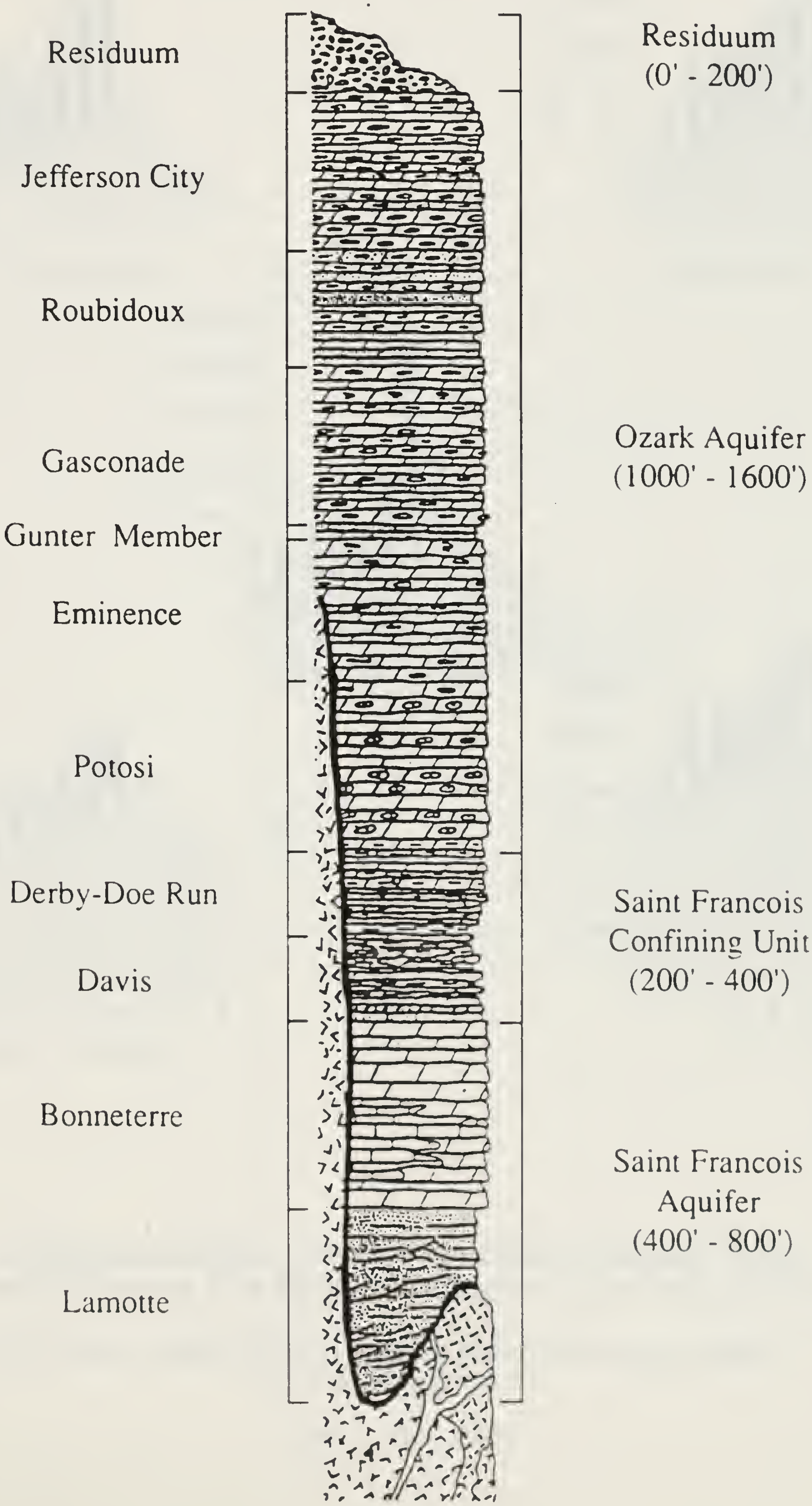
