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BIG SPRING
RECHARGE AREA

SOLE SOURCE
AQUIFER PETITION

Prepared for:

Arthur L. Sullivan, Superintendent
Ozark National Scenic Riverways
National Park Service

Prepared By:

Thomas Aley, Director
Ozark Underground Laboratory
Protem, Missouri

Wilgus B. Creath
W. B. Creath & Associates, Inc.
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Petitioner:

Mr. Arthur L. Sullivan, Superintendent
Ozark National Scenic Riverways
National Park Service

Contact Person:

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Interest in Administrator's Determination:

One of the most beautiful and picturesque sections of Missouri is the "Big Springs Country", a karst region centered on Shannon County. Because of the unique nature of this area, the Ozark National Scenic Riverways was established by the Congress of the United States in 1964 and dedicated in 1972 to preserve the natural conditions of the Current and the Jacks Fork Rivers. The National Park Service has been charged with the management and protection of rivers and springs within the boundries of the Ozark National Scenic Riverways. The aquifer system in the area for which a Sole Source Aquifer designation is being petitioned includes Big Spring, one of the largest and most scenic springs in the nation. Unfortunately, this spring and the associated aquifer system is particularly sensitive to contamination and pollution. In the case of surface streams, it is obvious

that a river cannot be protected without protecting the watershed area. Karst springs and their associated aquifer system present a similar situation in that one cannot protect them without protecting the aquifer recharge areas; the quality of springs is directly dependent upon the quality of waters recharging the groundwater system which they drain.

Timely approval of this application is considered by the National Park Service to be vital if the sole source of drinking water for approximately 20,000 people as well as unique natural resources, such as the Ozark National Scenic Riverways and Big Spring, are to be protected. The urgency of the request results from the possibility that mineral leases and mining permits may be issued by the Bureau of Land Management and the U. S. Forest Service in the petitioned area in the near future. Such actions may result in highly detrimental impacts on the petitioned aquifer. Mining and associated dewatering activities and waste disposal activities in the petitioned area will threaten the aquifer system feeding the water wells, springs, and the surface waters of the Ozark National Scenic Riverways.

The Sole Source Aquifer designation is needed because there currently exists no other planning mechanism that can provide the National Park Service and the residents of the region with the necessary protection of the groundwater recharge area for this aquifer in this hydrogeologic setting.

Petitioner:

12/5/89

Arthur L. Sullivan, Superintendent
National Park Service
Ozark National Scenic Riverways

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Location of Aquifer:

There is one aquifer system in the petitioned area. It consists of an upper aquifer unit (sometimes called the Ozark Aquifer) and a lower aquiferunit (sometimes called the St. Francis Aquifer). The upper aquifer unit extends from the surface of the land downward to the top of the Davis Formation. The lower aquifer unit extends from the base of the Davis Formation downward to Precambrian basement. The Davis Formation which separates the two aquifers is not productive, yet it is permeable and does connect the upper and lower aquifers into a single aquifer system. It is this complete aquifer system to which this petition applies.

The portion of the aquifer system requiring protection is located within the Salem Plateau physiographic subprovince of the Ozark Plateau Province in south-central Missouri (Figure 1). The total aquifer system underlies the Ozark Plateau and extends the width of Missouri south of the Missouri River, including both the Salem Plateau and the Springfield Plateau, and extends southward into Arkansas and southwestward into Oklahoma. That portion of this aquifer system which is of immediate concern to the National Park Service, and which is the subject of this petition, is located within the Current River and Eleven Point River topographic basins and includes southernmost Shannon County, western Carter County, northern Oregon County, and northeast Howell County. The entire area is within the state of Missouri. The total petitioned area encompasses approximately 967 square miles. The boundries of the aquifer, project review area, aquifer service area, streamflow source area, and recharge area are shown on Figure 2. These boundries were established by examination of topographic maps, dye tracing studies, review of the literature and government documents, and by many years of field investigations by Thomas J. Aley, a professional hydrogeologist.

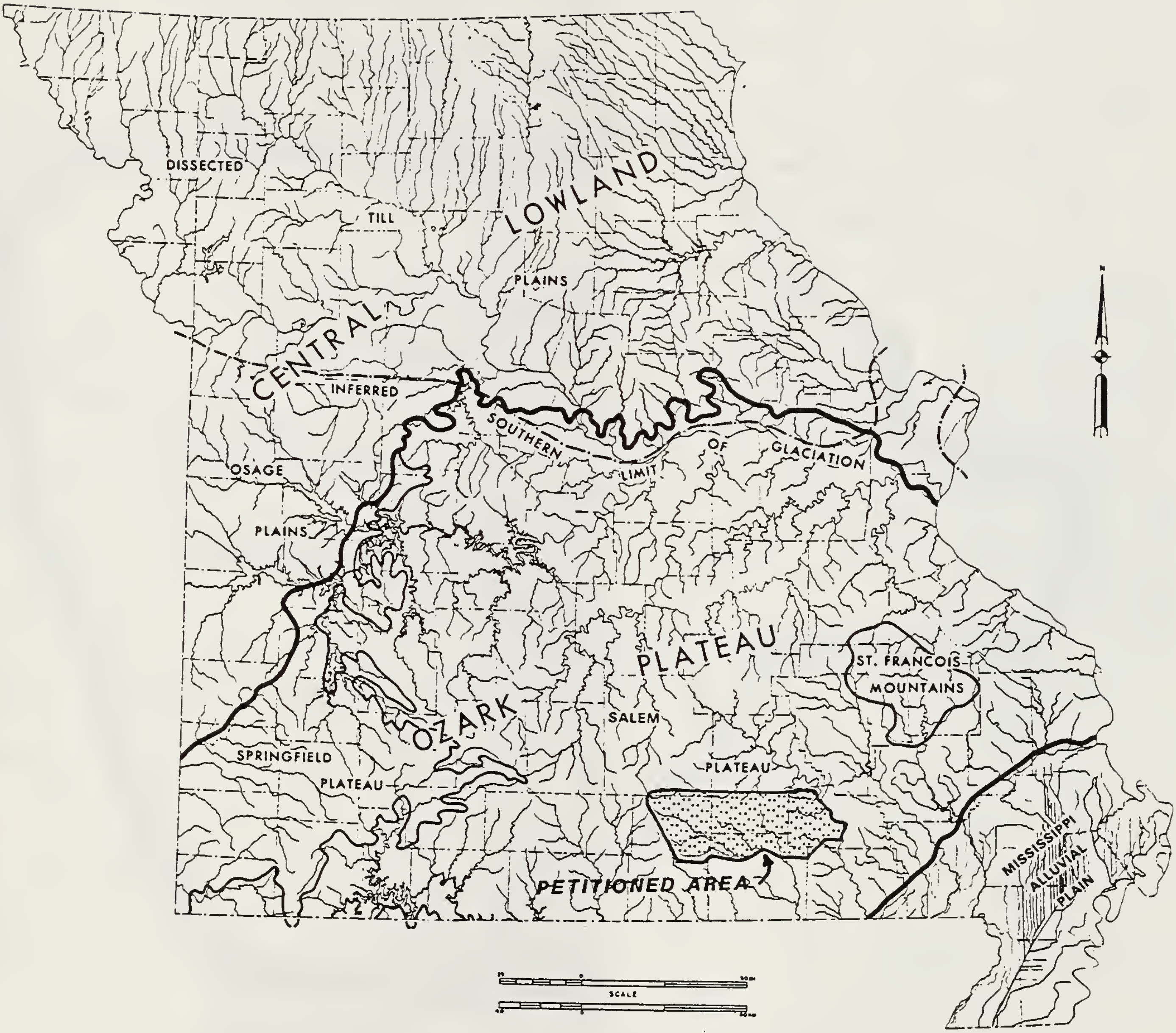


FIGURE 1

Location of Petitioned Area on a Physiographic Map of Missouri

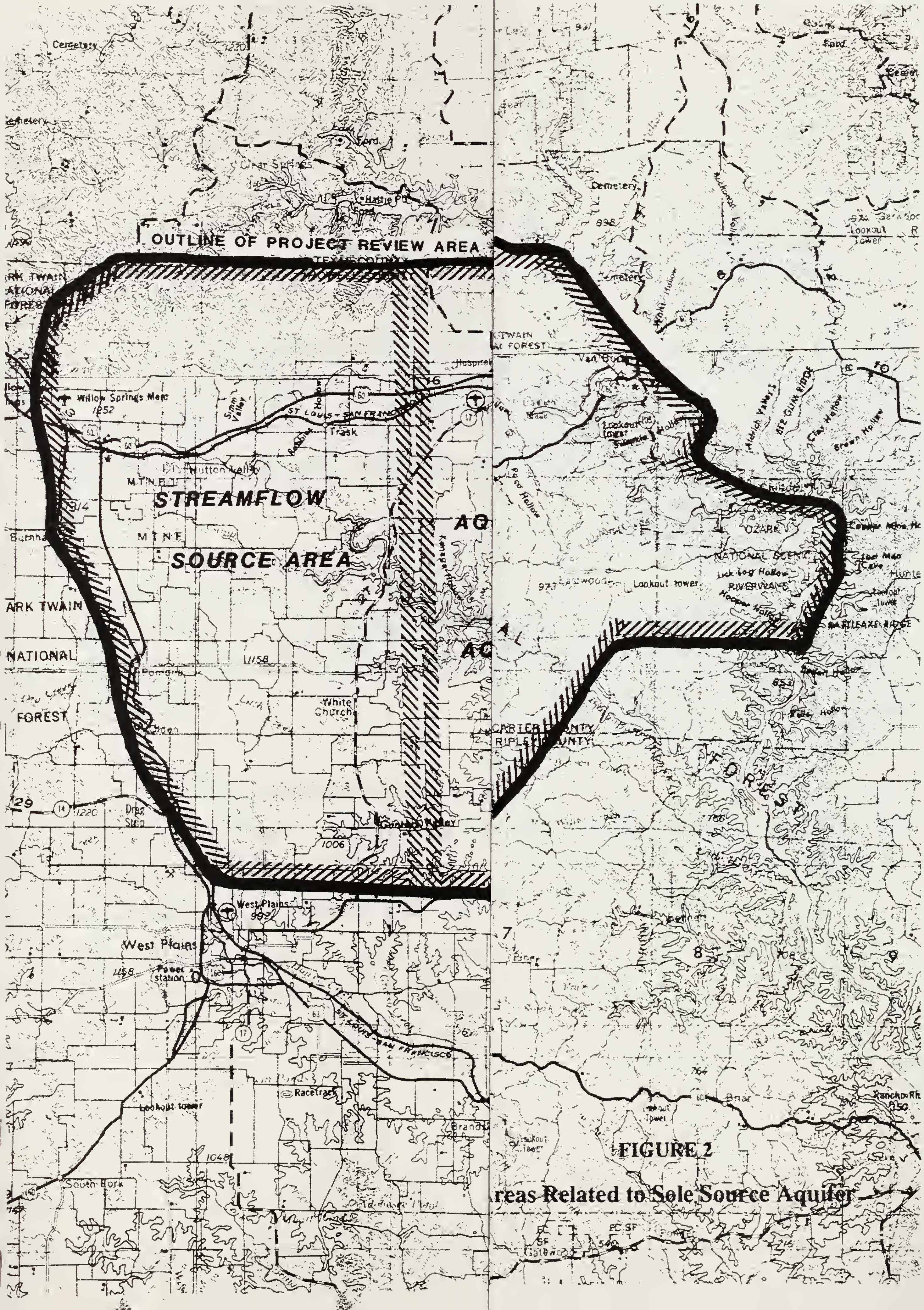


FIGURE 2

reas Related to Sole Source Aquifer

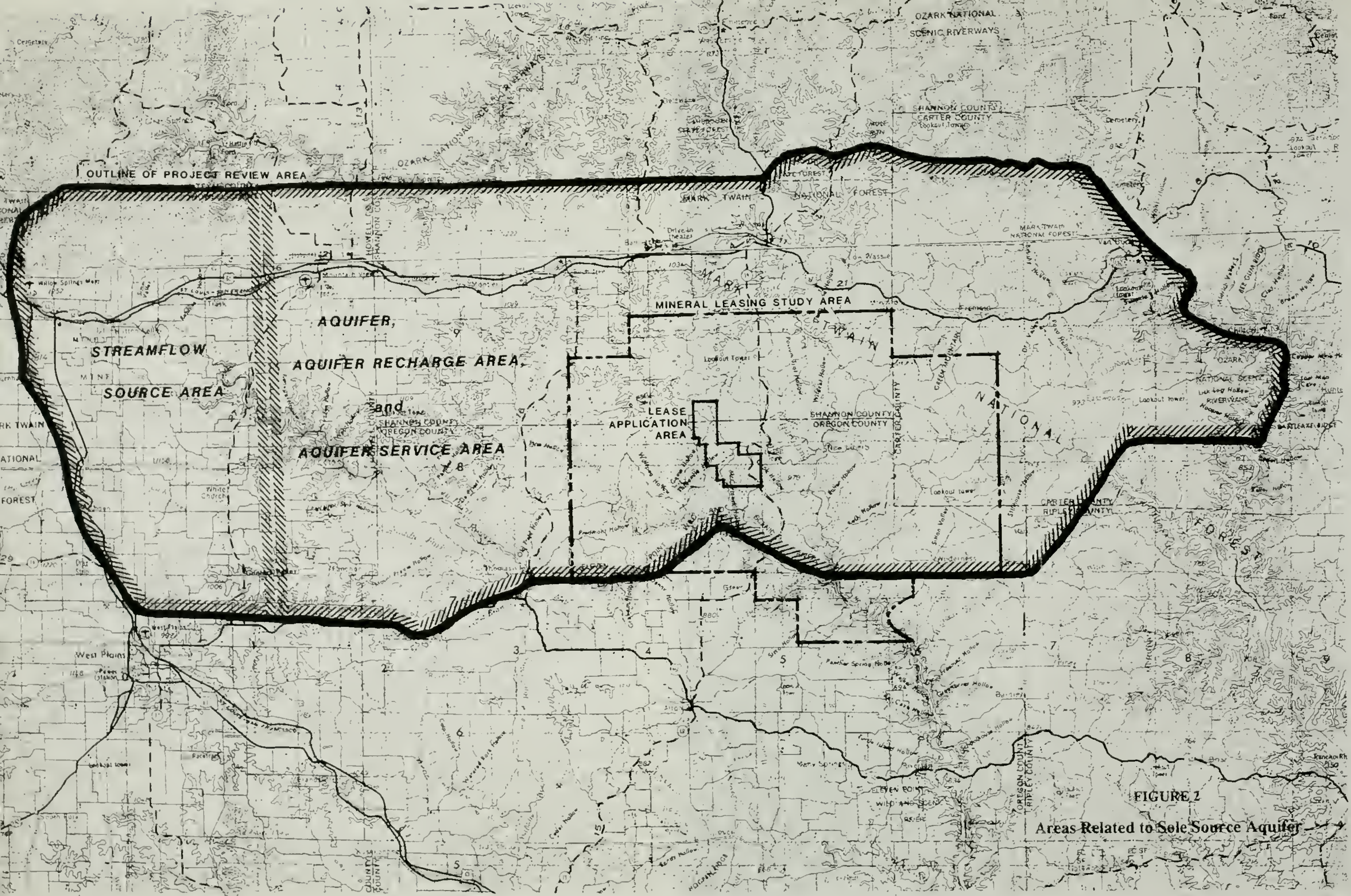


FIGURE 2

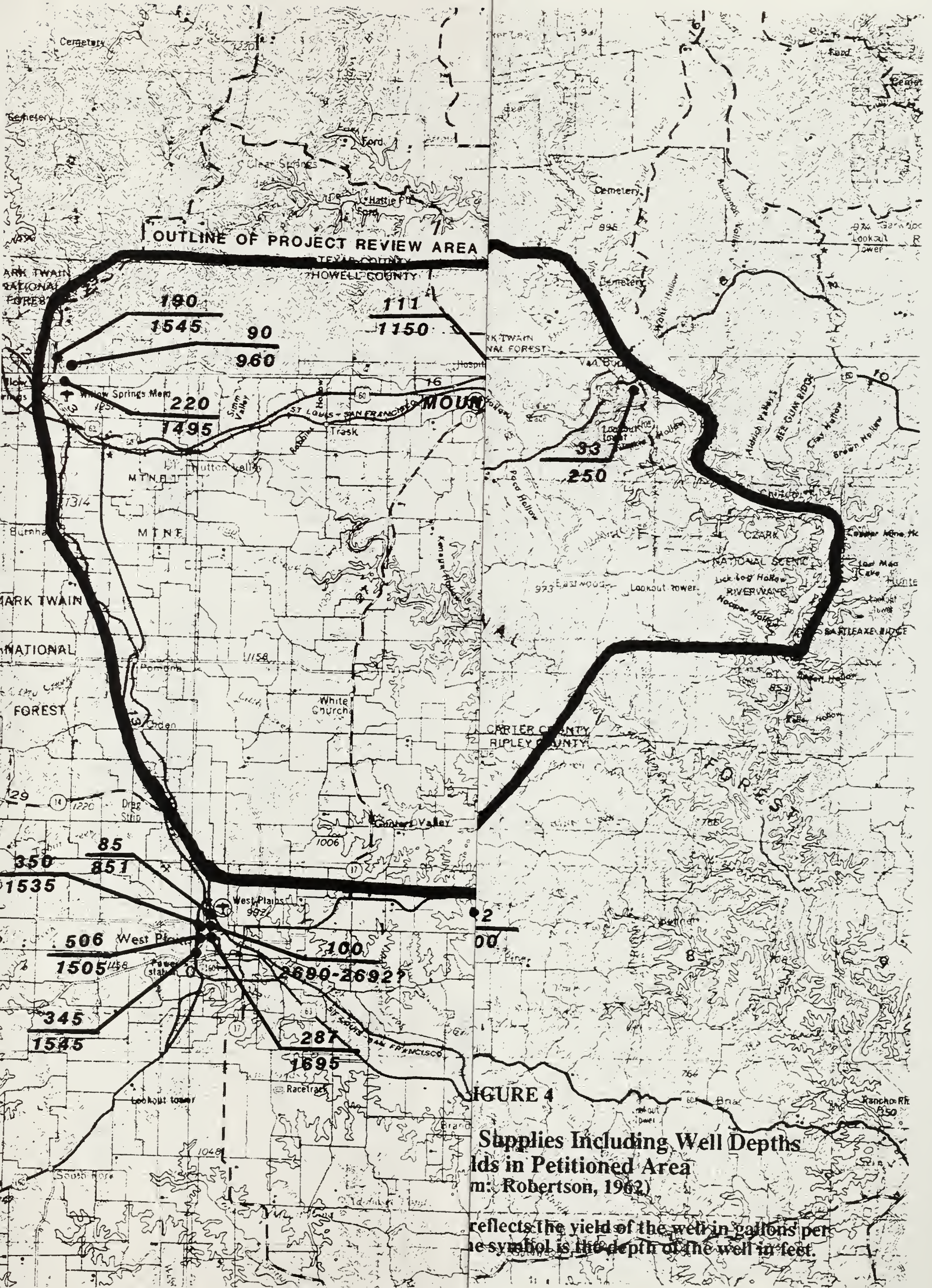
Areas Related to Sole Source Aquifer

Current Drinking Water Sources:

Based on the 1980 census, there are currently an estimated 10,412 persons residing within the petitioned area. Of this number, approximately 3,688 are living within the towns of Mountain View, Birch Tree and Winona; approximately 6,724 are scattered throughout the rural area. Within the petitioned aquifer service area 100% of this population is dependent upon the groundwater produced from this aquifer; there are *no alternative sources* of drinking water (Figure 3). The only surface waters of consequence are the Eleven Point River and the Current River. Both of these potential sources are too distant from the small population centers to be a viable alternative source of supply.

West Plains, with a 1980 population of 7,741, is immediately adjacent to the petitioned area; however, Aley's dye tracing studies (Aley, 1975) have produced no evidence that activities at West Plains affect the area included in this petition. Therefore, West Plains is excluded from the petitioned area.

Three public water systems now serve the population centers within the petitioned area. These are Birch Tree, Mountain View, and Winona. Figure 4 shows the location of these public water systems as well as some well depths and water yields for public and larger private wells in and immediately adjacent to the petitioned area. The following information on the public systems are extracted from "Census of Missouri Public Water Systems, 1987", published by the Missouri Dept. of Natural Resources, Division of Environmental Quality, Public Drinking Water Program.



IGURE 4

Supplies Including Well Depths
lds in Petitioned Area
m: Robertson, 1962)

reflects the yield of the well in gallons per
he symbol is the depth of the well in feet.

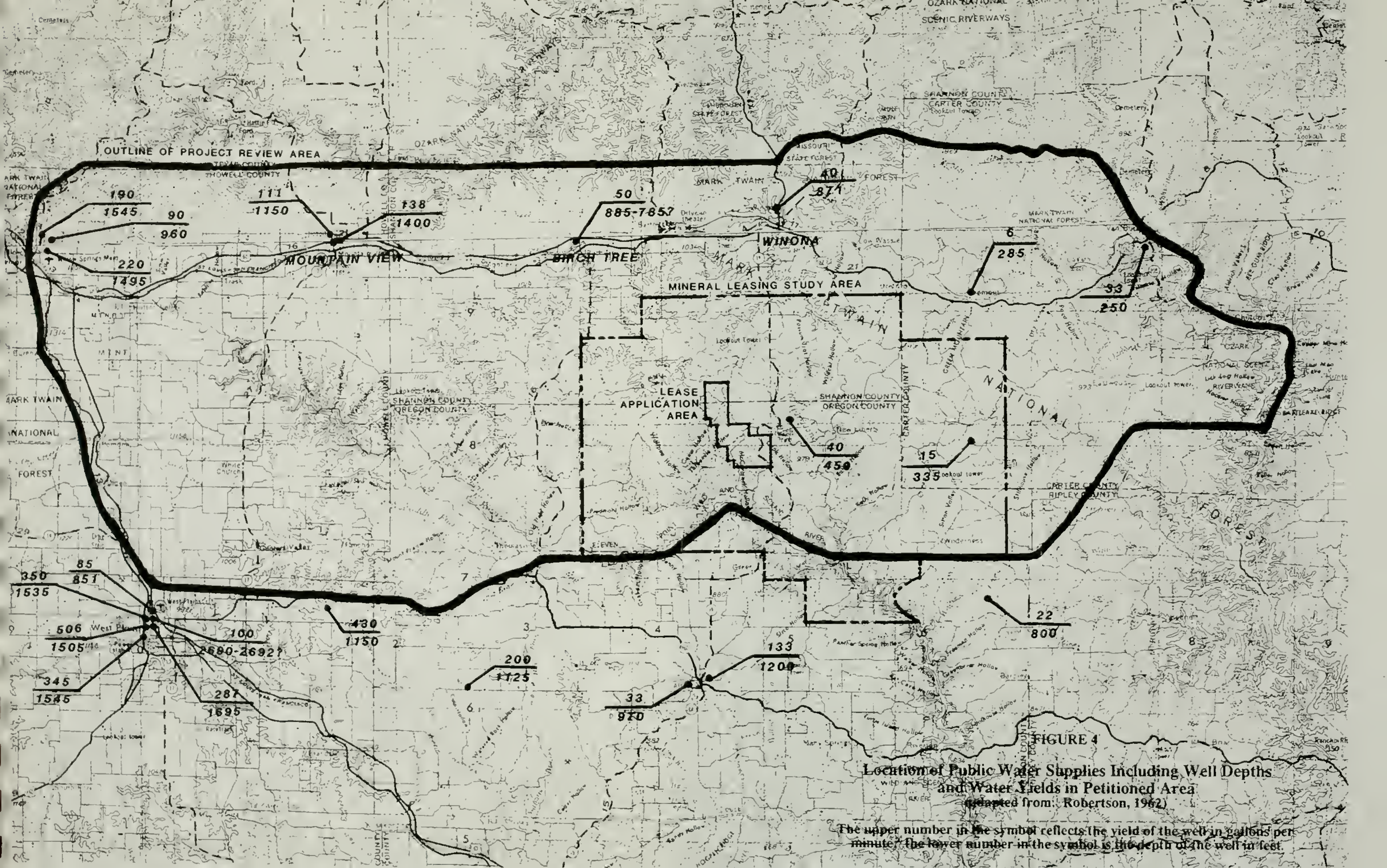


FIGURE 4

Location of Public Water Supplies Including Well Depths and Water Yields in Petitioned Area
(adapted from: Robertson, 1962)

The upper number in the symbol reflects the yield of the well in gallons per minute; the lower number in the symbol is the depth of the well in feet.

SOURCE / USE	PUBLIC WATER SUPPLY (COMMUNITY AND NON-COMMUNITY)	PRIVATE AND OTHER	TOTAL
Petitioned Aquifer	100 %	--	100 %
Other Aquifers	--	--	--
Surface Water	--	--	--
Transported from the Outside	--	--	--
Total	100 %	--	100 %

FIGURE 3

Current Drinking Water Sources for Aquifer Service Area

Birch Tree:

People served: 688

Connections: 321

Source: 3 drilled wells

Capacity: 230,000 gal. per day

Current consumption: 91,700 gal. per day

Treatment: Chlorination only

Mountain View:

People served: 2,000

Connections: 800

Source: 4 drilled wells

Capacity: 1,130,000 gal. per day

Current consumption: 301,000 gal. per day

Treatment: None

Winona:

People served: 1,000

Connections: 500

Source: 1 drilled well

Capacity: 230,000 gal. per day

Current consumption: 85,000 gal. per day

Treatment: None

Consumption in these three communities ranges from 85 gallons to 150 gallons per day per person. Industrial activity is limited at present in the petitioned area and the quantity of industrial water consumption has not been ascertained. The main commercial activity consuming or requiring water is the wood treating plant located at Mountain View. It is assumed that this company has an individual well and is not dependent upon the public water supply.

Figure 5 displays typical well yields from various geologic units in the Ozark Plateau. Figure 6 provides water quality data for Big Spring and the Current River below Hawes Camp Ground.

Big Spring is the largest groundwater discharge point in the petitioned area. The monitoring point on the Current River below Hawes Campground is about 15 miles downstream of Big Spring; it is reflective of surface water quality in this spring-fed river.

Reasons For Interest in Sole Source Aquifer Designation:

A proposed project of immediate concern, which is illustrative of the threats to the petitioned aquifer, is the introduction of lead and zinc mining into the recharge area for the aquifer furnishing water to the water wells of the area and to the springs and rivers of the Ozark National Scenic Riverways. The mining activity, if permitted, could either degrade the quality of the groundwater or lessen the quantity of groundwater available to important springs. It could do both simultaneously.

The nature of the proposed mining activities has been outlined in "Hardrock Mineral Leasing, Mark Twain National Forest, Missouri; Draft Environmental Impact Statement, October, 1988." To summarize, in November, 1983, USX, formerly U. S. Steel Corp., and AMAX Exploration, Inc. filed two lease applications to develop and produce lead, zinc, copper and associated Federal

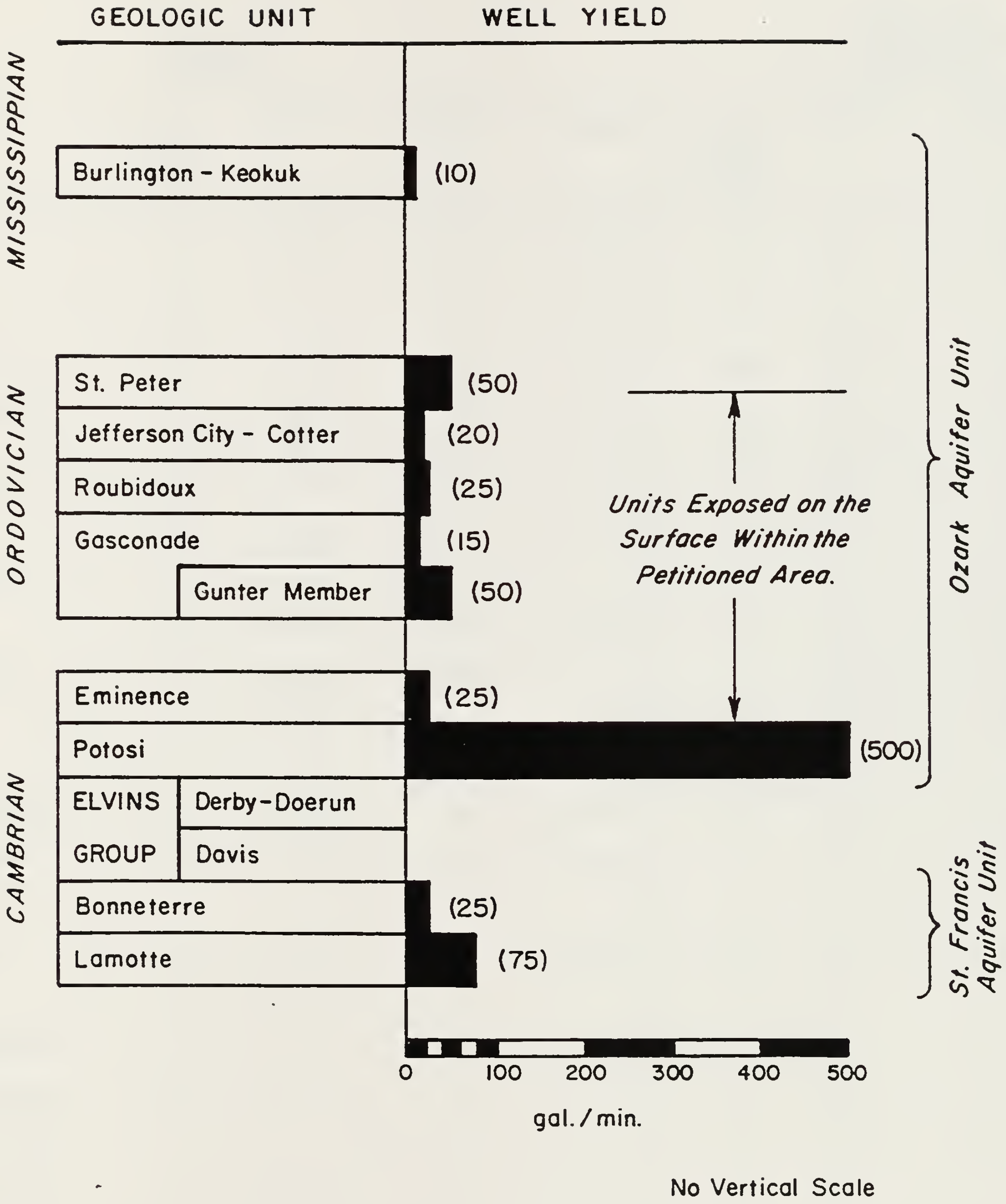


FIGURE 5

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

Figure 6
Water Quality in the Petitioned Area

	1975 to 1984 Big Spring				1975 to 1984 Current River Below Hawes Campground			
arameter & Units	# of measurements	Maximum	Minimum	Mean	# of measurements	Maximum	Minimum	Mean
pecific conductance	16	368	210	302	18	360	222	296
(umhos/cm)	--	--	--	--	--	--	--	--
H (units)	16	7.6	7.1	7.4*	18	8.3	7.5	8.1*
emperature (C)	16	16.0	13.0	14.4	18	22.0	7.5	17.9
issolved Oxygen mg/l	16	9.6	8.0	8.8	18	11.2	7.7	9.2
ecal Coliform	15	580	<1	13*	18	230	1	13*
colonies per 100 ml	--	--	--	--	--	--	--	--
ecal strep.	15	2100	<1	17*	17	440	<1	17*
colonies per 100 ml	--	--	--	--	--	--	--	--
lkalinity mg/l	5	196	140	163	7	186	123	148
itrite Nitrogen mg/l	4	<.020	<.010	--	4	<.020	<.010	--
itrite & Nitrate	6	.50	.30	.40	6	.30	.200	0.26
Nitrogen mg/l	--	--	--	--	--	--	--	--
mmonia Nitrogen mg/l	13	.090	.00	.010*	14	.04	.00	0.01*
mmonia Nitrogen &	4	.30	<.20	.25*	4	.50	<.20	.40*
Organic Nitrogen mg/l	--	--	--	--	--	--	--	--
hosphourus total	9	.140	.00	.010*	12	.04	.00	.01*
(mg/l as P)	--	--	--	--	--	--	--	--
admium total	8	8	0	<1*	10	10	0	<1*
recoverable ug/l as Cd	--	--	--	--	--	--	--	
b total recoverable ug/l	11	95	<1	7*	14	100	<1	5*
g total recoverable ug/l	11	1	0	1*	14	10	0	<1*
n total recoverable ug/l	11	130	0	20*	14	60	0	20*

Median Value
ource: USGS Annual Reports, 1975 thur 1984. Water Resources Data for Missouri.

minerals on 3,743 acres within Mark Twain National Forest. After filing the applications, USX and AMAX assigned all interests to St. Joe Minerals Corporation. St. Joe has since combined its interests with Homestake Minerals to form Doe Run Corporation. Doe Run currently (October, 1988) holds the interests in the two applications. A lease conveys the right to develop and produce Federal minerals, and additional applications appear likely. In addition to the current Doe Run lease applications, as of 1989 there are 10 prospecting permits issued and one pending permit application.

If mining occurs in the petitioned area, the aquifer could be damaged from above and below by mine dewatering in the subsurface and by the disposal of mine wastes on the surface. The four principal ways that heavy metals resulting from mining operations could enter the streams and groundwater of the petitioned area are 1) from mine drainage, 2) from leaching of mine tailings, 3) from mine tailings and processing wastes which enter the streams because of the failure of tailings dams, ponds, or other similar features, and 4) from the leaching of ore processing wastes. In addition, if mine dewatering induces accelerated sinkhole collapse, sediment concentrations may be sporadically increased in springs and streams of the area.

The Missouri Water Quality Management Plan (Missouri Dept. Natural Resources, Div. Environmental Quality, 1979) concluded that the greatest potential source of nonpoint pollution associated with mining appears to be the erosion of large tailings ponds, particularly after the mines have been abandoned or closed. Missouri has experienced catastrophic tailings dam collapse in the past. The Dresser Industries tailings dam failure polluted the Big River with tailings for a distance of 70 miles. A tailings dam failure associated with lead and zinc mining occurred in the Logan Creek Basin in 1977. These and other tailings dam failures, which have been documented by the Missouri Department of Conservation from elsewhere in Missouri, demonstrate that catastrophic failures are a significant risk associated with mine tailings disposal in the petitioned area.

The collapse of the sewage lagoon at West Plains in 1978 demonstrated that a similar collapse of tailings disposal ponds can endanger the aquifer when support for the impoundments disappear. Much of the petitioned area is subject to catastrophic sinkhole collapse (Aley et al., 1972). New sinkholes are constantly developing in the New Lead Belt area to the north and in the petitioned area. The processes involved in sinkhole development in the area are identified and discussed at length in Aley et al. (1972) with several of the case histories being from the petitioned area.

Dewatering of the ore-bearing Bonneterre, which is necessary to make mining possible, increases the probability of sinkhole collapse. A U. S. Forest Service memorandum dated November 26, 1974 (Warner, 1974) noted the development of a number of sizeable sinkholes in the vicinity of the AMAX mine in the New Lead Belt (Viburnam Trend) which were possibly linked to mine dewatering. Other mining activities, such as the drilling of ventilation shafts, have apparently been associated with the development of large sinkholes and the lowering of water levels in private wells near the mining activities.

There is little evidence to support the supposition that the Davis Formation is an effective aquiclude between the upper aquifer and lower aquifer (where any mineral extraction wiould take place) in prospective mining areas, but there are indications that mining activity, especially dewatering, in the Bonneterre below the Davis could directly affect those geologic units above the Davis. This is discussed in more detail in the section entitled "Separation of Aquifers".

Pumping rates necessary to permit mining in the petitioned area have not been determined by the Forest Service or the mining companies, but that substantial pumpage would be necessary is certain. In the New Lead Belt, mining companies were pumping a total of 18,000 gallons of water 40
per minute from eight operating mines in 1971 (Warner et al., 1974). The Environmental Impact

Statement prepared in connecton with the proposed mineral leasing states that site specific factors will cause great variances in the amount of water to be pumped. However, as emphasized in Aley's critique of the Environmental Impact Statement (Aley, 1987), the volume of water which could move downward through overlying strata and into the mining zones is of critical importance in assessing the environmental impact of the mining on the water wells, major springs and the Ozark National Scenic Riverways. Approximately 250 exploratory test holes were drilled by the mining companies but the hydrologic and geologic data required to help solve this important issue either were not collected during this drilling or were not made public.

A comment received during review of a preliminary draft of this petition noted that much of the mine pumpage in the New Lead Belt is transported from the area via surface streams whereas much or most mine pumpage in the petitioned area would sink back into the groundwater system. While this recharging of pumpage waters might help offset some water quantity impacts on the groundwater system, it could increase water quality risks and risks of catastrophic sinkhole development. On balance, the net groundwater impacts in the petitioned area would likely be greater than those in the New Lead Belt area.

In order to work the mines in the New Lead Belt, it is necessary to lower the potentiometric surface of the deep aquifer (the Bonneterre) at mine sites by 600 to 1,200 feet depending on the mine location. Similar conditions in the petitioned area are anticipated. As of 1971, the major influence of this dewatering extended a radius of approximately five miles from each mine with minor effects being felt at slightly greater distances (Warner et al., 1974). Warner et al. (1974) further state that ...."In order to compensate for the amount of water being removed from the deep aquifer, flow may be lateral and from the outcrop areas of the Bonneterre and Lamotte Formations or it may be vertical as a result of leakage across the Davis Formation from the shallow aquifer. If leakage across the Davis Formation were great enough, decline in the level of the

shallow aquifer water table could result, possibly affecting some water supplies and causing such secondary effects as the drying up of springs, reduction in the base flow of streams, and development of sinkholes."

The lack of an array of shallow monitoring wells at the mines in the New Lead Belt precludes verifying whether or not dewatering is resulting in drawdown of wells in the shallow aquifer. The only known shallow aquifer monitor wells are in the vicinity of the Ozark Lead Company mine. One well located near the mine shaft showed a water level decline of 117 feet between 1965 and 1971. A second well about one-half mile from the shaft recorded a decline of 32 feet for the same period. Additionally, Warner et al. (1974) note reports that declines in the shallow aquifer water table have been induced by dewatering activities in the vicinity of faults that have apparently fractured the Davis Formation. Personal communication with citizens of Bixby, Missouri by W. B. Creath on July 15, 1989 verified that in 1987-1988 numerous water wells either went dry or had the water levels lowered as much as 150 feet and that sinkholes developed when the Doe Run mine drilled a ventilation shaft one-half mile away. Despite the fact that the ventilation shaft is now reportedly grouted, the water levels have not recovered.

Although the Sole Source Aquifer designation is concerned with protection of drinking water sources, we should not forget that decreases in water quality and/or water quantity will also have effects upon local communities and their residents, upon tourism, and upon plant and animal life. The water resources of the petitioned area have trememdous economic, social, and ecological values. As an illustration, tourism provides substantial employment within the petitioned area; much of the tourism is associated with the springs and rivers which are fed by the petitioned aquifer.

Caves within the petitioned area provide habitat for both the grey bat (*Myotis grisescens*) and the Indiana bat (*Myotis sodalis*). Both of these bats are federally listed endangered species, and both species use caves. Changes in the groundwater regimen could impact these species by changing cave microclimate conditions. Additionally, introduction of heavy metals into the ecosystem could impact food sources for the bats.

The data on the following pages demonstrate the fragile nature of the petitioned aquifer system and how the introduction of a polluting activity, such as mining, could affect groundwater supplies in the region and within the Ozark National Scenic Riverways.

Description of Aquifer and Recharge Area:

General Description of Area: The Salem Plateau physiographic subprovince, within which the petitioned area is located, surrounds the St. Francois Mountains, a Precambrian basement complex. Aley (1968) divided the Salem Plateau in the petitioned area into 1) the uplands and rolling hills, and 2) the dissected lands physiographic zones. Approximately 75% of the petitioned area lies within the uplands and rolling hills zone (Figure 7). The dissected lands zone is characterized 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 the lack of rock outcrops because of residuum 60 or more feet deep, topographic relief of less than 100 feet, and abundant large sinkholes

Climate: A humid continental climate characterizes the petitioned area (Aley, 1975). The typical annual temperature range is from near zero degrees Fahrenheit to about 100 degrees Fahrenheit. Records from the U. S. Weather Bureau station at Birch Tree indicate that the coldest

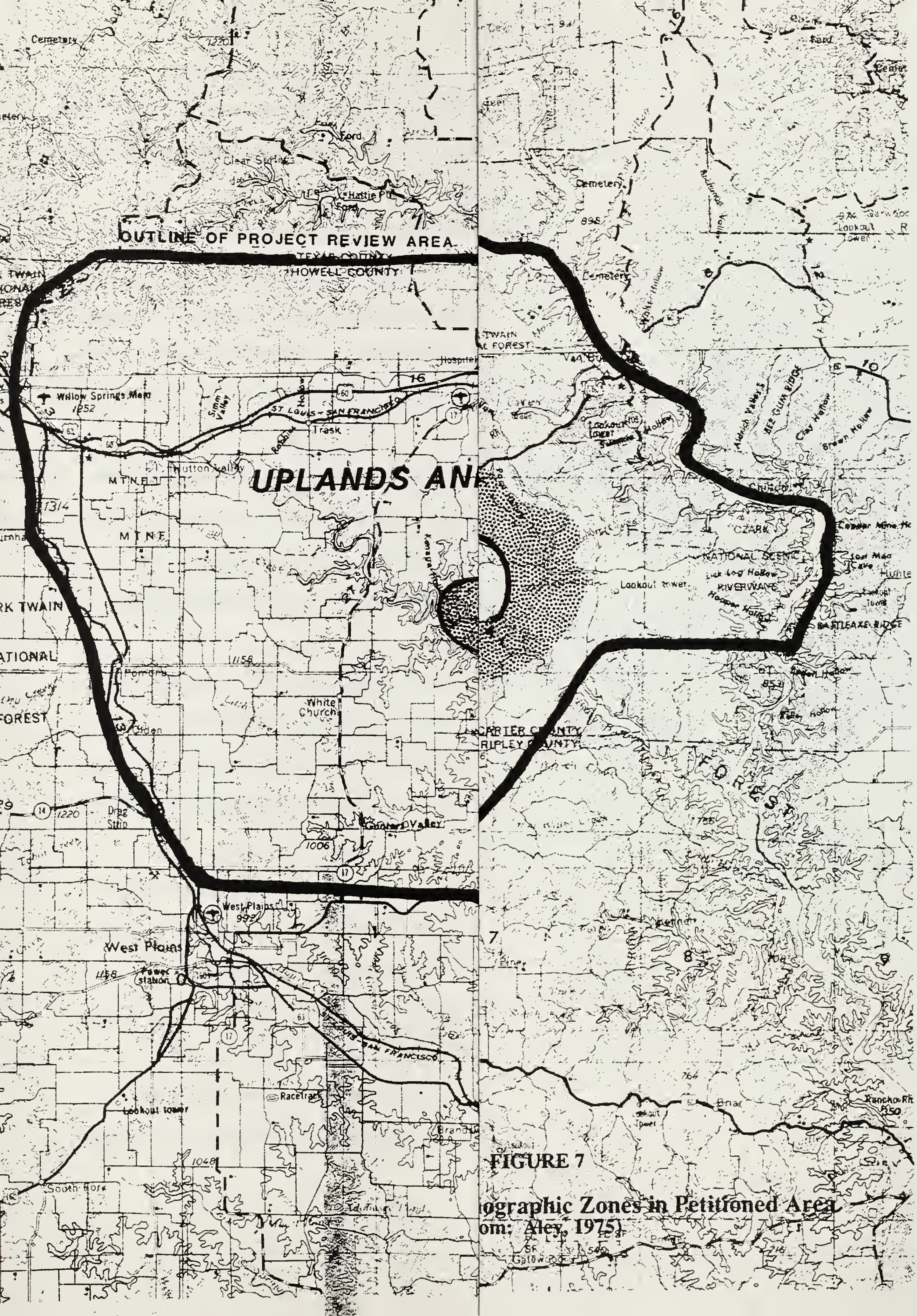


FIGURE 7

ographic Zones in Petitioned Area
om: Aley, 1975)

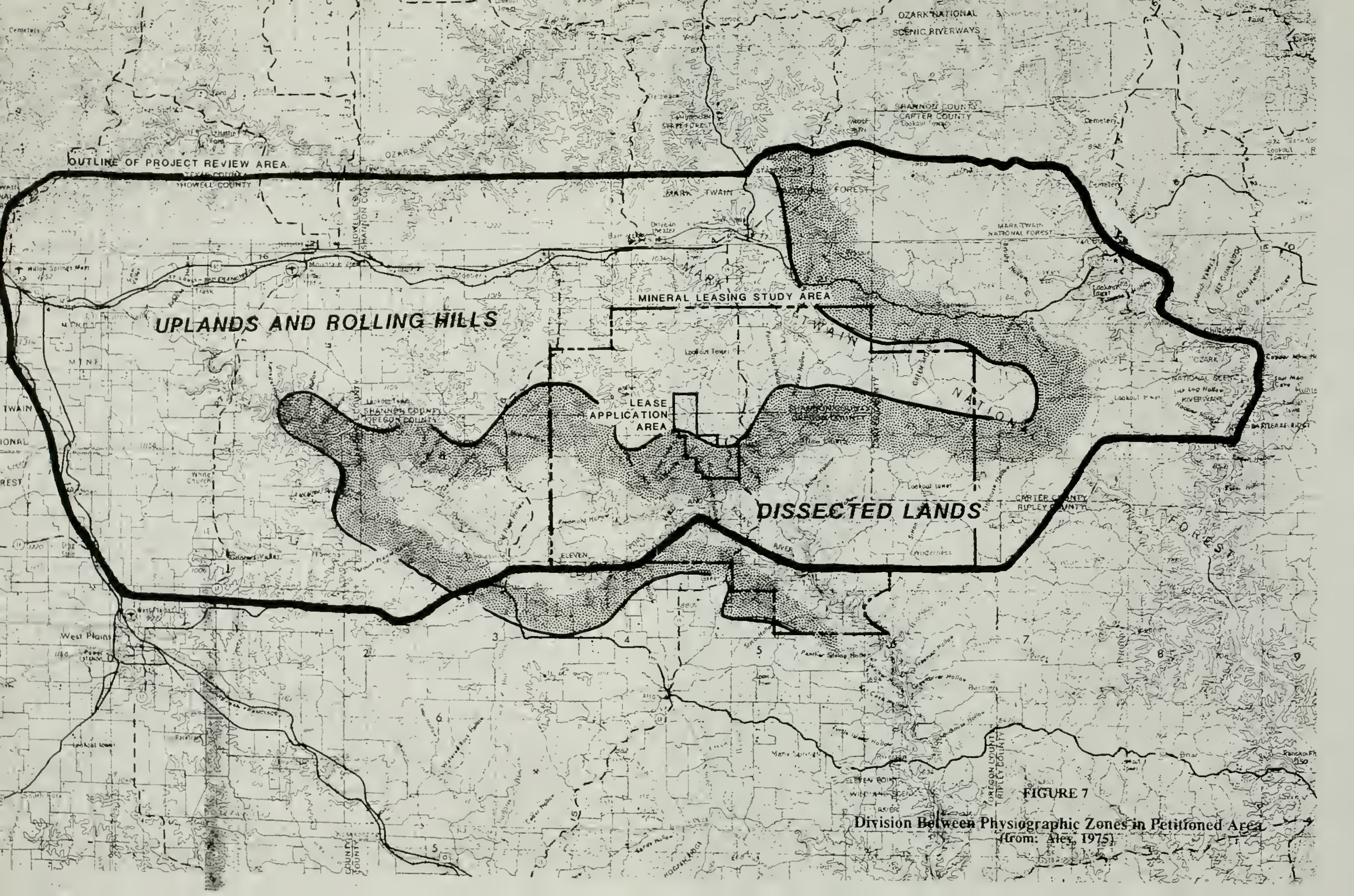


FIGURE 7

Division Between Physiographic Zones in Petitioned Area
(from: Aley, 1975)

month is January with a mean monthly temperature of 33.5 degrees Fahrenheit; the warmest month is July with a mean monthly temperature of 78.0 degrees Fahrenheit.