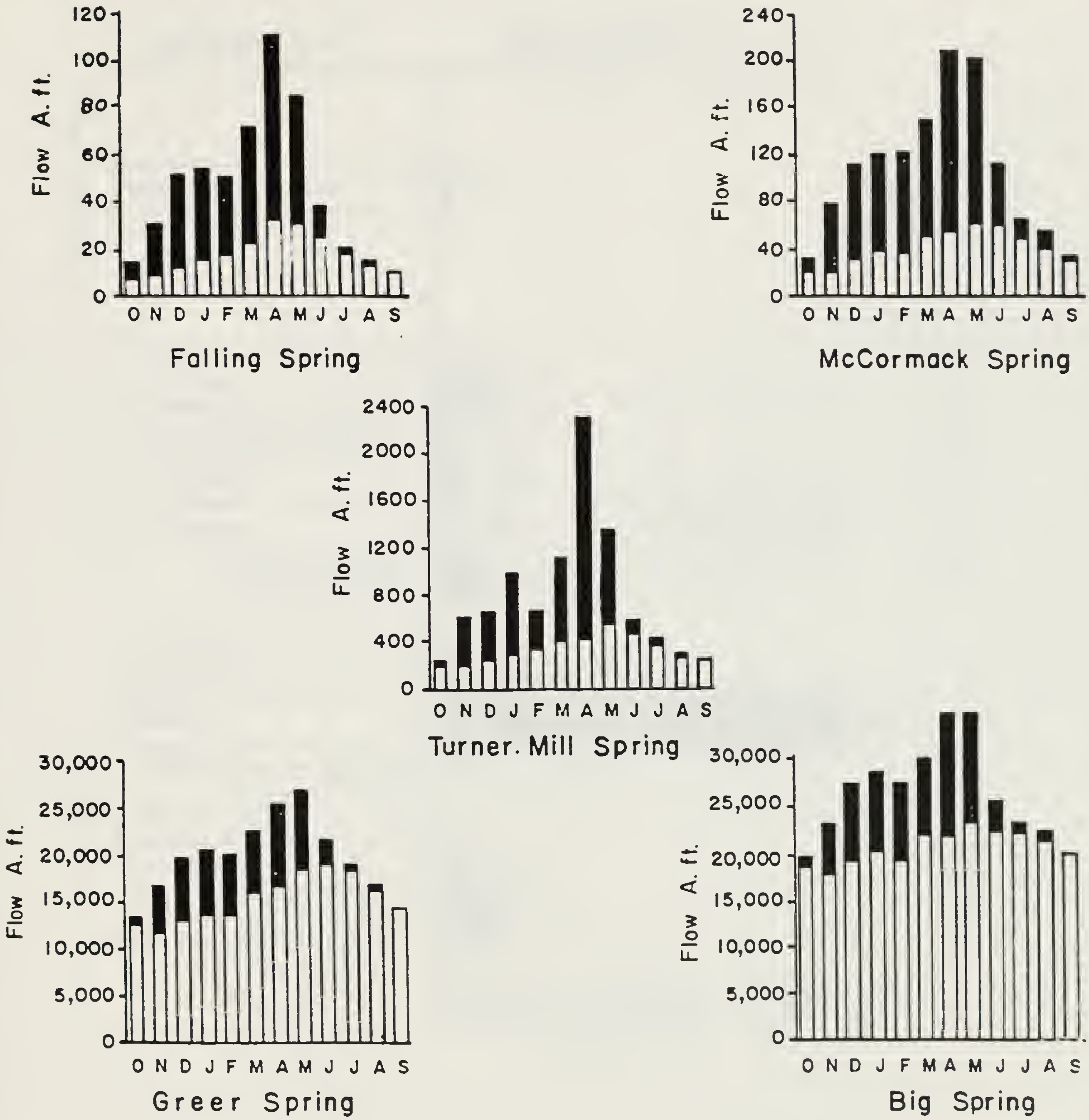