The mean annual precipitation at Birch Tree is 44.18 inches with the minimum precipitation occurring in December and the maximum in May. The contribution of snowfall is negligible. Missouri is noted for its summer thunderstorms and these storms account for a variability in monthly precipitation between areas in close proximity to each other. Significantly, these thunderstorms tend to introduce water and any associated pollutants into the aquifer in "slugs".

Soils: Soils surveys for Shannon, Carter and Oregon counties are only partially completed and a published survey is available for only part of the area (Gott et al., 1975). Surveys for Howell and Texas counties were published prior to 1940 and are no longer available. The following soils descriptions are adapted from the Draft EIS, Hardrock Mineral Leasing, 1987.

The broad, relatively flat ridges have soils consisting of deep loam and clay capped with loess. They are moderately well-drained, moderately to slowly permeable and low in fertility. They are easily eroded 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 the 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. The soils recover quickly after disturbance if fertilized.

There are several different types of bottomland soils. Those formed on silty alluvium in 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 resistant to compaction. The soils in the wide bottomlands form low stream terraces, are well drained and are the best for cultivation and contain high-value tree species. They are easily compacted when wet.

Geology: The geology and geomorphology of the area has been extensively reported by a number of authors including, among others, Aley (1975), Warner et al. (1974), and Melton (1976). The aspects of regional geology most affecting the hydrology of the aquifer are the sequence and composition of the stratigraphic units and the structure. Figure 8 depicts the general outcrop pattern of the Eminence, Gasconade, Roubidoux, Jefferson City, and Cotter formations. The stratigraphic sequence of rocks occurring in the petitioned area is shown on Figure 9.

During the Precambrian, erosion of the basal igneous rocks produced a rugged, topographically pronounced surface. In the New Lead Belt, northeast of the petitioned area, Warner et al. (1974) reported the Precambrian relief to have exceeded 2,500 feet. This means that these pinnacles can penetrate the Eminence. Figure 11 shows the pinnacle relief existing on this basement surface along the northern border of the petitioned area. During late Cambrian time, a basal sandstone and a sequence of carbonates and shales were deposited upon much of the Precambrian erosional surface by encroaching Paleozoic seas. The sediments have a generally westerly dip of approximately 1.0 degrees; however, initial dips are greater around the Precambrian knobs or topographic highs.

Because of the significant topographic variation of the Precambrian erosional surface, the deposition of the late Cambrian sediments is confined to the Precambrian valleys and lowlands. These sediments either pinched out against, or were not deposited over, the Precambrian knobs and

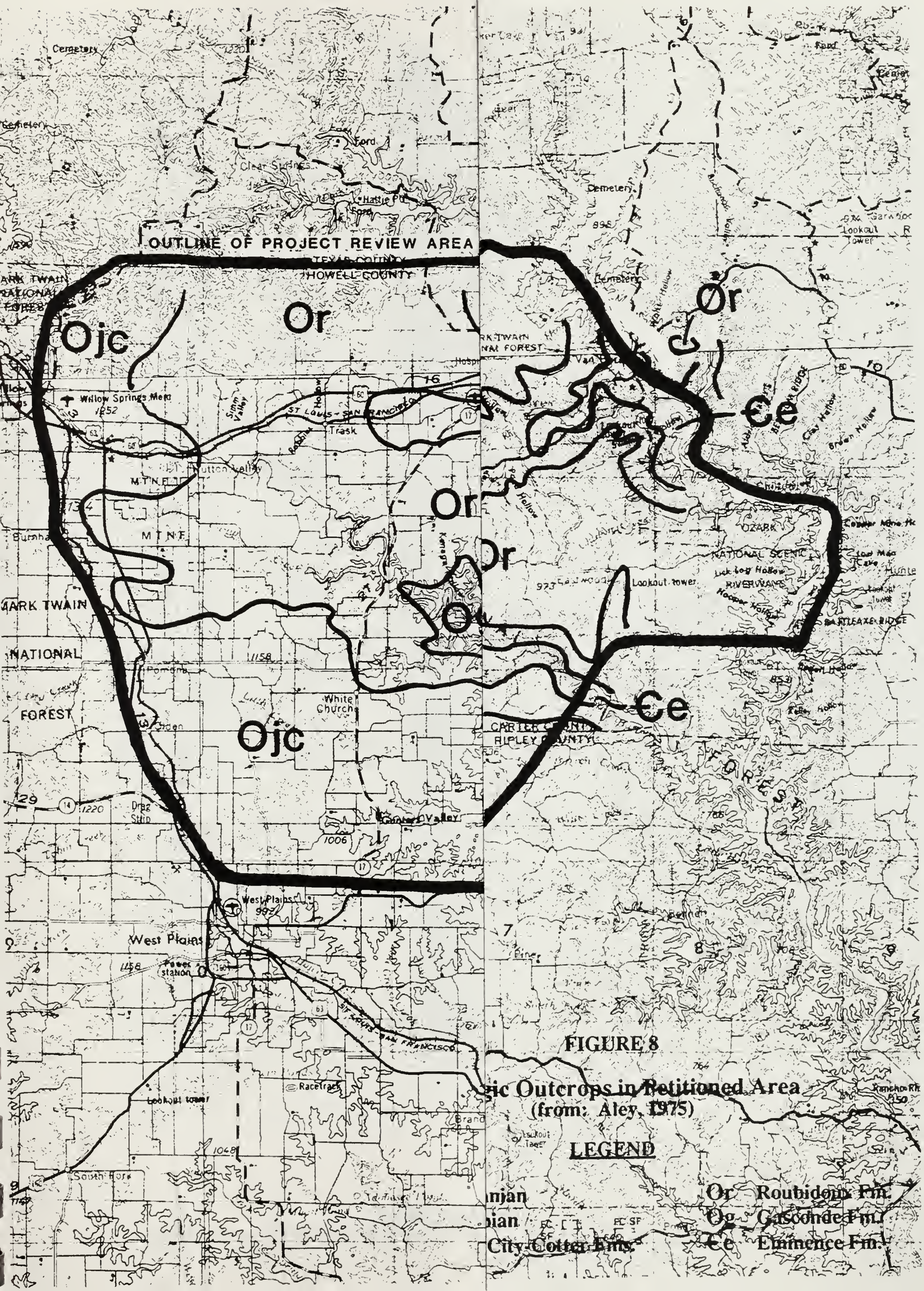


FIGURE 8

gic Outcrops in Petitioned Area
(from: Aley, 1975)

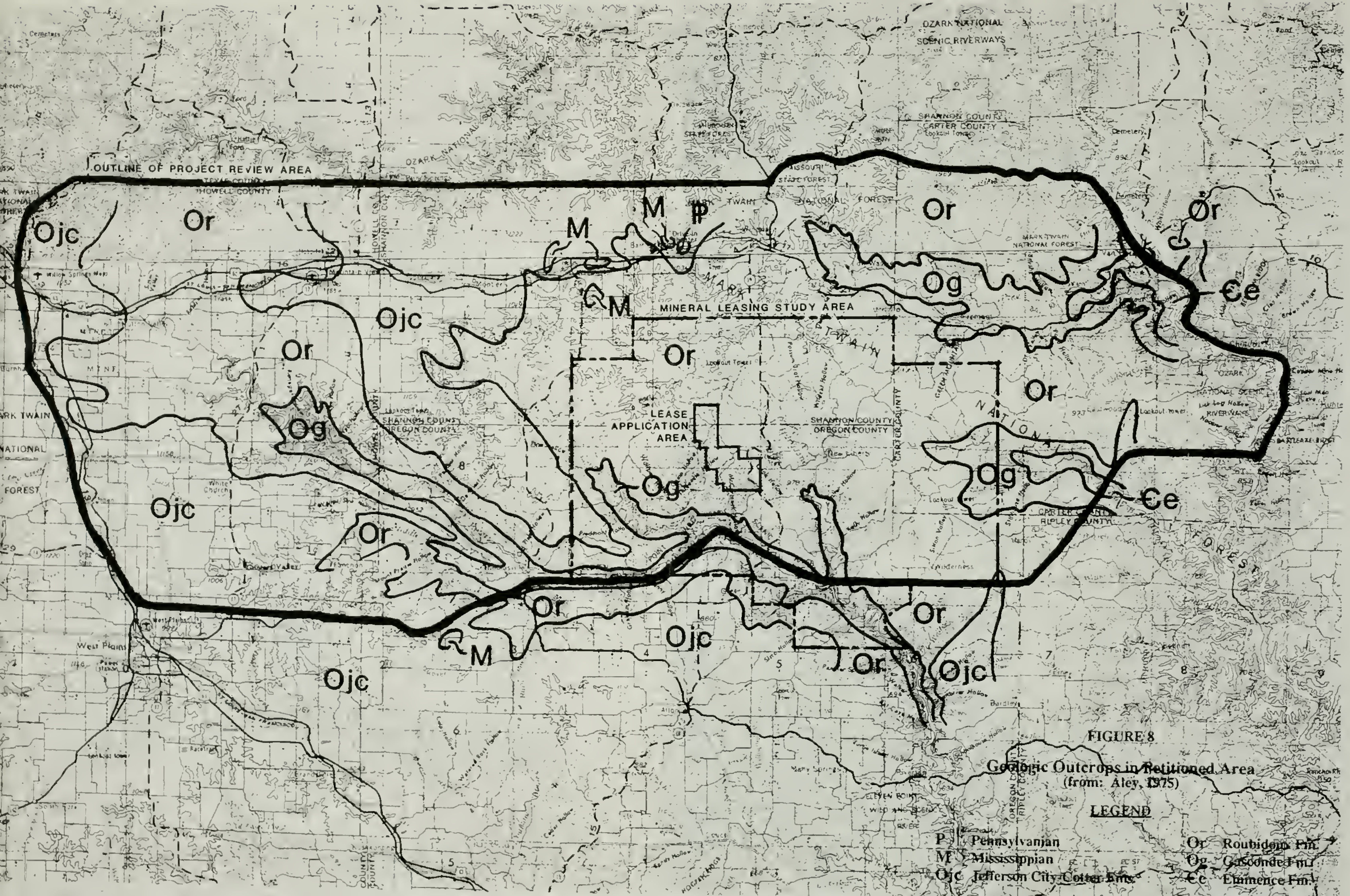


FIGURE 8

Geologic Outcrops in Petitioned Area
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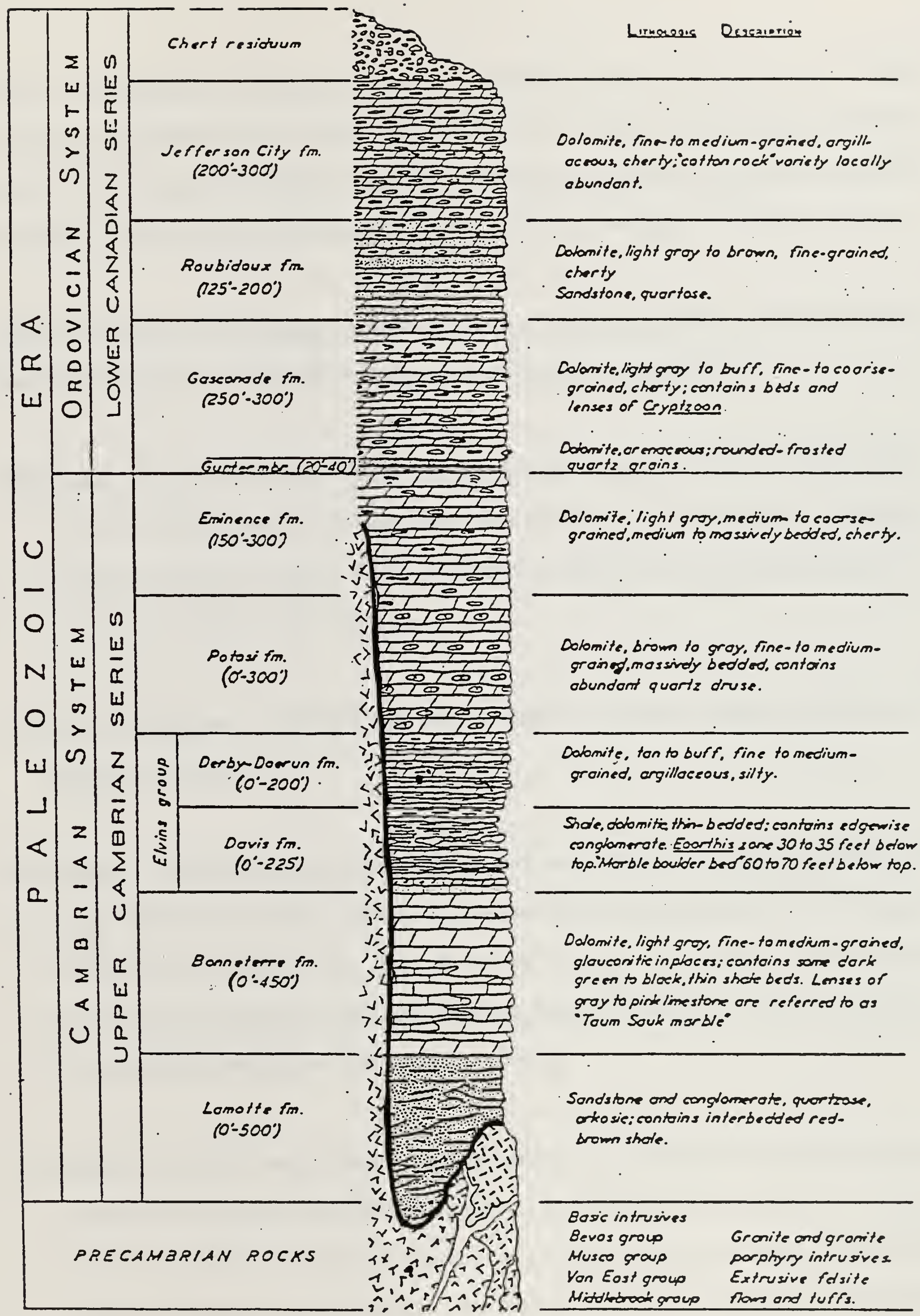


	Lithologic Description
Chert residuum	
Jefferson City fm. (200'-300')	Dolomite, fine-to medium-grained, argillaceous, cherty; "cotton rock" variety locally abundant.
Roubidoux fm. (125'-200')	Dolomite, light gray to brown, fine-grained, cherty Sandstone, quartose.
Gasconade fm. (250'-300')	Dolomite, light gray to buff, fine-to coarse-grained, cherty; contains beds and lenses of <u>Cryptzoon</u>.
Gunter mbr. (20'-40')	Dolomite, arenaceous; rounded-frosted quartz grains.
Eminence fm. (150'-300')	Dolomite, light gray, medium- to coarse-grained, medium to massively bedded, cherty.
Potosi fm. (0'-300')	Dolomite, brown to gray, fine-to medium-grained, massively bedded, contains abundant quartz druse.
Derby-Doerun fm. (0'-200')	Dolomite, tan to buff, fine to medium-grained, argillaceous, silty.
Davis fm. (0'-225')	Shale, dolomitic, thin-bedded; contains edgewise conglomerate. <u>Eoorthis</u> zone 30 to 35 feet below top. "Marble boulder bed" 60 to 70 feet below top.
Bonneterre fm. (0'-450')	Dolomite, light gray, fine-to medium-grained, glauconitic in places; contains some dark green to black, thin shale beds. Lenses of gray to pink limestone are referred to as "Taum Sauk marble"
Lamotte fm. (0'-500')	Sandstone and conglomerate, quartzose, arkosic; contains interbedded red-brown shale.
PRECAMBRIAN ROCKS	Basic intrusives Bevos group Musco group Van East group Middlebrook group Granite and granite porphyry intrusives. Extrusive felsite flows and tuffs.

FIGURE 9

Stratigraphic Column
(adapted from: Hardrock Minerals Leasing, Environmental Impact Statement)

pinnacles. The Precambrian topography was not completely buried by sediments until Middle Ordovician time (Missouri Geol. Survey, 1961; Warner et al., 1974). From Middle Ordovician through Pennsylvanian time the region underwent several periods of marine invasion and uplift that culminated in a massive erosion that once again exposed some of the higher Precambrian knobs.

Figure 9 displays the stratigraphic column as it exists in the petitioned area. From the top of the section downward, the sedimentary lithologies can generally be described as:

Residiuum: Depth of residiuum highly variable, usually ranging from 55 to 200 feet (Aley, 1975). Depths as great as 510 feet have been recorded in a well drilled by the Forest Service in Section 6, T27N, R3W, in Shannon County on the northern edge of the petitioned area (Aley, et al., 1972).

Jefferson City-Cotter: Light brown to brown, medium to finely crystalline dolomite and argillaceous dolomite.

Roubidoux: Interbedded complex of sandstone and sandy dolomite in the lower portion and sandy dolomite in the upper portion. Sandstone, thin- to medium-bedded, with abundant crossbedding and ripple marks is the dominant lithology. Some dense or oolitic cherts may be present. The deep weathering of the outcropping Roubidoux is responsible for the deep residiuum covering most of the petitioned area.

Gasconade: Massively bedded cherty dolomite with a 25 to 30 feet thick sandstone (Gunter member) near the base overlying an erosional unconformity representing the division between the Cambrian and the Ordovician. The Gunter, in the New Lead Belt area, is an arenaceous dolomite containing thin, discontinuous lenses of sandstone. In some areas,

there is a basal conglomerate containing pebbles from the underlying Eminence. The thickness of the Gunter ranges from approximately 2 to 25 feet. 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.

Eminence: Medium to massively bedded, medium to coarse-grained gray dolomite, with abundant chert. The upper part differs from the lower in that the more massive beds are contained in the lower with the upper beds being thinner and more uniform. The cherts occur both as beds and as irregular branching masses.

Potosi: The Potosi is often simplistically described as massively bedded, tan dolomite with abundant quartz in the upper part. Wagner (1961) divided the Potosi into three separate facies with distinct lithologies. These lithologies, in order of abundance, are algal reef rock, oolitic and other clastic carbonate beds, and dense carbonate slime beds. The subsurface thickness of the formation in the New Lead Belt area varies from 320 to 380 feet.

Elvins Group:

Derby-Doerun: Fine to medium crystalline dolomite with shale partings. The lower part is thickly bedded, massive, non-cherty dolomites with conspicuous crossbedding. The lower part is thinnly bedded, fine- to medium-grained, argillaceous dolomite. The thickness of the formation is highly variable but is approximately 120 feet throughout the New Lead Belt area.

Davis: The Davis is frequently referred to as the Davis Shale because it is the only notable shale horizon in the Cambro-Ordovician sequence of the Ozark region. However, it is actually consists of shales, siltstones, thin-bedded carbonates, mostly dolomitic, limestone conglomerate, and minor amounts of very fine-grained sandstone. On a regional basis, the Davis varies greatly in clastic content. Dake (1930) noted that the Davis contains much less shale in the vicinity of the porphry peaks. These are the areas where much of the mineralization is likely to occur in underlying rock units. The effect of the basement peaks and knobs on subsequent sedimentation is dramatically shown on the isopach map of the Elvins Group (Figure 10) for the northern border of the petitioned area. Sediments deposited over and around these sharp porphyry pinnacles are drastically thinned; some of the lower units may be absent. In the case of the Elvins Group, Figure 10 shows the sediments rapidly thinning from a thickness greater than 300 feet to a thickness of less than 25 feet. It is likely that the Davis is missing over and around these peaks and that, at most, only the Derby-Doe Run is present. These conditions must be expected to facilitate hydrologic interactions between the upper and lower aquifers. As previously stated, the highest Precambrian knobs were not covered during the Cambrian. Published control does not exist south of Winona and U. S. Highway 60 to enable the mapping of additional basement knobs and pinnacles, however, the fact that the knobs and pinnacles control to some extent the mineralization in the Bonneterre and that the companies are proposing mining activities south of U. S. Highway 60 implies that additional and similar pinnacles and knobs to those found in the New Lead Belt exist in the petitioned area.

Bonneterre: The Bonneterre is the host rock for the major lead-zinc deposits and 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

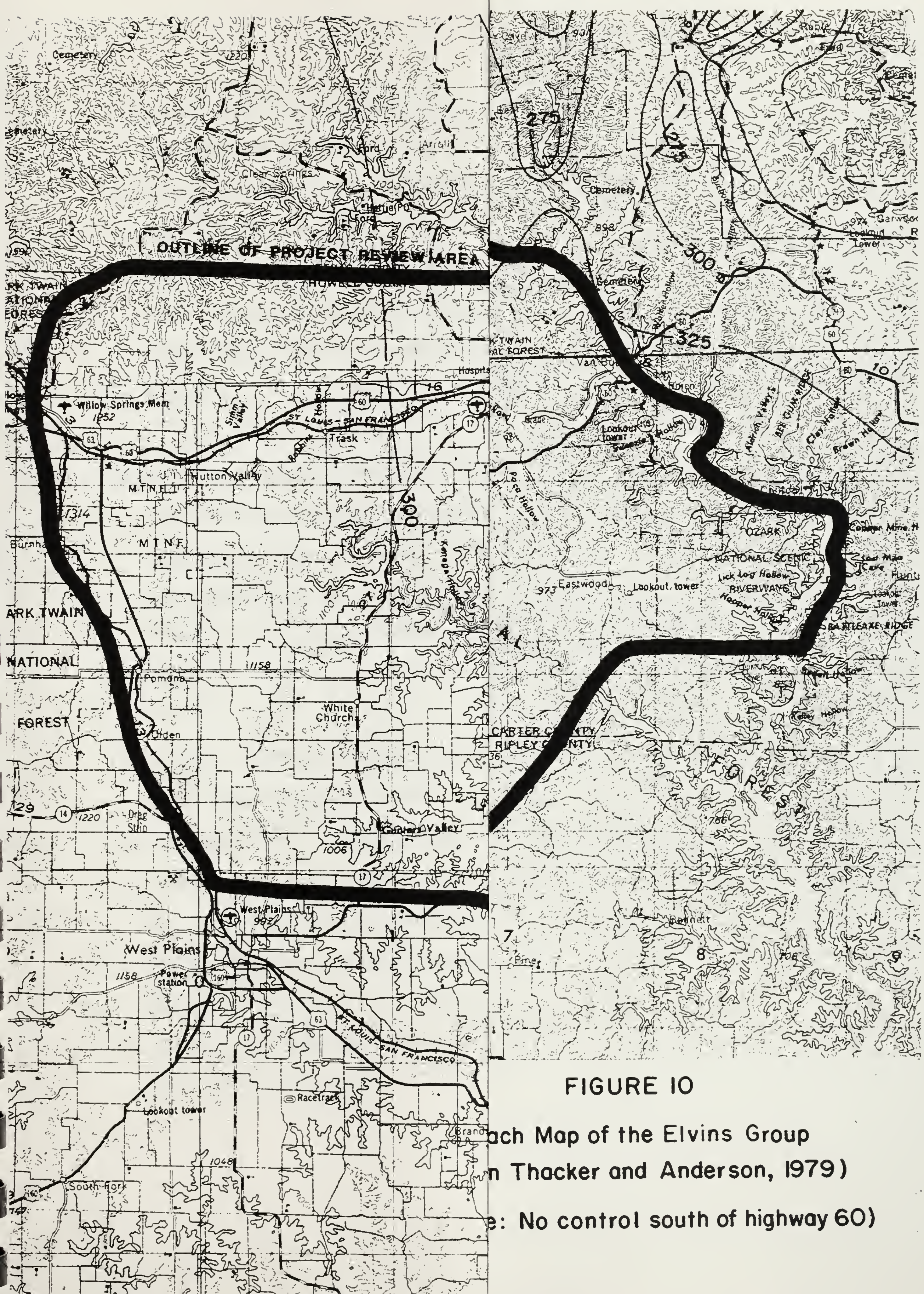


FIGURE 10

ach Map of the Elvins Group

n Thacker and Anderson, 1979)

e: No control south of highway 60)

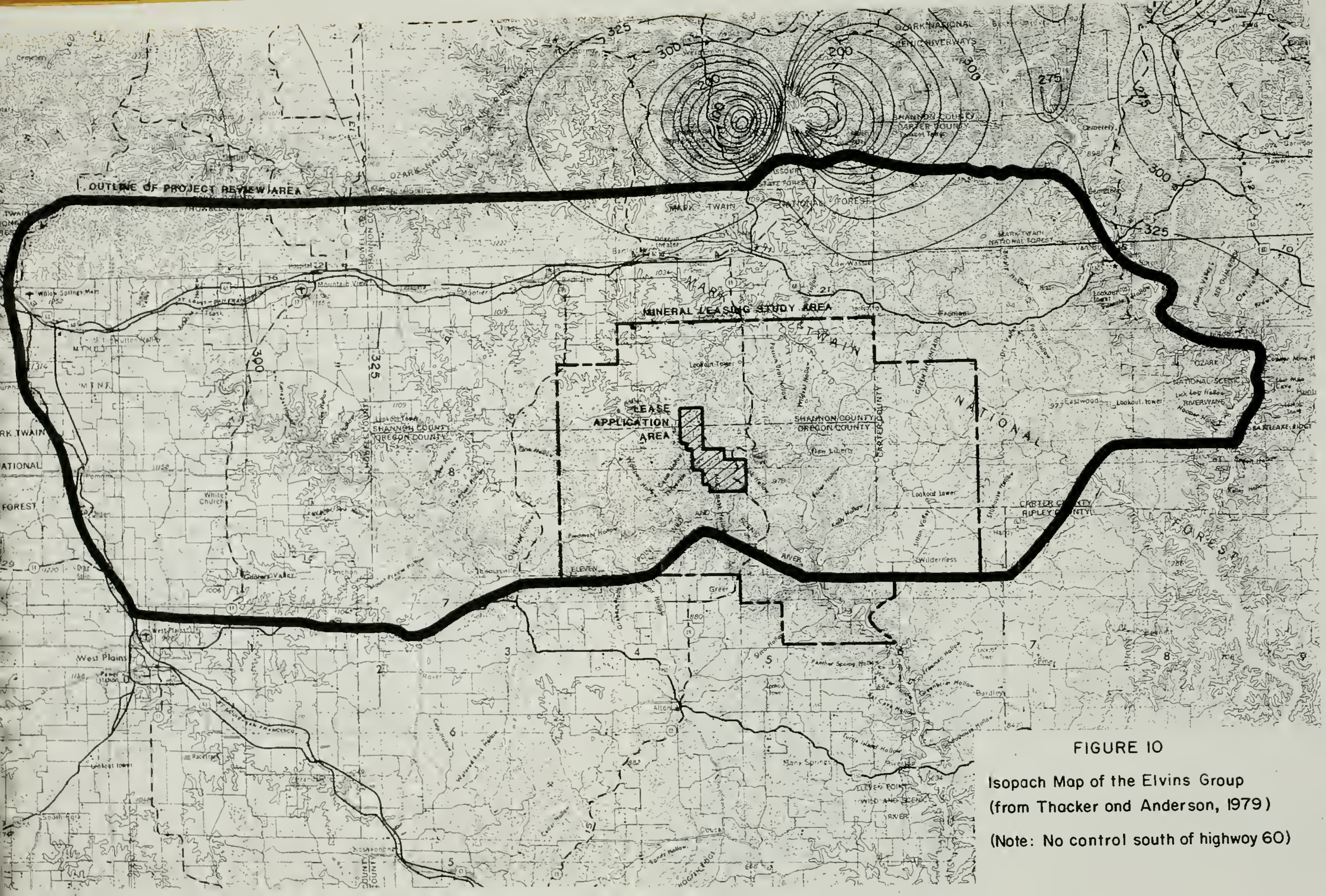


FIGURE 10

Isopach Map of the Elvins Group (from Thacker and Anderson, 1979)

(Note: No control south of highway 60)

with localized area of calcareous shale. Reefal structures were developed in the Bonnetere just offshore on the seaward (west) side of the exposed Precambrian pinnacles and knobs. These reef structures served as the host structure for the lead and zinc deposits of the New Lead Belt. The Bonneterre is characterized by a complex facies distribution which has been described by Warner et al. (1974), Gerdemann and Myers (1972), and Snyder and Odell (1958). The regional thickness of the Bonneterre ranges from 0.0 feet to approximately 150 feet over the Precambrian knobs to approximately 400 feet in the basins.

Lamotte: A quartzose sandstone, typically white or light gray. The lowermost part, in close proximity to the Precambrian knobs, grades laterally into arkose and felsite conglomerate. 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, pinching out against the Precambrian pinnacles.

Precambrian: Rhyolite porphry, granite porphry, and granite are the most prevalent Precambrian rocks in the region with rhyolite porphry being the most abundant. Both the granite and rhyolite porphries form the outcrop peaks where exposed. The rhyolite porphry is dense, with a noncrystalline groundmass, varies in color from red to black, and has small amounts of small phenocrysts of glassy quartz and pink orthoclase The rhyolite porphry has been interpreted by Dake (1930) to be extrusive. The granite porphry is pinkish in color with a crystalline groundmass and quartz and orthoclase phenocrysts between 3 and 8 millimeters being common. The granite porphry has been interpreted by Dake (1930) to be intrusive.

The New Lead Belt is characterized by high angle normal faults. There is a general lack of available data regarding the extent of faulting in the petitioned area; however, the lack of published details on faulting in the area is more a function of the deep residuum obscuring the faults than it is a lack of faulting. Dake (1930) observed throws in the field of from approximately 400 to 1,200 feet at the north end of the New Lead Belt in the Palmer Fault Zone. In the New Lead Belt the throws do not exceed 150 feet (Warner and others, 1974).

The fact that mining companies have identified portions of the petitioned zone as one of high and commercial grade mineralization indicates that significant faulting is probably present. "Mineralization resulted from circulation of warm brines through the porous reef structures after burial. The brines probably originated during the compaction and dewatering of metalliferous shales in deep parts of the basins to the south and east, but the *mechanisms involved in transporting* (emphasis added) the brines is not yet certain" (Hardrock Mineral Leasing, Draft EIS, 1987, p. 29). Faulting not only provides a means for ground water transport, it is very frequently the route taken by the highly mineralized waters which form many types of ore deposits. The presence of localized mineralization in this area makes it highly likely that substantial faulting exists.

A detailed mapping of the orientation of joints was conducted within the Hurricane Creek basin by Henry Hilliard 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 measured with a Brunton compass on 22 outcrops of the Gasconade and Roubidoux formations. Almost all the joints measured were vertical or nearly vertical with the major joint sets occurring at N60E, N78E and N10W. Two less prominent sets of joints were measured striking N45W and N78W. Figure 11 is a plot of the joint sets as measured by Hillard (from Aley, 1975).

Lineaments in this area are considered to be surface expressions of vertical or near vertical zones of fracturing and faulting extending to depth. Figure 12 is a composite of the major lineaments as identified by Aley (1975) and structure in the north of the petitioned area as mapped by Anderson (1979). The orientation of the lineaments and the orientation of the mapped faults are identical. No attempt was made by Aley (1975) to identify all lineaments; he identified only those that had a controlling effect on valley orientation. A detailed analysis of lineaments and the orientation of joint sets by Aley (1975) leads to the conclusion 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. Figure 13 is a table showing the relationship of sinkholes to lineaments and Figure 14 depicts the orientation of 85 sinkhole lineations in the petitioned area.

One of the largest sinkholes occurs in the Hurricane Creek basin and is approximately 1300 feet in diameter and about 80 feet deep. Other large sinkholes undoubtedly occur which affect ground water recharge but cannot be detected at the surface because they are rapidly obliterated by surface streams. The Sycamore Creek Sink, formed in 1966 adjacent to the channel of Sycamore Creek, was 25 feet in diameter and 60 feet deep. Within two years the sinkhole was filled with coarse alluvial material transported by the creek (Aley, 1975). In 1974, in the New Lead Belt, the U. S. Forest Service reported the development of a number of sinkholes in the vicinity of the AMAX mine (Warner and others, 1974). It is likely that these sinkholes are associated with groundwater level declines caused by mine pumping. One morning, at the Brushy Creek mine, a "litter of sinkholes" developed in the mine yard and a sinkhole 15 feet across and 10 feet deep developed in a main road. There are additional reports that the drilling of a ventilation shaft by St. Joe Lead at Viburnam dried up three springs in June and July of 1976. A Forest Service memorandum dated March 16, 1977 reports on a sinkhole collapse that had occurred on March 14th in the northbound lane of the Karkaghne Trail in Section 11, T33N, R2W, in Reynolds

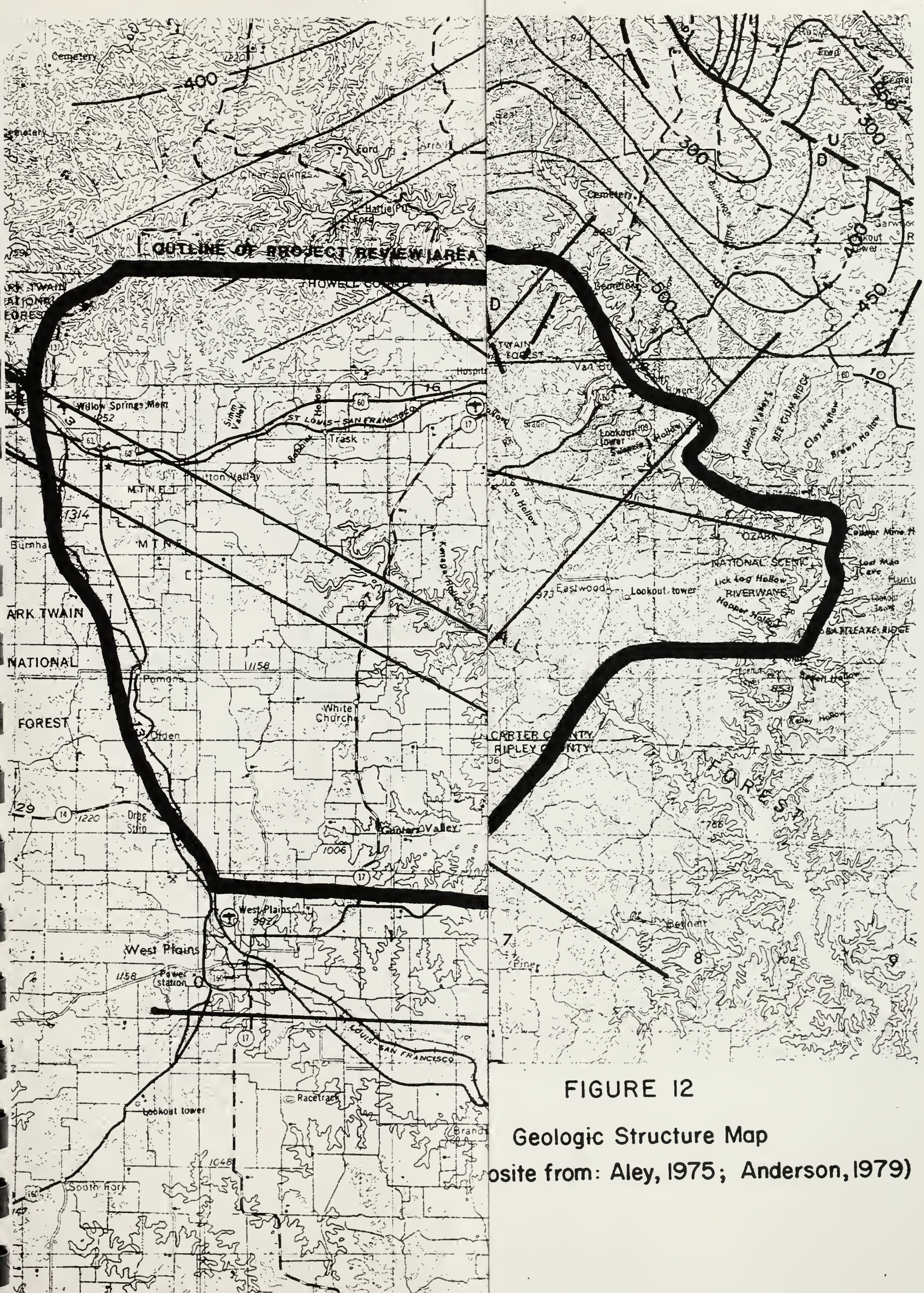


FIGURE 12

Geologic Structure Map

osite from: Aley, 1975; Anderson, 1979)

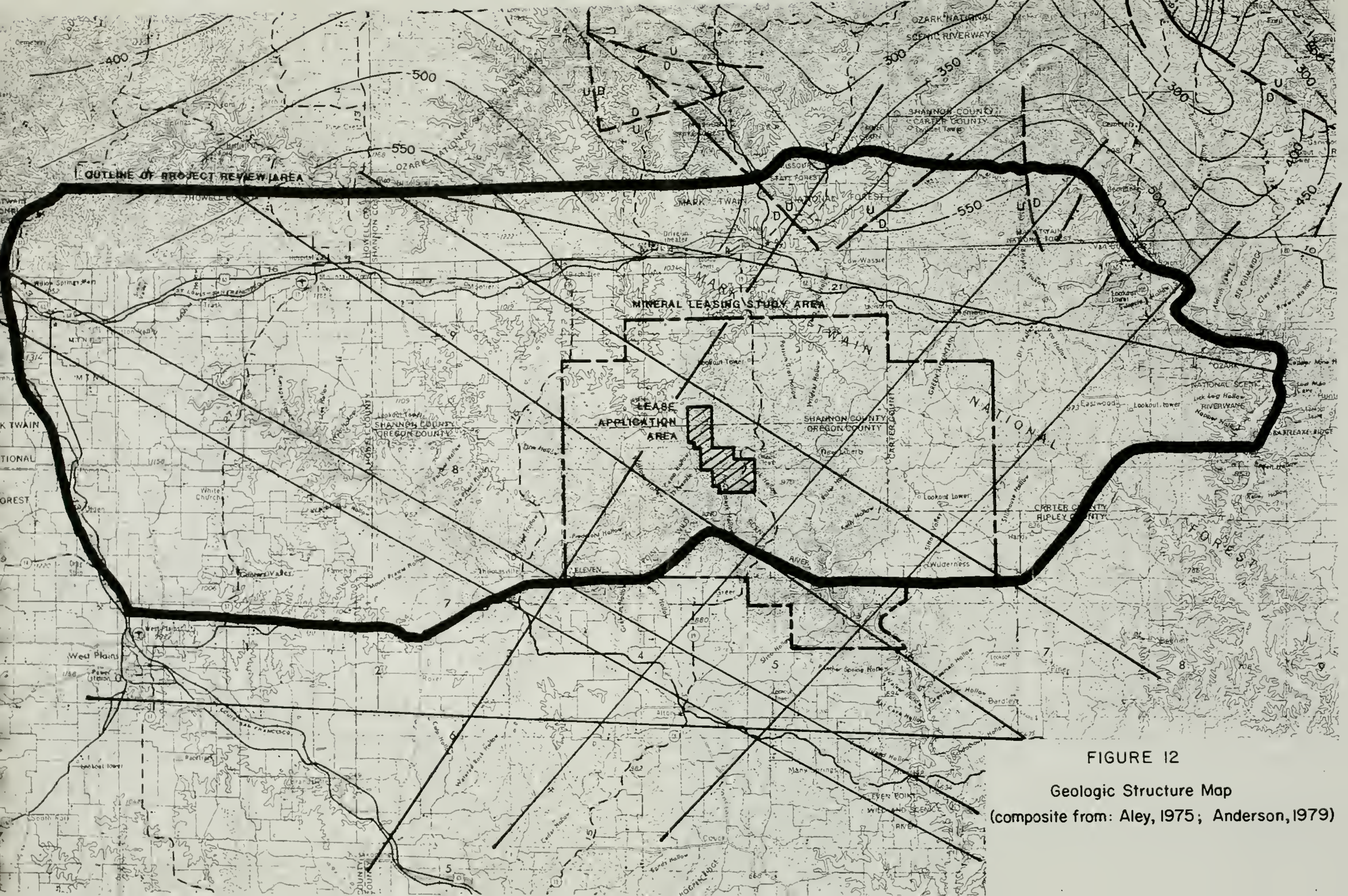


FIGURE 12

Geologic Structure Map
(composite from: Aley, 1975; Anderson, 1979)

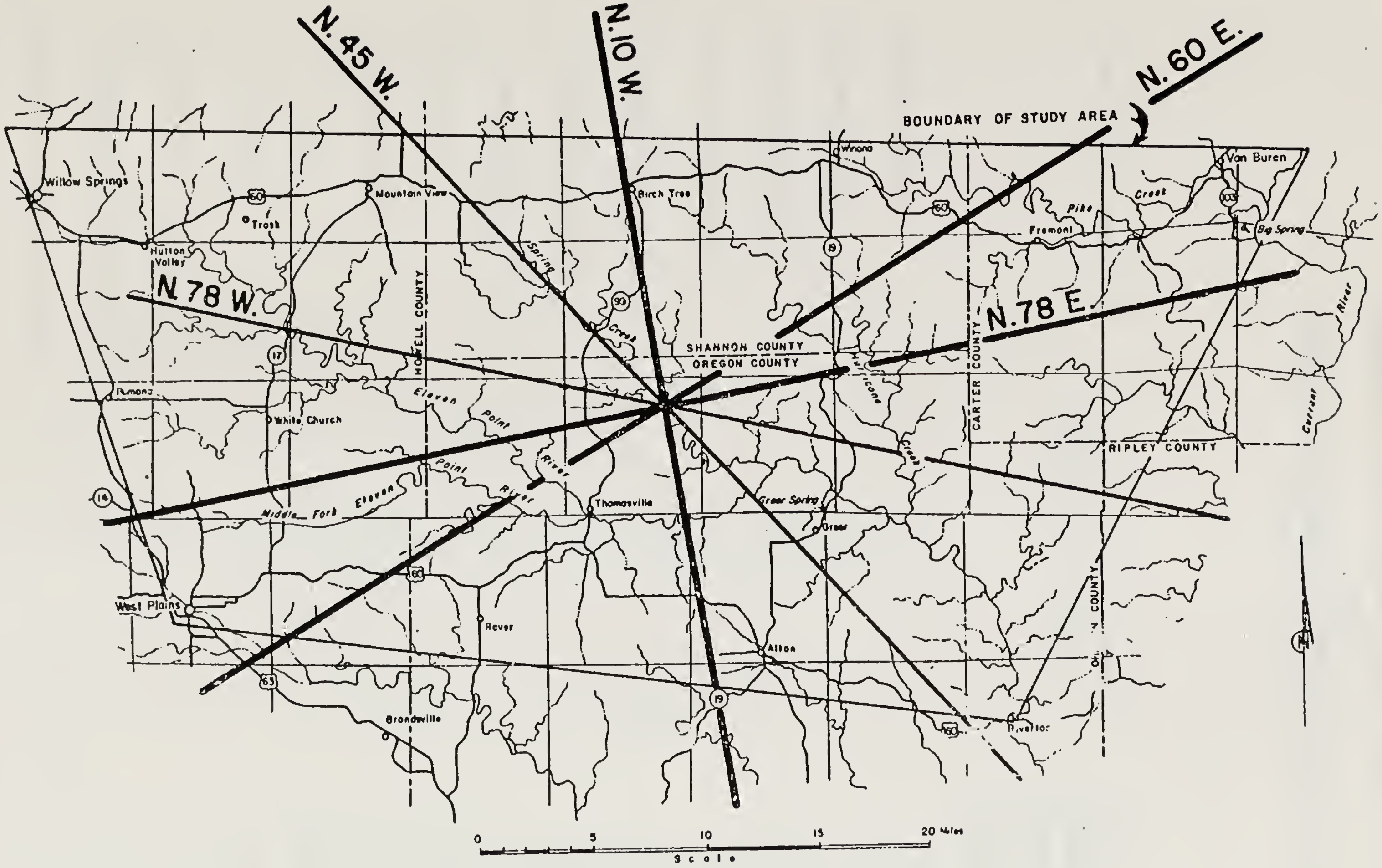


FIGURE 11

Joint Orientations Within the Petitioned Area

Heavier lines indicate more prominent joint sets

(from : Aley, 1975)