Figure 4

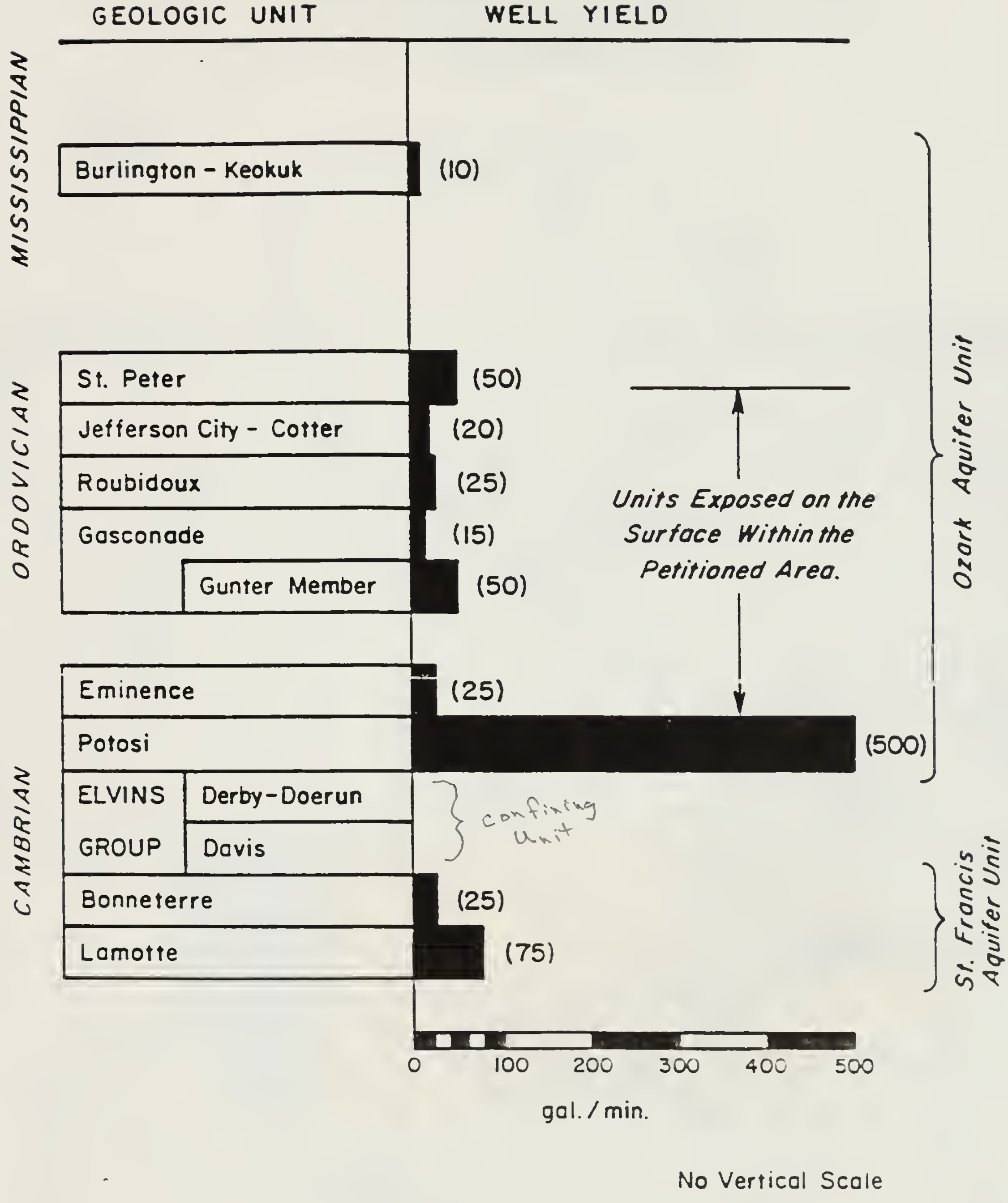



Comparison of Mean Monthly Estimates of Storage Water
and Transit Water at Five Springs For Period Water Years 1967 - 1973

Dark upper portion of bars represent transit water; light portions represent storage water