FIGURE 13

Relationship of Sinkholes to Lineamants in a 720 Square Mile Area West of Big Spring

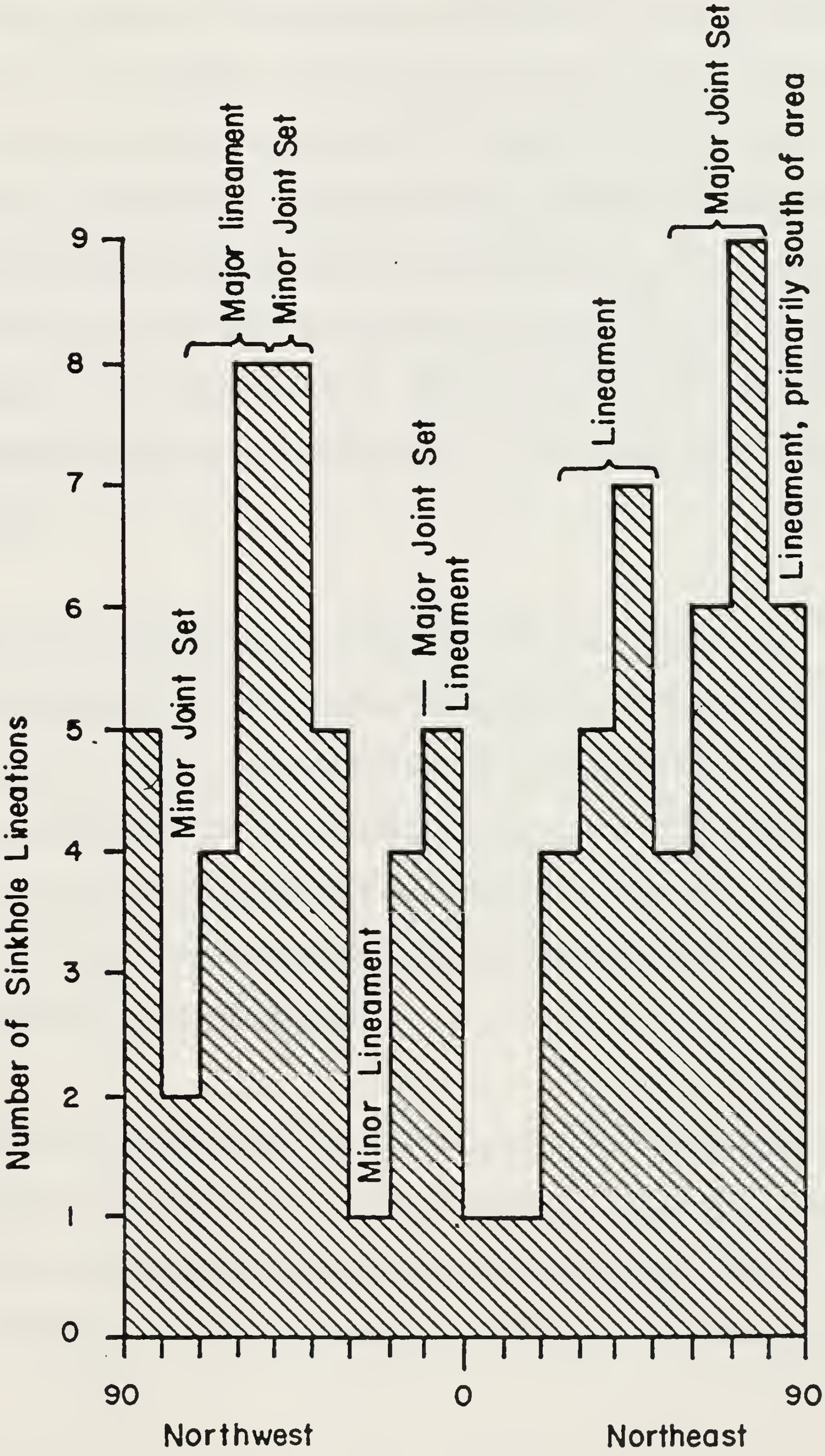
(from: Aley, 1975)

Name of Lineament	Length within measurement area (miles)	Number of sinkholes within 1/2 mile of lineament	Sinkholes per mile
Big Spring	26	12	0.46
Eleven Point	28	5	0.18
Blowing Spring	43	8	0.19
Hurricane Creek	36	28	0.78
Greer Spring No. 1	41	23	0.56
Greer Spring No. 2	31	20	0.65
Greer Spring No. 3	42	17	0.40
Winona	19	12	0.63
Pine Hollow	26	15	0.58
Total	292	140	--
Mean	32.4	15.6	0.49
Random traverse No. 1	29	21	0.72
Random traverse No. 2	18	5	0.28
Random traverse No. 3	26	20	0.77
Total	73.0	46.0	--
Mean	24.3	15.3	0.59

FIGURE 14

Histogram of the Orientation of 85 Sinkhole Lineations Within the Big Spring Recharge Area

(from: Aley, 1975)



County. The collapse may have been induced by dewatering activities at St. Joe's Brushy Creek mine one and one-half miles to the south of the collapse.

In 1987, a large sinkhole developed near the intersection of Highway 32 and the turnoff into the Cominco mine at Bixby, Missouri. At the same time, the local water table began to drop and by the summer of 1988 many of the Bixby wells had gone dry, pumps burned out, and elderly residents had to carry water to their homes in buckets. The sinkhole development and the drying up of the water wells was associated with the drilling of a mine ventilation shaft about one-half mile away. On July 15, 1988, citizens of Bixby told W. B. Creath that their water levels were still about 150 feet below what they were before the ventilation shaft was drilled. New wells had to be drilled and some existing wells had to be deepened. Wells now have to be about 450 feet deep, necessitating the purchase of larger pumps at great expense. The maintenance costs on the wells also had risen dramatically.

A visit was made to the site of the sinkhole on July 15, 1988. The sinkhole was an estimated 75 feet in diameter and approximately 30 feet deep. Of special interest was that the sinkhole was located at a drill site where the mining company had drilled an exploratory hole. No other sites were visited, but it was reported to Mr. Creath that there were many more sinkholes that had developed in the area that could be associated with mining activities and that many were at the sites of exploration drill holes. This has serious implications for mining related activities carried out in the aquifer system in the Big Spring recharge area.

According to information presented at the USX EIS Technical Team Meeting at Rolla, Missouri on September 13, 1988, the procedures for drilling and abandoning prospect holes are the following. An 8 inch to 9 inch hole is drilled from the surface through the Davis and the Bonneterre is cored. The hole is cased through the alluvium/residuum. A rubber plug is set and 20

to 30 feet of cement is poured to plug the Davis. The hole is them backfilled with drill cuttings. Another 20 to 30 foot cement plug is set at the top of the bedrock. If these procedures are currently being implemented in the New Lead Belt the system is evidently not working. There was no casing or cement plug evident at the Bixby sinkhole site.

Hydrology:

The Eleven Point River, originating near Willow Springs, is the only major river within the petitioned area. A small portion of the Current River forms the eastern boundary of the area; however, the Current River receives water from the aquifer rather than contributing to it. Figures15 depicts the topographic drainage basins and the locations of stream and spring gauging stations, some of which are no longer in operation. Figure 16 displays the flow data as recorded at those stations to 1974. Figure 17 is a location map of the major springs.

Figure 18 displays the relationship of groundwater recharge to groundwater discharge in the petitioned area and summarizes the conceptualized hydrologic model developed by Aley (1975). The pie diagram shows diffuse recharge as the major source for storage water and the discrete recharge from sinkholes, losing streams, and estavelles as the major source of the water in transit.

A number of the surface rivers and streams are losing streams, meaning they recharge waters into groundwater supplies. The mean annual flow per square mile on the Current River near Eminence is typically very close to the mean annual flow of all areas drained by the Eleven Point and Current Rivers in Missouri (Aley, 1975). Based on the water yield per square mile which occurred in 1969 at Eminence, water production for the Eleven Point River near Thomasville, if that basin had not recharged the groundwater system, should have equalled about 505 cfs rather than the 184 cfs as actually measured. Similarly, the mean water production for Hurricane Creek

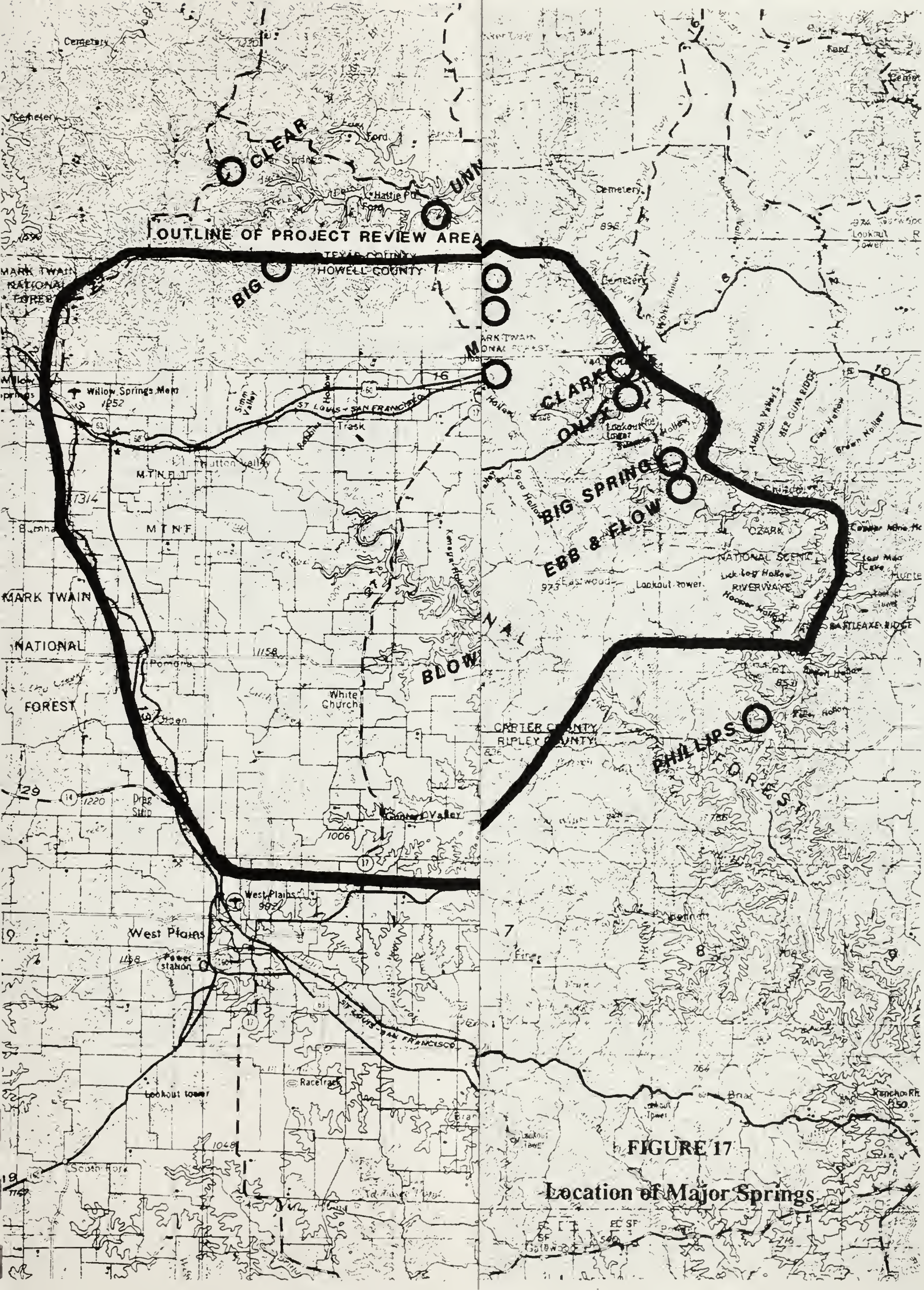


FIGURE 17

Location of Major Springs

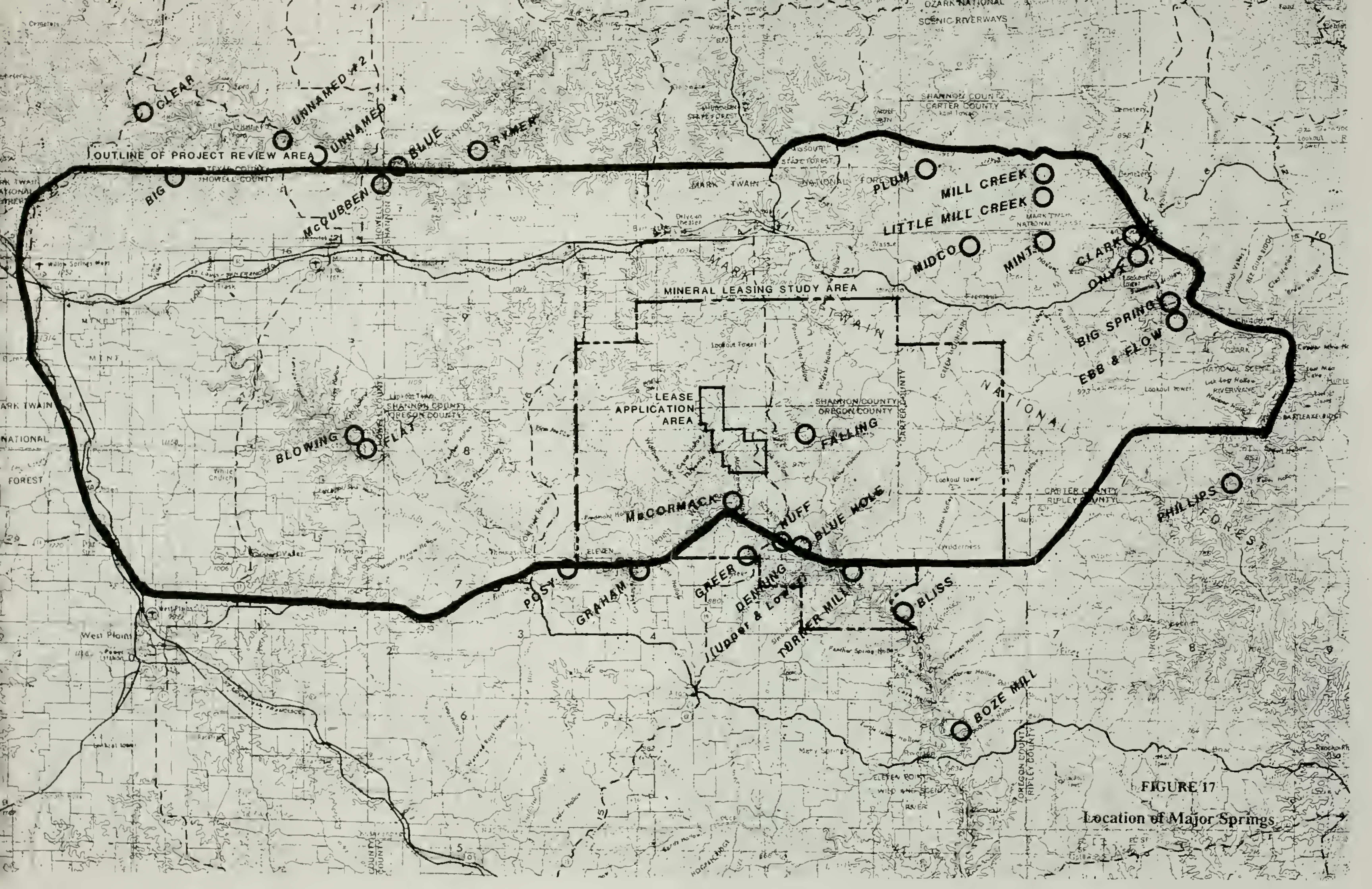
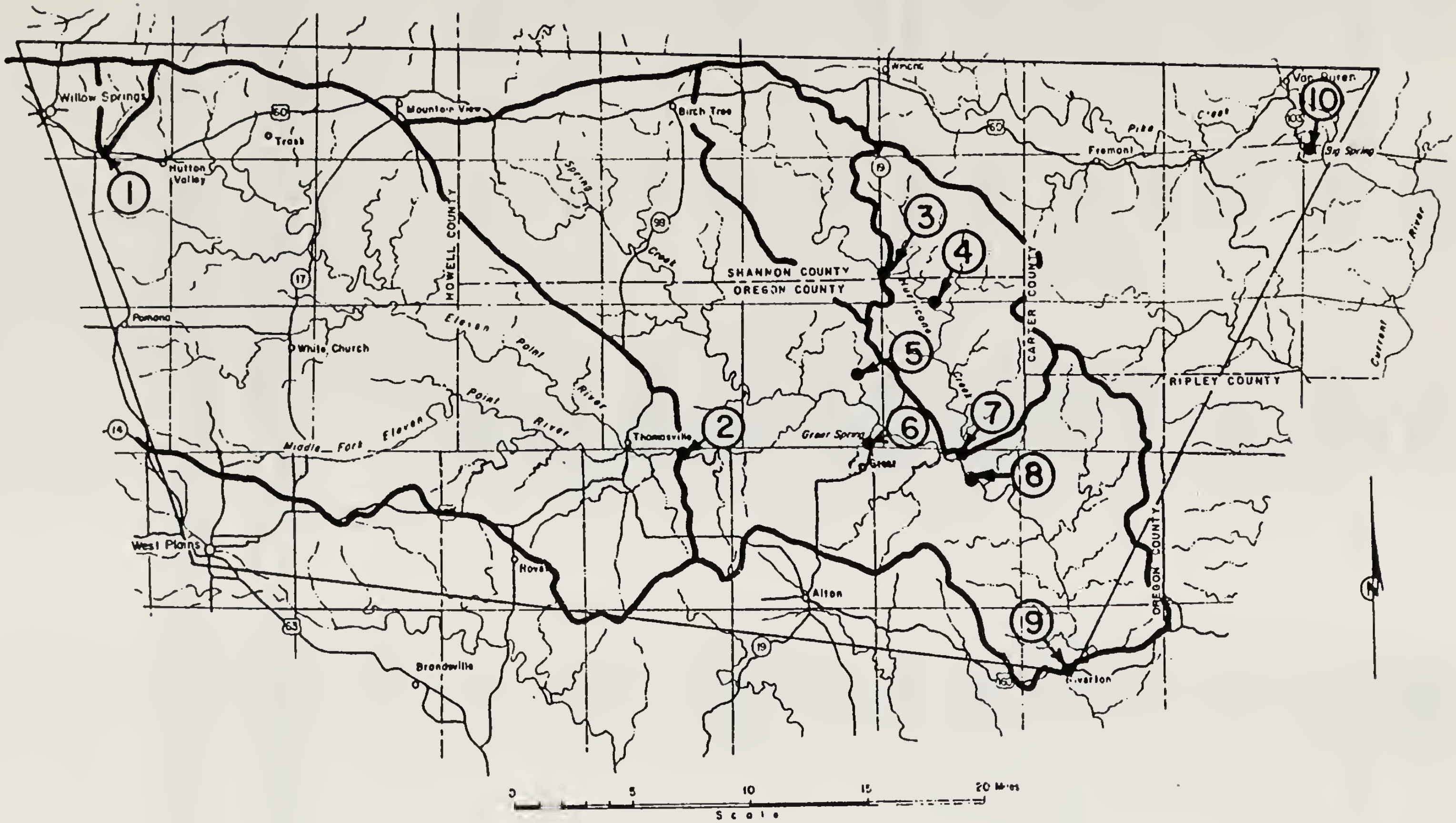


FIGURE 17

Location of Major Springs



1. Kings Creek near Willow Springs
2. Eleven Point near Thomasville
3. Hurricane Creek at Highway 19
4. Falling Spring
5. McCormack Spring
6. Greer Spring
7. Hurricane Creek at Weir
8. Turner Mill Spring
9. Eleven Point near Bradley
10. Big Spring

FIGURE 15

Topographic Drainage Basins and Location of Stream Gaging Stations
(from: Aley, 1975)

Figure 16
Stream and Spring Flow Gaging Stations Within The Petitioned Area

ation Name	Gaged by	Period of Record Used	Topgraphic Drainage Area sq. mi.	Mean Flow cfs *	Mean Flow inches
urricane Cr.	USFS	9/1/66 to Oct. 1973	112.8	24.5	2.83
cCormack Spr.	USFS	6/11/65 to Oct. 1973	--	1.76	--
lling Spr.	USFS	10/1/66 Oct. 1973	--	0.74	--
urner Mill Spr.	USFS	4/17/68 to Oct. 1973	--	13.05	--
urricane Cr. at lwy. 19 **	USFS	10/1/66 to Oct. 1973	53.8	2.19	0.55
even Point River r. Thomasville	USGS	Oct. 1950 to Oct. 1973	361	86.7	3.26
eer Sp.	USGS	Oct. 1921 to 1973	--	328	--
even Point River r. Bardley	USGS	Oct. 1921 to 1973	793	734	12.40
g Spring	USGS	Oct. 1921 to 1973	--	428	--
urrent River at Van Buren	USGS	Oct. 1921 to 1973	1,667	1,825	14.87
ngs Cr. nr. Willow Springs	USGS	9/55 to 11/67	4.91	0.60	1.66

SGS stations use data from USGS (1970).

Mean values as of 1973. 1973 was used as ending year since several of the stations ceased operation after that date.

urricane Creek at the Weir, Falling Spring, and McCormack Spring mean flows based on 7 year period from water year 1967 through ater year 1973.

urner Mill Spring mean flows based on 5 year period from water year 1969 through water year 1973.

Due to instrumentation problems, complete data are available only for water years 1970 through 1972; mean flows reflect this period.

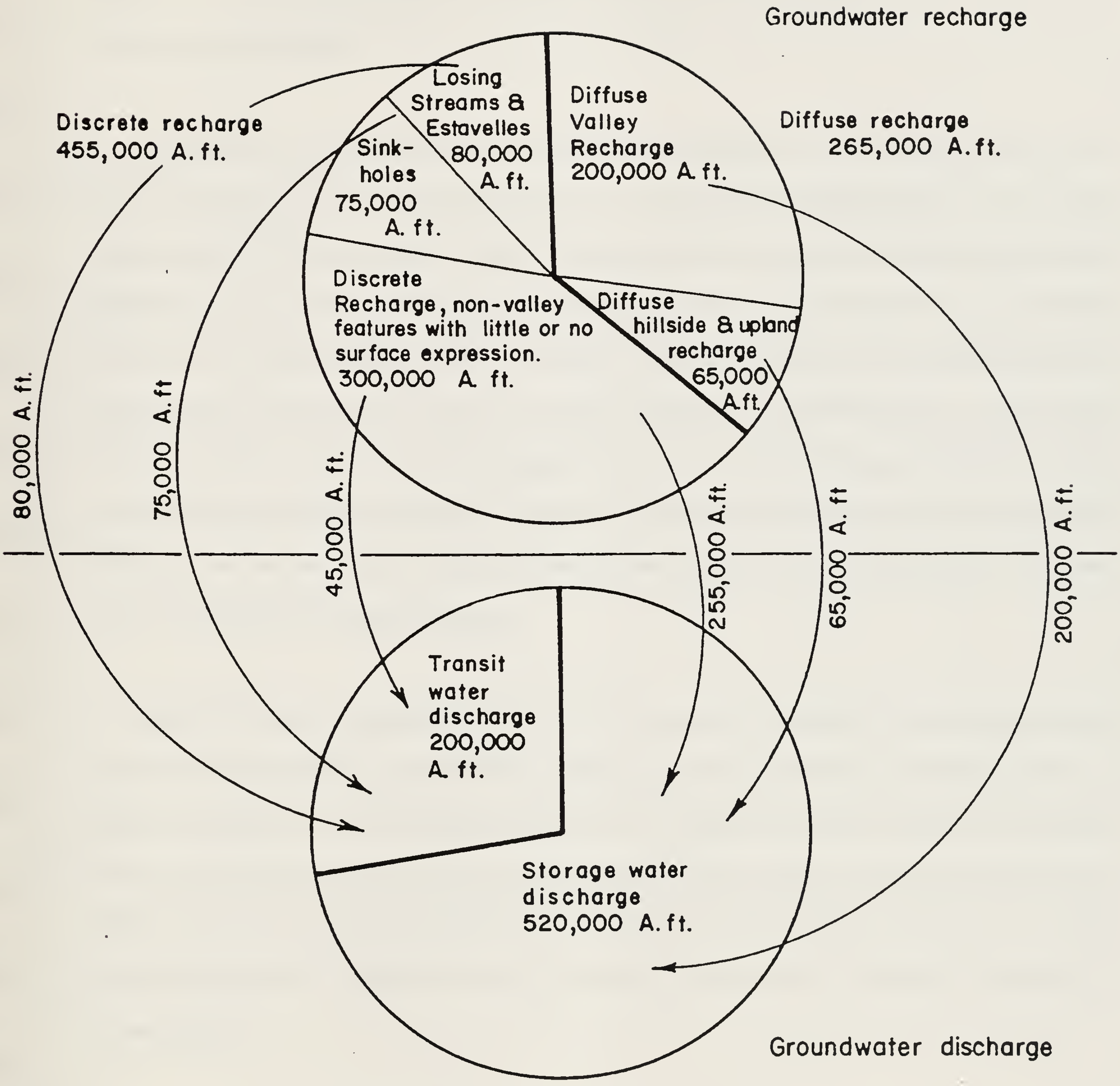


FIGURE 18

Relationship of Groundwater Recharge to Groundwater Discharge
(from: Aley, 1975)

should have equalled about 158 cfs rather than the 30.08 cfs as measured. These values are indicative of the substantial losses of surface waters into the groundwater systems taking place within the petitioned area.

The high rate of stream loss to the subsurface 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. Figure 19 is a table showing the close relationship between precipitation events and the peak daily flows at Big Spring and of the Current River at Van Buren. For 8 of the 15 storms recorded between November, 1968 and February, 1971, the peak daily flow of Big Spring occurred on the same day as the peak daily flow of the Current River at Van Buren and, for 4 of the 15 storms, Big Spring lagged only one day behind the peak daily flow of the Current River at Van Buren. Figure 20 compares flow records for three smaller streams and four springs in the petitioned area. A similar correspondence between dates of precipitation and peak flows on streams and springs is apparent.

Figures 21 and 22 graphically display the fact that at many springs in the petitioned area, as illustrated by Turner Mill Spring and Falling Spring, peak flows constitute a substantial portion of the total annual flow and further implies that discrete recharge is a major component of the spring flow. Figure 23 displays Aley's (1975) estimated mean annual recharge through both discrete and diffuse recharge zones within the petitioned area. Although diffuse recharge is dominant, it is vital to recognize that the considerable discrete recharge component is particularly sensitive to contamination.

The National Park Service is concerned about both the discrete recharge component and the diffuse recharge component as it affects the Ozark National Scenic Riverways. Figure 24 is a tabulation of the discharges of some of the more significant springs in and adjacent to the petitioned

FIGURE 19

Comparison of Dates of Peak Daily Flows at Big Spring and the Current River at Van Buren

(from: Aley, 1975)

Birch Tree Date	Precipitation Quantity (inches)	Date of Peak Daily Flow	
		Big Spring	Current River at Van Buren
11/1/68	1.07		
11/2/68	1.03		
11/3/68	1.15	11/3/68	11/2/68
11/26/68	0.40		
11/27/68	0.94		
11/28/68	0.75	11/28/68	11/27/68
12/27/68	2.43		
12/28/75	0.23	12/27/68	12/27/68
1/29/69	2.35	1/31/69	1/30/69
3/23/69	2.45		
3/24/69	0.38	3/25/69	3/25/69
4/9/69	1.53	4/9/69	4/10/69
3/1/70	0.20		
3/2/70	0.27		
3/3/70	0.26		
3/4/70	0.03	3/3/70	3/3/70
4/17/70	0.13		
4/18/70	1.46		
4/19/70	1.87	4/20/70	4/19/70
4/30/70	3.47	5/1/70	5/1/70
8/6/70	0.30		
8/7/70	0.22		
8/8/70	0.88		
8/9/70	3.53	8/9/70	8/9/70
10/12/70	0.20		
10/13/70	3.76	10/14/70	10/14/70

(Figure 19 continued)

Birch Tree Date	Precipitation Quantity (inches)	Date of Peak Daily Flow	
		Big Spring	Current River at Van Buren
10/26/70	0.54		
10/27/70	0.87		
10/28/70	0.37	10/28/70	10/28/70
1/3/71	0.86	1/4/71	1/5/71
1/13/71	1.28	1/15/71	1/15/71
2/21/71	0.82		
2/22/71	0.04	2/22/71	2/23/71

FIGURE 20

Effect of Rainstorm on Daily Discharge Rates at Four Springs and Three River Gaging Stations

(from: Aley, 1975)

Date 1967	Hurricane Cr.	McCormack Spr.	Falling Spr.	Big Spr.	Greer Spr.	Elev. Pt. Riv. nr. ThomasvL	Elev. Pt. Riv. nr. Bardley
12/20	9.95	3.22	0.67	570	418	71	976
12/21	177.7	4.21	2.23	700	490	2000	1600
12/22	89.99	6.00	3.50	850	573	1640	5120
12/23	78.93	6.00	1.91	800	568	550	2320
12/24	57.26	5.77	1.47	770	564	368	1760
12/25	43.79	5.29	1.12	740	555	288	1550
12/26	33.99	4.47	0.83	720	545	234	1380
12/27	28.66	3.80	0.64	690	532	201	1280
12/28	23.34	3.07	0.56	670	518	176	1200

Precipitation on the Hurricane Creek basin was as follows:

12/20	0.10 inches
12/21	2.16
12/27	0.09

Hurricane Creek: Rise began between 1815 and 1830 hrs. 12/21. Crest at 2030 hrs. 12/21.

Falling Springs: Rise began between 0600 and 0900 hrs. 12/21. Crest between 2000 and 2100 hrs. 12/21.

McCormack Spring: Rise began 0630 hrs. 12/21. Crest at 2220 hrs. 12/21. Crest stayed constant for 2 days.

FIGURE 21

Percent of Annual Flow During: 1) Peak Flow Date, 2) Five Highest Flow Dates, and 3) Ten Highest Flow Dates

(from: Aley, 1975)

Water Year	McCormack Spring	Falling Spring	Turner Mill Spring	Big Spring	Hurricane Cr. at Weir
			Peak Flow Date		
1967	2.1%	3.1%	*	0.6%	0.8%
1968	1.1	3.2	*	0.6	8.7
1969	0.9	3.1	6.7%	0.6	15.6
1970	1.4	5.2	6.3	0.6	3.6
1971	0.9	2.3	2.9	0.5	1.0
1972	1.8	5.3	9.4	0.6	4.7
1973	0.8	1.9	3.4	0.5	3.8
			Five Highest Flow Dates		
1967	8.7%	11.0%	*	3.1%	3.7%
1968	4.8	13.9	*	2.7	20.4
1969	4.0	10.9	21.7%	2.7	25.0
1970	7.2	20.7	17.7	2.7	16.7
1971	4.5	8.7	7.9	2.4	4.5
1972	8.7	19.2	28.0	3.1	16.8
1973	3.3	7.9	13.8	2.3	14.0
			Ten Highest Flow Dates		
1967	14.5%	17.5%	*	5.6%	6.9%
1968	9.3	22.8	*	5.1	30.4
1969	7.6	19.1	29.8%	5.0	32.7
1970	14.2	30.7	24.3	5.3	28.5
1971	8.8	14.1	13.1	4.5	7.9
1972	17.1	30.5	35.1	5.9	29.3
1973	5.8	13.9	23.0	4.6	21.3

* The gaging station at Turner Mill Spring was not in operation until April, 1968.

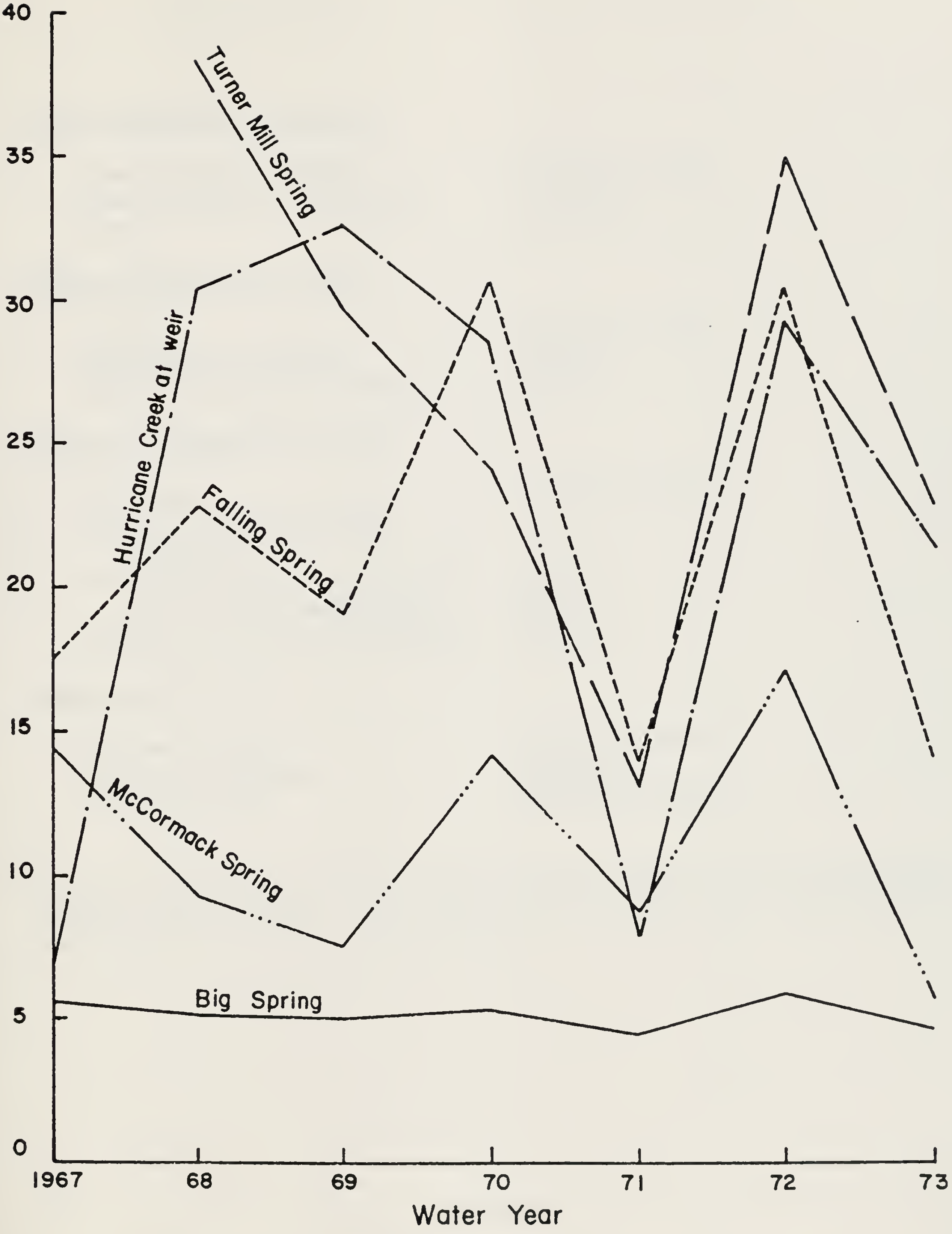


FIGURE 22

Percent of Total Annual Flow at Five Gaging Stations
Occurring on Ten Highest Flow Dates
(from: Aley, 1975)

Total Groundwater Recharge

Mean annual springflow	720,000 acre feet
Mean annual well extraction	1,500 *
Total	720,000 acre feet *

Diffuse Recharge (per year)

Valleys	200,000 acre feet
Hillsides and Uplands	65,000
Subtotal for diffuse recharge	265,000

Discrete Recharge (per year)

Sinkholes	75,000 acre feet
Losing streams including estavelles	80,000
Non-valley features with little or no surface expression	300,000
Subtotal for discrete recharge	455,000

Summary (per year)

Diffuse recharge	265,000 acre feet
Discrete recharge	455,000
Total recharge	720,000 acre feet

* 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 acre feet per year.

FIGURE 23

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

Figure 24

Discharges of Springs In and Adjecent to Petitioned Area
(from: Springs of Missouri, J.D. Vineyard and others, 1982)

ring	Country	Location	Rate of Flow cfs	Measurement Date
g Spring	Carter	SE, NW Sec. 6, 26N, 1E	438.00	* mean for 63 yrs of record from 1921-1984
g Spring	Howell	SW, NW Sec.4, 27N, 8W	1.41	6-6-66
iss	Oregon	NW, NE Sec. 18, 24N, 2W	0.80	9-20-64
owing	Howell	NW, NE Sec. 11, 25N, 7W	0.98	6-6-66
uehole	Oregon	NW, SW Sec. 32, 25N, 3W	8.84	10-18-46
ze Mill	Oregon	SE, SE Sec. 9, 23N, 2W	23.00 (10)	* 1925-1966
ark	Carter	SW, SW SEc. 23, 27N, 1W	0.57	10-24-63
ear	Texas	SE, NE Sec. 19, 28N, 8W	0.89	12-3-35
enning (upper)	Oregon	SW, SE Sec. 32, 25N, 3W	3.06	10-18-46
nning (lower)	Oregon	SE, SW Sec. 32, 25N, 3W	7.38	10-18-46
b and Flow	Carter	NW, SE Sec. 6, 26N, 1E	0.41	5-19-39
lling	Oregon	NW, NW Sec. 4, 25N, 3W	0.74	* mean flow water yrs. 1967-1973
at	Howell	SE, NW Sec. 12, 25N, 7W	0.31	6-6-66
aham	Oregon	NE, Sec. 6, 24N, 4W	0.30	8-15-25
reer	Oregon	SE, SW Sec. 36, 25N, 4W	334.00	* mean for 63 yrs of record from 1921-1984
uff	Oregon	SE, SE Sec. 31, 25N, 3W	0.78	10-18-46
tle Mill Creek	Carter	SW, NE Sec. 7, 27N, 1W	0.82	10-25-63
cCormack	Oregon	SE, NE Sec. 23, 25N, 4W	1.76	* mean flow water yrs. 1967-1973
cCubben	Shannon	NW, Sec. 6, 27N, 6W	2.37	9-25-27
idco	Carter	SE, SE Sec. 22, 27N, 2W	2.70	6-23-28
ll Creek	Carter	NW, SE Sec. 6, 27N, 1W	40.40	11-20-42
hillips	Carter	NW, SE Sec. 15, 25N, 1E	8.81	8-15-25
osy	Oregon	NE, NE Sec. 3, 24N, 5W	1.89 (17)	1950-1963
ymer	Shannon	NE, NE Sec. 35, 28N, 6W	0.24	12-1-64
urner Mill	Oregon	NE, SE Sec. 3, 24N, 3W	13.1	* mean flow water yrs. 1969-1973
nnamed #1	Texas	NW, NE Sec. 29, 28N, 7W	.07	8-22-64
nnamed #2	Texas	NW, Sec. 34, 28N, 7W	.01	8-23-64

Mean value. Number of measurements shown in parenthesis.

area. Figures 25 through 42 depict and compare the estimates of storage water and transit water for five area springs for the period water year 1967-1973. The mean annual transit water discharge from the smaller springs (Falling, McCormack, and Turner Mill) is about 62% of their total discharge. Big Spring is characterized by a mean annual transit water discharge of about 22% of its total discharge. These data indicate that transit water discharge is about 2.8 times greater for the smaller springs than for the larger springs. Storage water discharge is about 78% of mean annual discharge for the larger springs; it is about 38% for the smaller springs. Thus, storage water discharge is twice as great for the larger springs than for the smaller springs.

Water in transit is much more subject to contamination and pollution hazards than is water in storage because:

1. Discrete recharge is more important in the replenishment of water in transit than it is in replenishing water in storage. Discrete recharge typically provides less effective adsorption and filtration than diffuse recharge.

2. Travel rates are more rapid; there is less time for bacterial and viral decay.

3. Effective filtration and adsorption within the conduits transporting the waters in transit are undependable and unlikely.

Pollutants entering the rapid transit conduit system will enter the waters feeding the National Ozark Scenic Riverways in the shortest possible time. However, once the source of pollution is corrected, the pollutants can be expected to flush through the groundwater system in a relatively short time. Those pollutants that enter the water in storage component will take longer to appear but will affect water quality for a prolonged period of time until pollutant sources are removed and

Month	Falling Spring	McCormack Spring	Turner Mill Spring	Greer Spring	Big Spring
Oct.	49.6	34.0	20.8	5.2	5.6
Nov.	72.3	73.8	68.9	28.3	22.8
Dec.	77.9	72.7	63.1	33.7	29.6
Jan.	72.2	67.7	70.7	32.5	29.5
Feb.	66.2	68.8	49.2	31.5	29.6
Mar.	69.4	65.8	64.3	28.4	26.6
Apr.	76.5	73.8	81.4	34.3	36.8
May	64.8	69.3	60.0	31.3	33.0
June	35.2	47.0	16.1	11.5	12.4
July	7.0	22.8	9.8	1.6	3.8
Aug.	7.4	25.5	6.5	2.9	4.0
Sept.	3.2	7.6	0.0	2.1	0.0
Year*	63.5	61.4	57.7	21.9	21.5

* Yearly percentage values are as calculated earlier in this chapter. They are derived from mean flow volumes for the seven-year (or in the case of Turner Mill Spring five-year) period. They are not an arithmetic mean of percentages.

FIGURE 25

Comparison of Mean Monthly Values for the Percent of Transit Water at Five Springs in the Petitioned Area
(from: Aley, 1975)

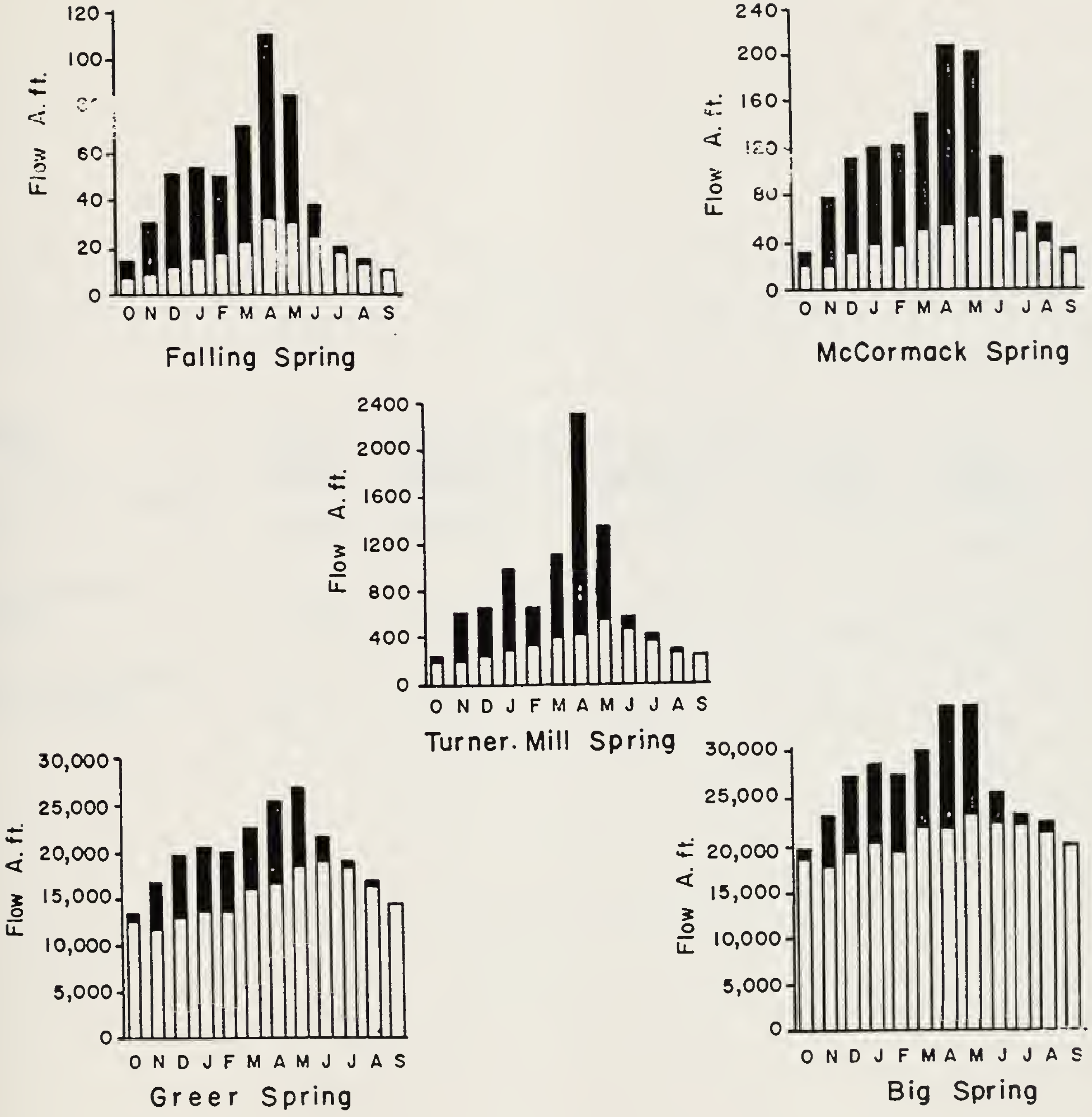


FIGURE 26

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)

Period	Falling Spring	McCormack Springs	Turner Mill Spring	Greer Spring	Big Spring
November through May	93.5%	88.0%	96.3%	91.7%	91.1%
June through October	6.5%	12.0%	3.7%	8.3%	8.9%
Data derived from Table number	4-5	4-8	4-10	4-12	4-14

FIGURE 27

Seasonal Distribution of Transit Water Discharge
at Five Gaged Springs

Values are percentages of mean annual transit water discharge for each spring

(from: Aley, 1975)

Water Year	Total annual flow A. ft.	Storage water A. ft.	Transit water A. ft.	Percent transit water
1967	182	107	75	41.2
1968	569	191	378	66.4
1969	617	291	326	52.8
1970	356	146	210	59.0
1971	522	202	320	61.3
1972	336	138	198	58.9
1973	1179	297	882	74.8
Mean	537	196	341	63.5*

* Mean percent of transit water is calculated from the mean values for the seven-year period and not as an arithmetic mean of percentages. Therefore, 341 A. ft. /537 A. ft. = 63.5%.