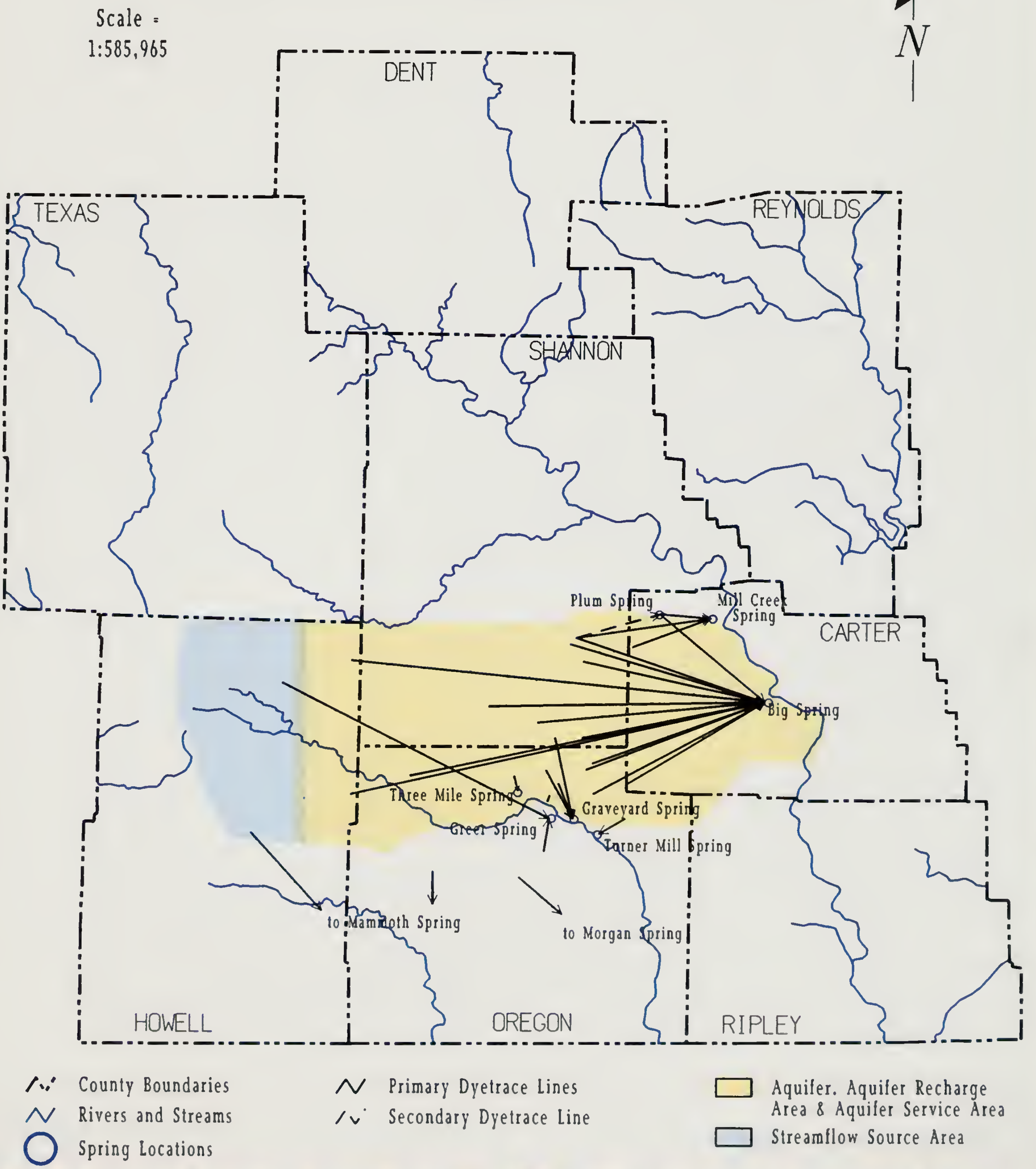
(from: Aley, 1975)

Figure 5




Typical Yields of Wells in Principal Geologic Units of the Ozark Plateau
(adapted from: Melton, 1976)

# BIG SPRING RECHARGE AREA
## DYETRACE MAP



# BIG SPRING RECHARGE AREA

## OZARK AQUIFER POTENTIOMETRIC SURFACE