FIGURE 28

Falling Spring - Mean Monthly Estimates of Storage Water, Transit Water, and Total Spring Discharge for the Period Water Years 1967 - 1973 (from: Aley, 1975)

Month	Mean total flow A. ft.	Mean storage water A. ft.	Mean transit water A. ft.	Mean % transit water
Oct.	13.5	6.8	6.7	49.6
Nov.	29.2	8.1	21.1	72.3
Dec.	50.3	11.1	39.2	77.9
Jan.	52.6	14.6	38.0	72.2
Feb.	48.8	16.5	32.3	66.2
Mar.	70.3	21.5	48.8	69.4
Apr.	109.8	25.8	84.0	76.5
May	83.8	29.5	54.3	64.8
June	36.6	23.7	12.9	35.2
July	18.6	17.3	1.3	7.0
Aug.	13.5	12.5	1.0	7.4
Sept.	9.4	9.1	0.3	3.2
Year*	537	196	341	63.5

* Yearly values from Table 4-4. Because of rounding, the sum of monthly values may not exactly equal the totals.

FIGURE 29

Falling Spring - Mean Monthly Estimates of Storage Water, Transit Water, and Total Spring Discharge for the Period Water Years 1967 - 1973
(from: Aley, 1975)

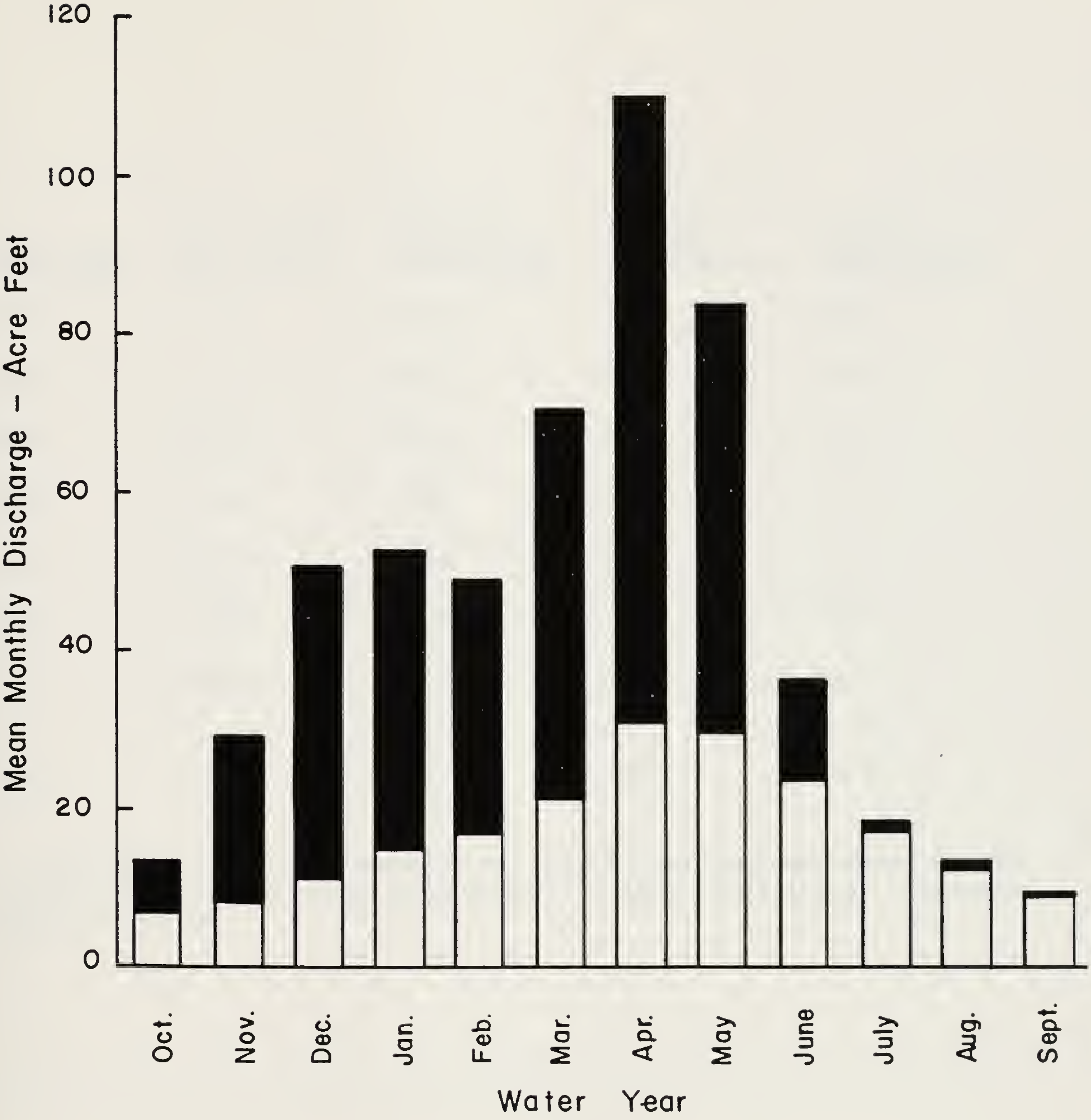


FIGURE 30

Falling Spring - Histogram of Mean Monthly Estimates of Storage Water, Transit Water, and Total Spring Discharge for the Period Water Years 1967 - 1973

Lower light segment of bar represents storage water; upper dark segment represents transit water

(from: Aley, 1975)

Water Year	Total annual flow A. ft.	Storage water A. ft.	Transit water A. ft.	Percent transit water
1967	370	190	180	48.6
1968	1400	500	900	64.3
1969	1780	870	910	51.1
1970	870	460	410	47.1
1971	1290	530	760	58.9
1972	680	340	340	50.0
1973	2530	570	1960	77.5
Mean	1270	490	780	61.4*

* Mean percent of transit water is calculated from the mean values for the seven-year period and not as an arithmetic mean of percentages. Therefore, 780/1270 = 61.4%.

FIGURE 31

McCormack Spring - Annual Estimates of Storage Water and Transit Water for the Period Water Years 1967 - 1973
(from: Aley, 1975)

Month	Mean total flow A. ft.	Mean storage water A. ft.	Mean transit water A. ft.	Mean % transit water
Oct.	31.8	21.0	10.8	34.0
Nov.	76.2	20.0	56.2	73.8
Dec.	111.4	30.4	81.0	72.7
Jan.	120.2	38.8	81.4	67.7
Feb.	120.1	37.5	82.6	68.8
Mar.	147.8	50.6	97.2	65.8
Apr.	208.0	54.6	153.4	73.8
May	201.1	61.7	139.4	69.3
June	112.2	59.5	52.7	47.0
July	63.2	48.8	14.4	22.8
Aug.	53.0	39.5	13.5	25.5
Sept.	32.8	30.3	2.5	7.6
Year*	1270	490	780	61.4

* Yearly values from Table 4-7. Because of rounding, the sum of monthly values may not exactly equal the totals.

FIGURE 32

McCormack Spring - Mean Monthly Estimates of Storage Water, Transit Water, and Total Spring Discharge for the Period Water Years 1967 - 1973
(from: Aley, 1975)

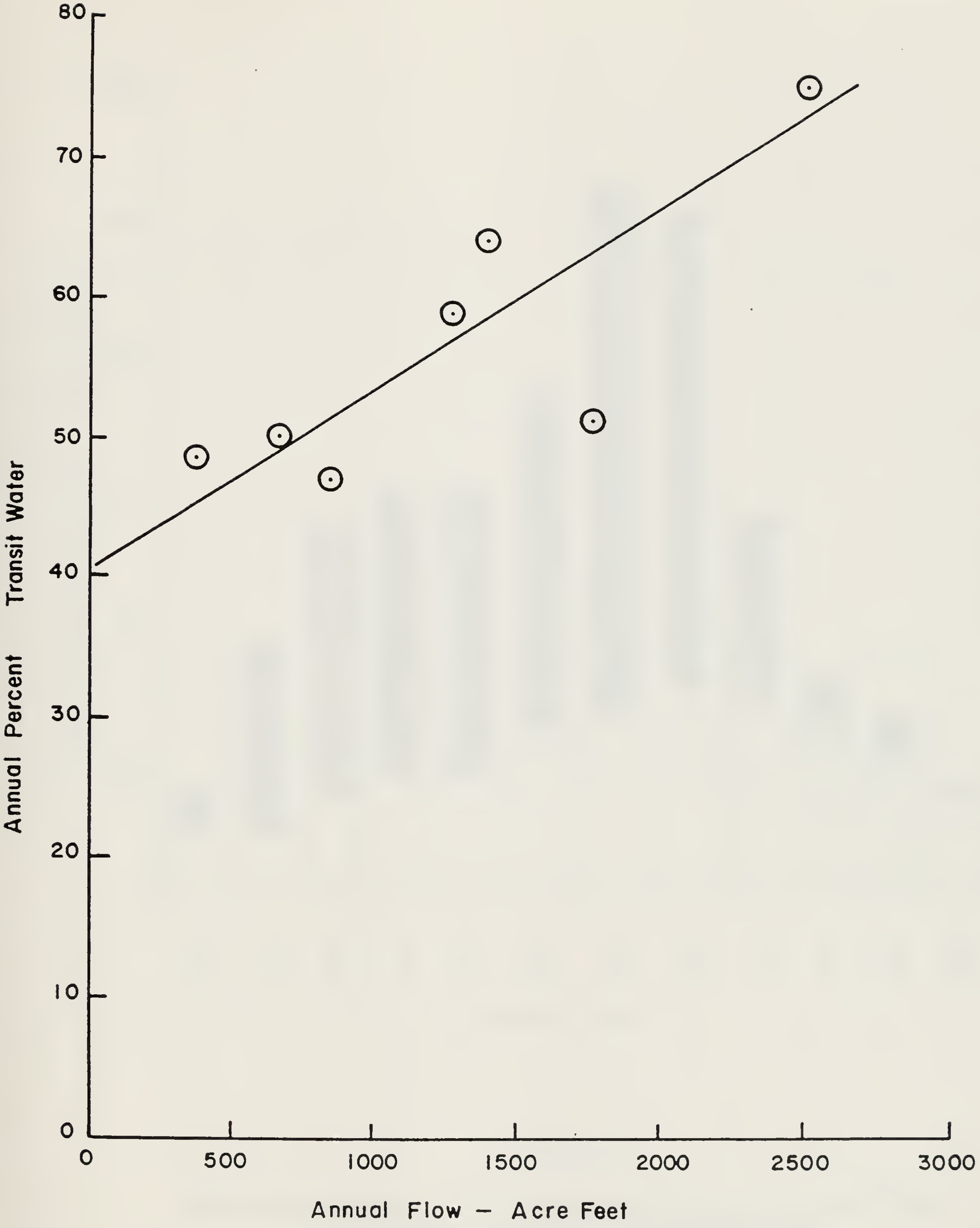


FIGURE 33

McCormack Spring - Relationship Between the Percent of Transit Water
and Total Annual Flow for the Period Water Years 1967 - 1973
(from: Aley, 1975)

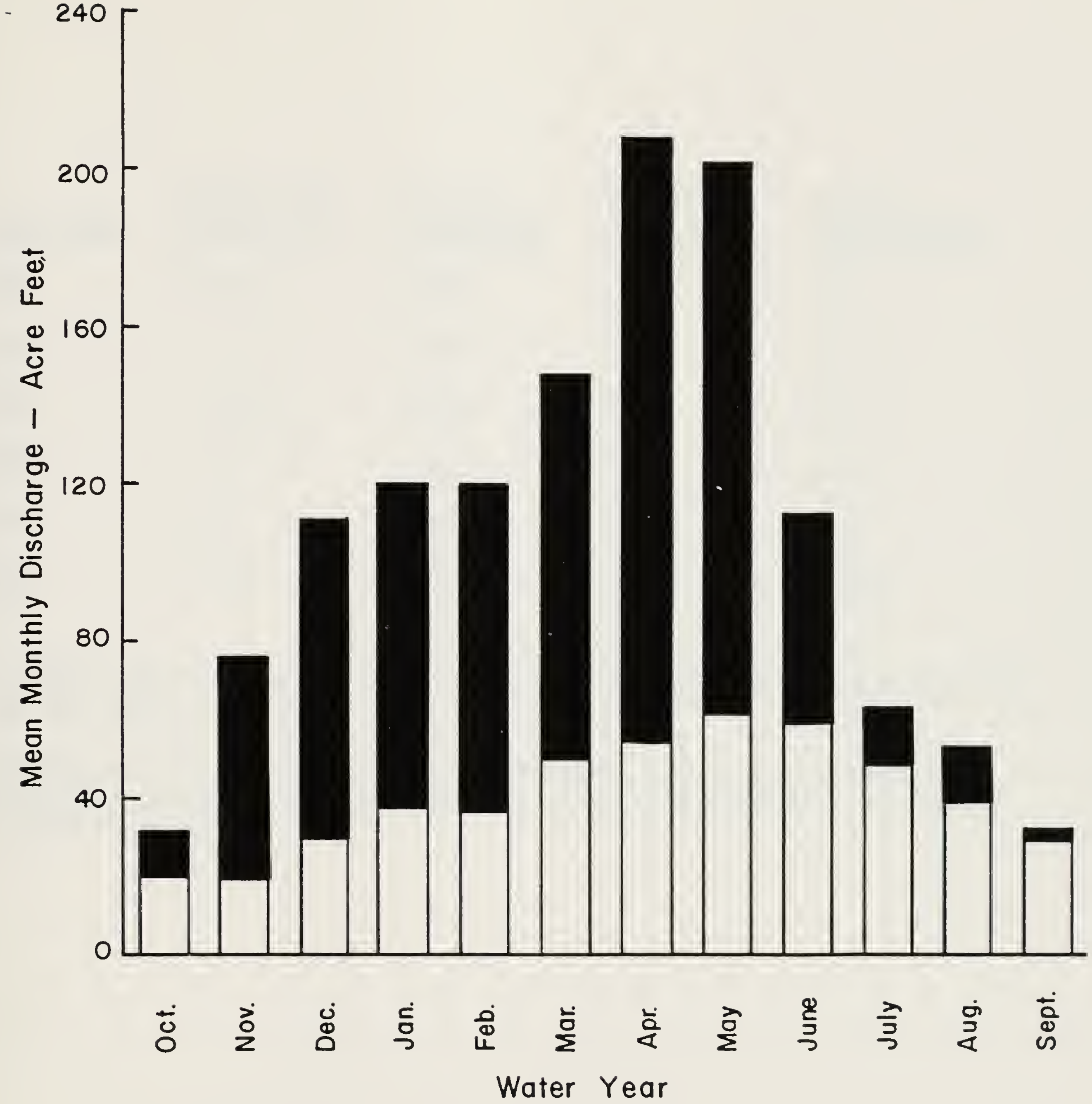


FIGURE 34

McCormack Spring - Mean Monthly Estimates of Storage Water, Transit Water, and Total Spring Discharge for the Period Water Years 1967 - 1973

Lower light segment of bar represents storage water; upper dark segment represents transit water

(from: Aley, 1975)

Water Year	Total annual flow A. ft.	Storage water A. ft.	Transit water A. ft.	Percent transit water
1969	10,750	4,670	6,080	56.6
1970	4,710	2,670	2,040	43.3
1971	5,500	3,230	2,270	41.3
1972	4,760	2,430	2,330	48.9
1973	21,440	6,960	14,480	67.5
Mean	9,430	3,990	5,440	57.7**

* Station began operation during water year 1968; the first complete year of data was water year 1969.

** Mean percent of transit water is calculated from the mean value for the five-year period and not as an arithmetic mean of percentages. Therefore, 5440/9430 = 57.7%.

FIGURE 35

Turner Mill Spring - Annual Estimates of Storage Water and Transit Water for the Period Water Years 1967 - 1973
(from: Aley, 1975)

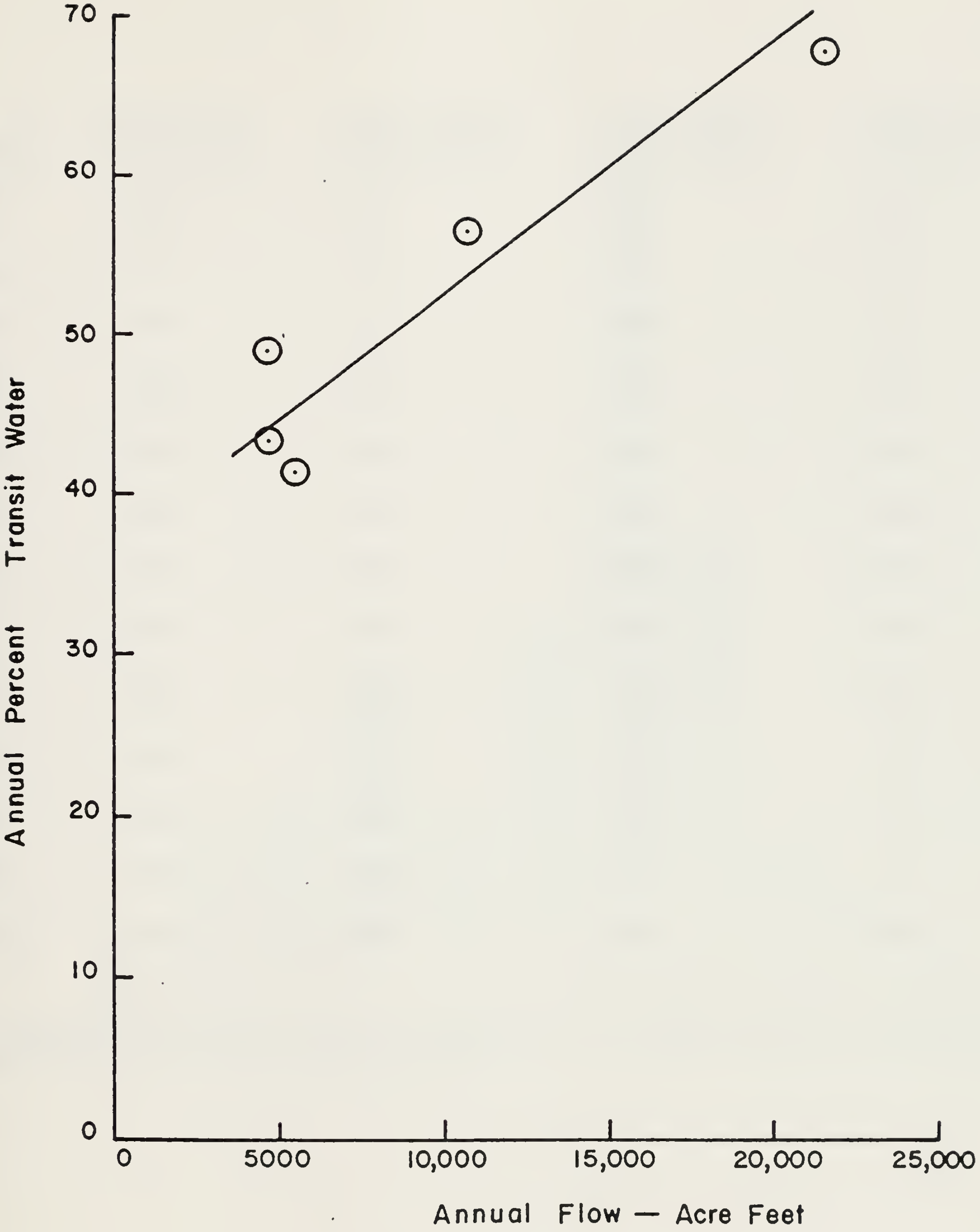


FIGURE 36

Turner Mill Spring - Relationship Between Percent of Transit Water and Total Annual Flow For Period Water Years 1969 - 1973
(from: Aley, 1975)

Month	Mean total flow A. ft.	Mean storage water A. ft.	Mean transit water A. ft.	Mean % transit water
Oct.	240	190	50	20.8
Nov.	610	190	420	68.9
Dec.	650	240	410	63.1
Jan.	990	290	700	70.7
Feb.	650	330	320	49.2
Mar.	1120	400	720	64.3
Apr.	2310	430	1880	81.4
May	1350	540	810	60.0
June	560	470	90	16.1
July	410	370	40	9.8
Aug.	310	290	20	6.5
Sept.	240	240	0	0
Year*	9430	3990	5440	57.7

* Yearly values from Table 4-9. Because of rounding, the sum of monthly values may not exactly equal the totals.

FIGURE 37

Turner Mill Spring - Mean Monthly Estimates of Storage Water, Transit Water, and Total Spring Discharge for the Period Water Years 1967 - 1973
(from: Aley, 1975)

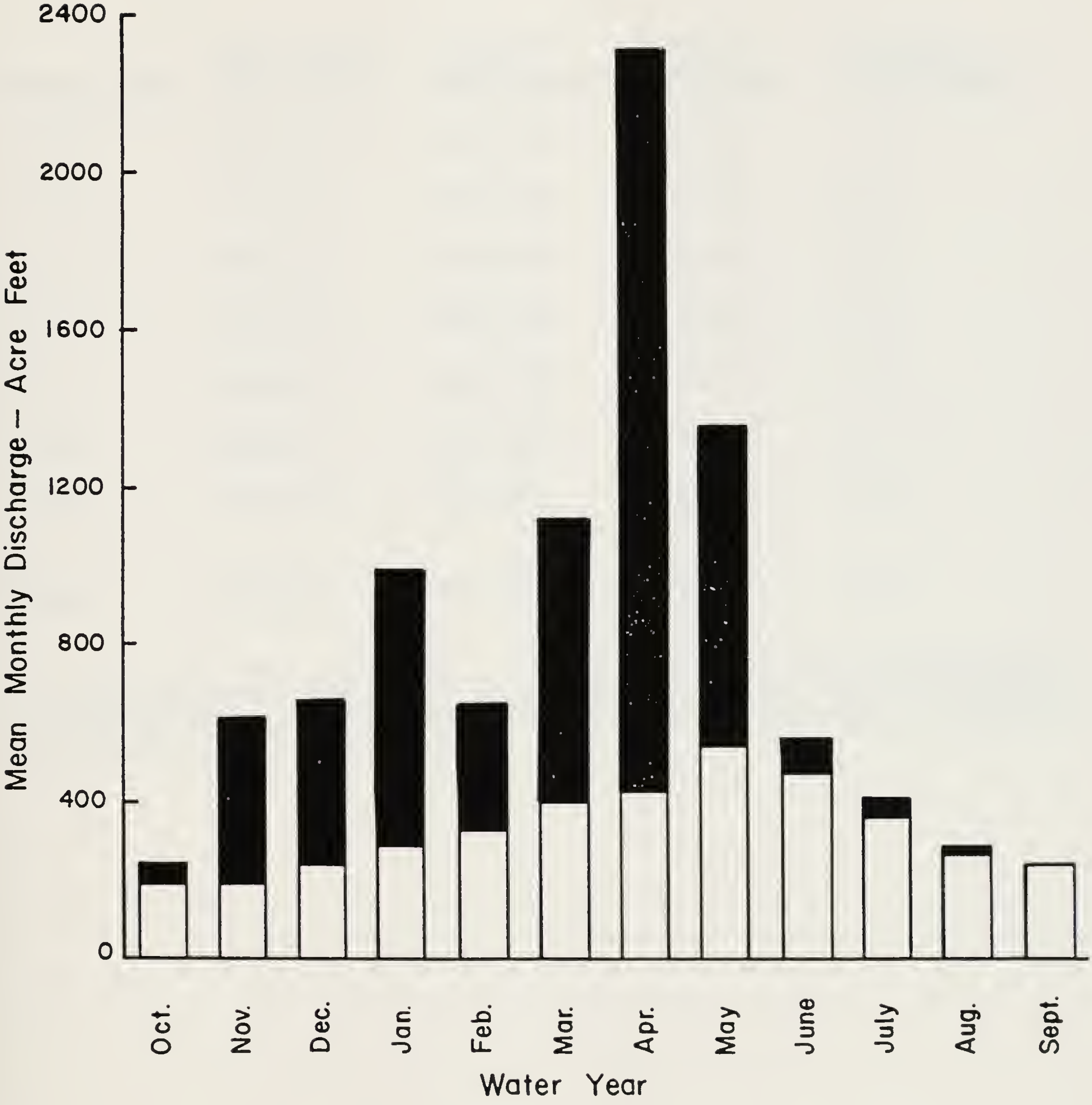


FIGURE 38

Turner Mill Spring - Histogram of Mean Monthly Estimates of Storage Water, Transit Water, and Total Spring Discharge for the Period Water Years 1967 - 1973

Lower light segment of bar represents storage water; upper dark segment represents transit water

(from: Aley, 1975)

Water Year	Total annual flow A. ft.	Storage water A. ft.	Transit water A. ft.	Percent transit water
1967	246,500	225,300	21,200	8.6
1968	325,300	259,200	66,100	20.3
1969	369,700	275,600	94,100	25.5
1970	277,200	234,400	42,800	15.4
1971	288,200	249,100	39,100	13.6
1972	280,700	227,700	53,000	18.9
1973	447,600	282,900	164,700	36.8
Mean	319,300	250,600	68,700	21.5

* Mean percent of transit water is calculated from the mean values for the seven-year period and not as an arithmetic mean of percentages. Therefore, 68,700/319,300 = 21.5%.

FIGURE 39

Big Spring - Annual Estimates of Storage Water and Transit Water for the Period Water Years 1967 - 1973
(from: Aley, 1975)

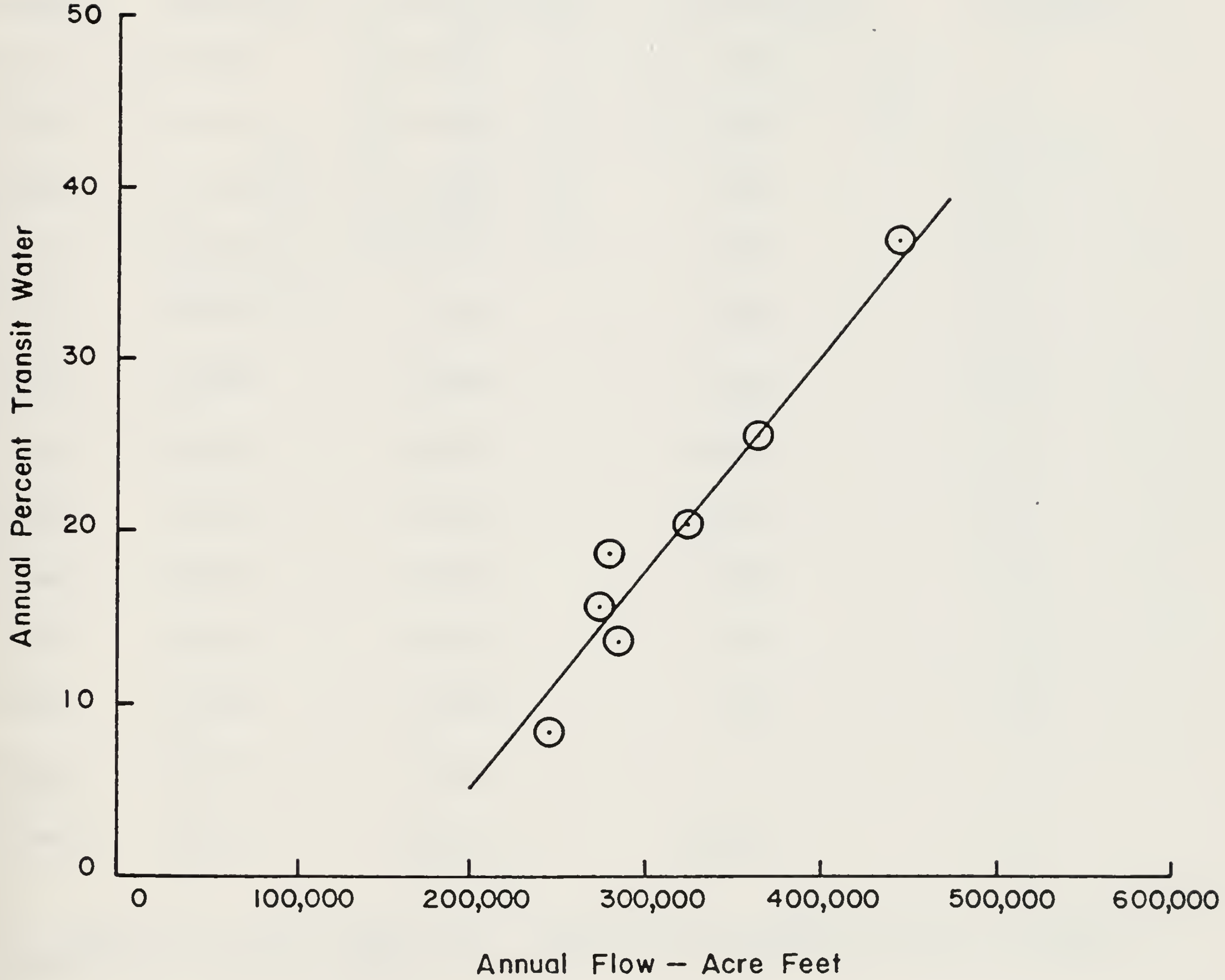


FIGURE 40

Big Spring - Relationship between the Percent of Transit Water and the Total Annual Flow for the Period Water Years 1967 - 1973
(from: Aley, 1975)

Month	Mean total flow A. ft.	Mean storage water A. ft.	Mean transit water A. ft.	Mean % transit water
Oct.	19600	18500	1100	5.6
Nov.	23200	17900	5300	22.8
Dec.	27400	19300	8100	29.6
Jan.	28800	20300	8500	29.5
Feb.	27700	19500	8200	29.6
Mar.	30400	22300	8100	26.6
Apr.	35100	22200	12900	36.8
May	35200	23600	11600	33.0
June	25800	22600	3200	12.4
July	23400	22500	900	3.8
Aug.	22500	21600	900	4.0
Sept.	20200	20200	0	0
Year*	319,300	250,600	68,700	21.5

* Yearly values from Table 4-13. Because of rounding, the sum of monthly values may not exactly equal the totals.

FIGURE 41

Big Spring - Mean Monthly Estimates of Storage Water, Transit Water, and Total Spring Discharge for the Period Water Years 1967 - 1973
(from: Aley, 1975)

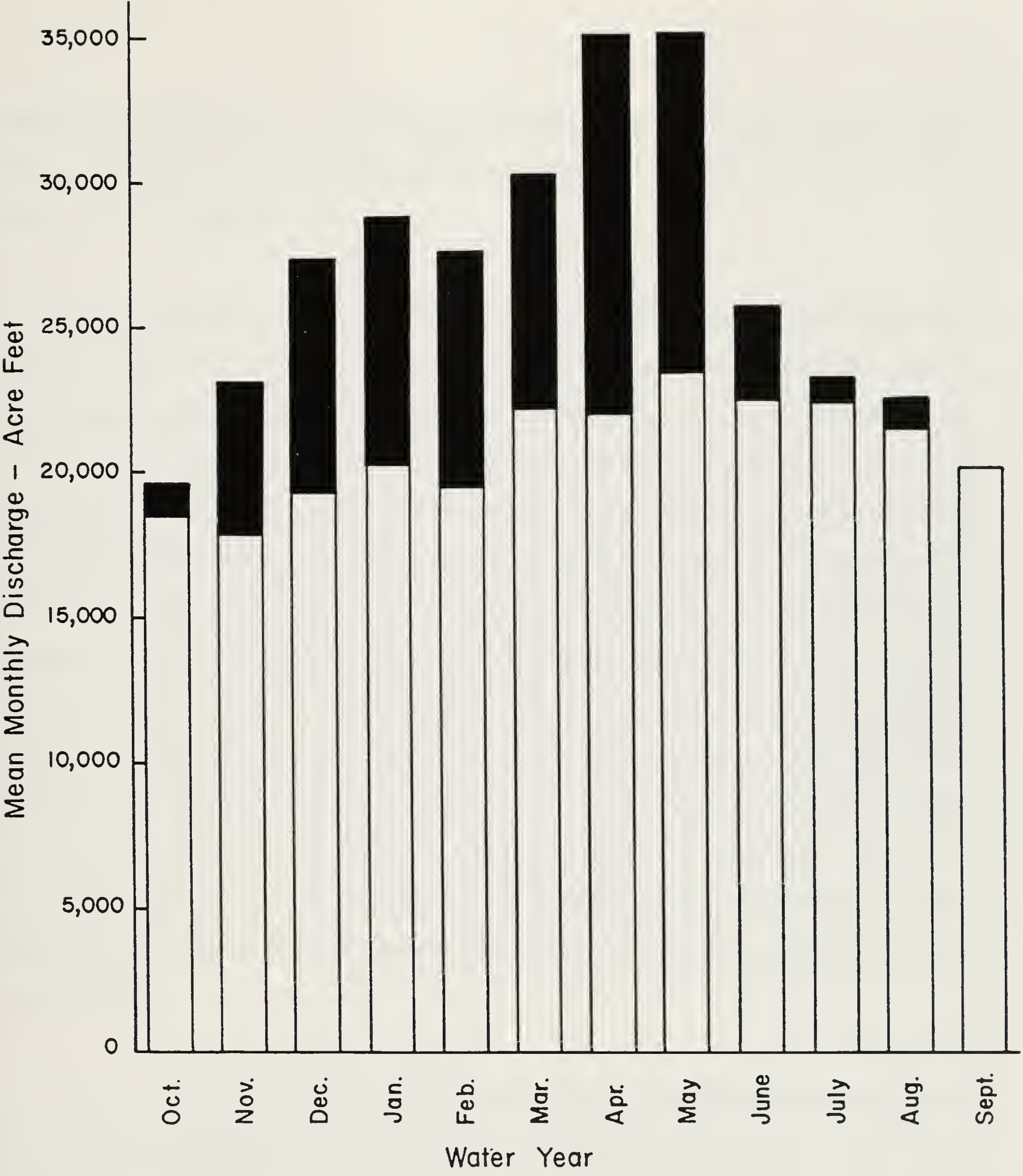


FIGURE 42

Big Spring - Histogram of Mean Monthly Estimates of Storage Water, Transit Water,and Total Spring Discharge for the Period Water Years 1967 - 1973

Lower light segment represents storage water; upper dark segment represents transit water

(from: Aley, 1975)

natural cleansing takes place. Unfortunately, the largest spring, Big Spring, makes the greatest volumetric contribution to the Ozark National Scenic Riverways, and it derives about 78% of its water from water in storage.

In deeply weathered carbonate terrain, such as occurs in the petitioned area, water is conducted freely to aquifers and springs by losing streams, sinkholes and solution openings ,and the groundwater levels in such areas respond rapidly to precipitation. Figure 43 is a hydrograph from a well 1,305 feet deep at West Plains that produces primarily from the Potosi Formation. (Note: other wells have been drilled at West Plains to depths as great as 2,692 feet and are bottomed in Precambrian igneous rocks). The hydrograph shows the dramatic relationship of the rise and fall of the water in the West Plains wells to precipitation and demonstrates the short time interval required for surface waters to travel the vertical distance into the area's aquifer system. Cavernous connections from the ground surface to depths as great as 1,500 feet are known to occur at West Plains. The West Plains municipal well water becomes turbid after rainstorms despite the fact that the upper 1,000 feet of the wells are pressure-grouted. The hydrograph shows that much of the area's stream flow is lost to underground drainage systems. The hydrograph of a well at Washington, Missouri is shown for contrast and is included to illustrate how ground water responds less to precipation in areas where weathering is less pronounced and the residiuum less well-developed.

Figure 44 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 (Figure 45) indicate subsurface movement of water for distances as great as 40 miles at velocities ranging from less than 0.1 to 3.2 miles per day. Any pollutant spilled into one of the sinkholes or losing streams in the petitioned area will quickly enter the aquifer system, and subsequently be discharged from wells and/or springs.

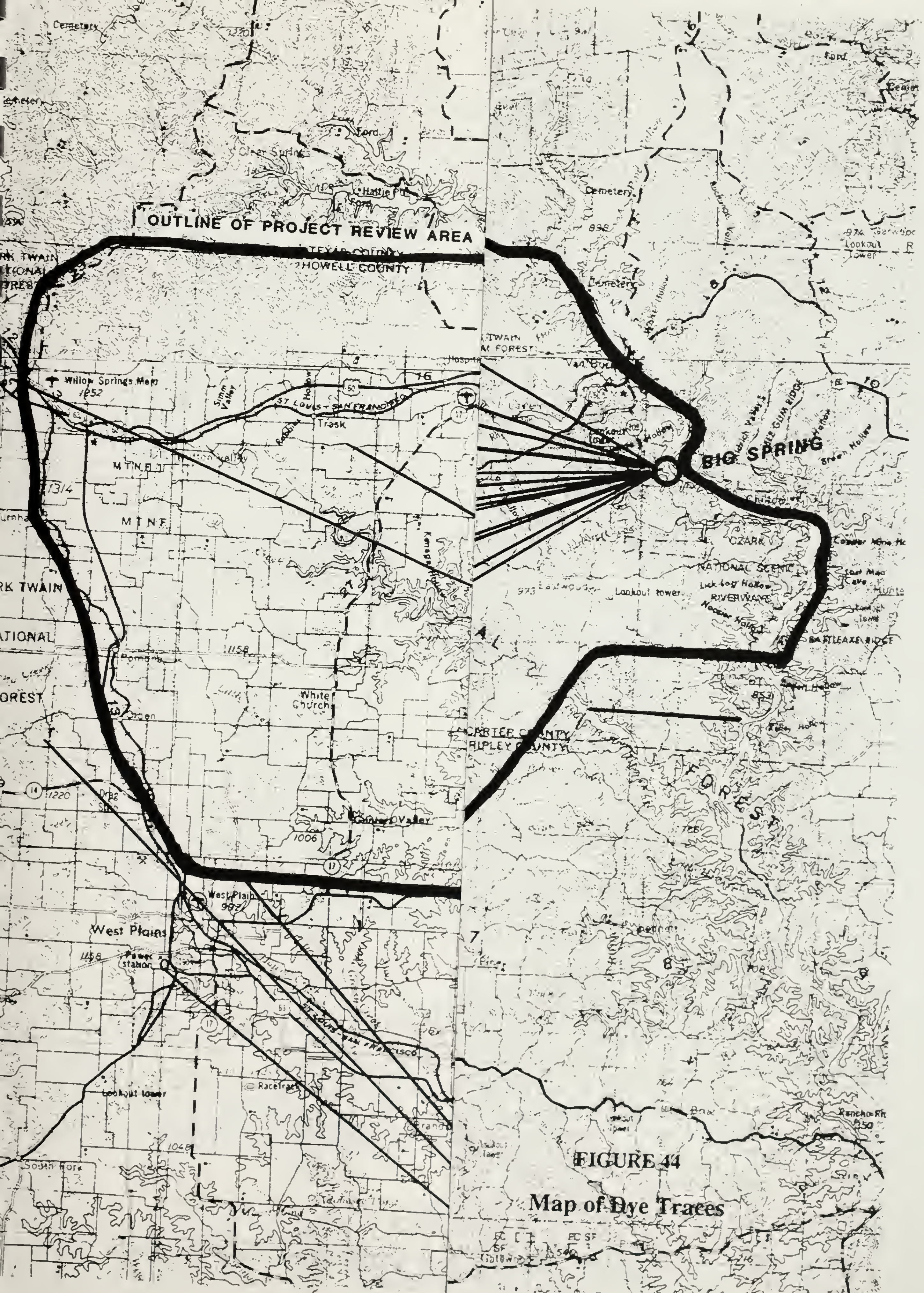


FIGURE 44

Map of Dye Traces

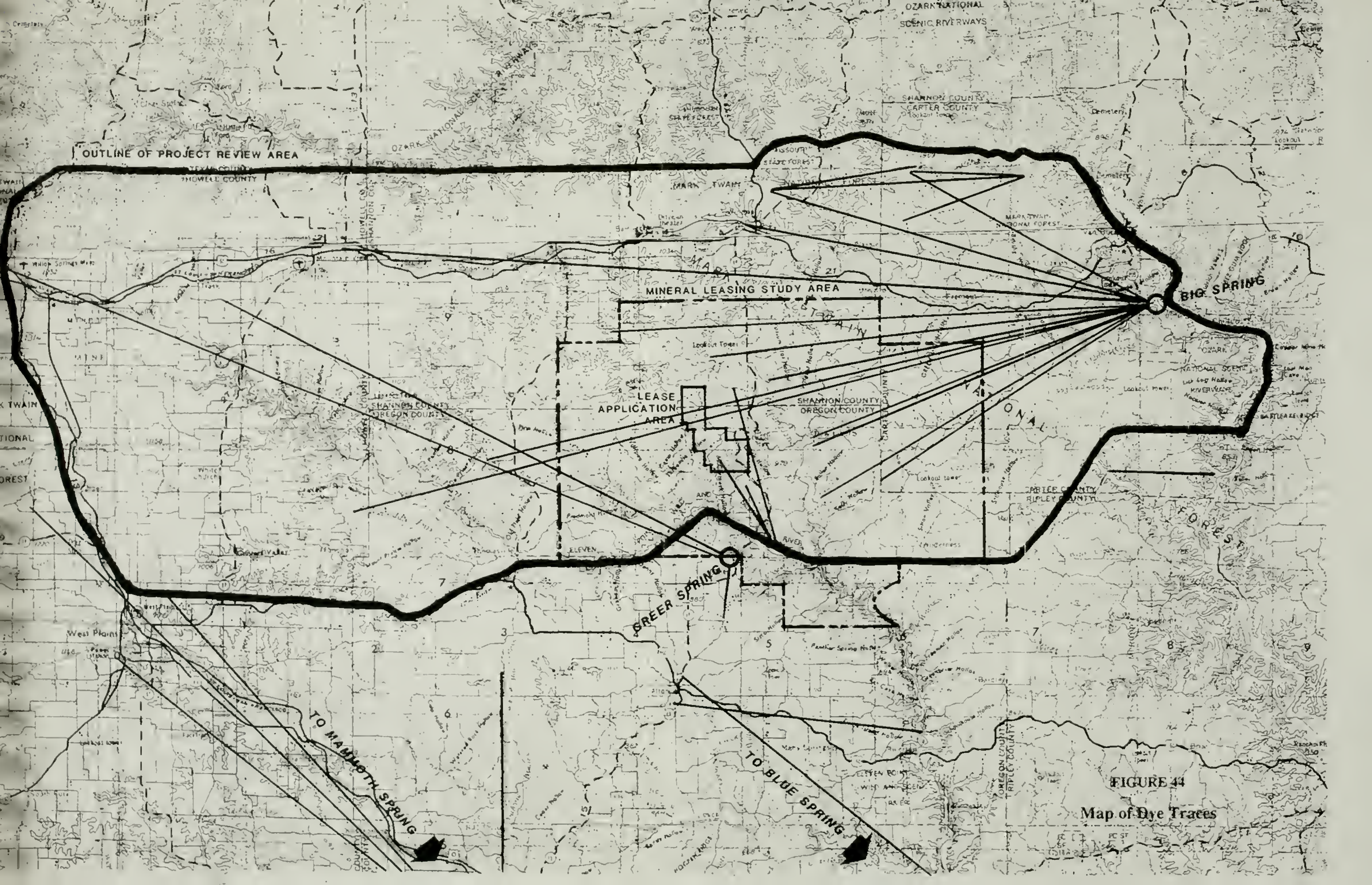


FIGURE 44

Map of Dye Traces

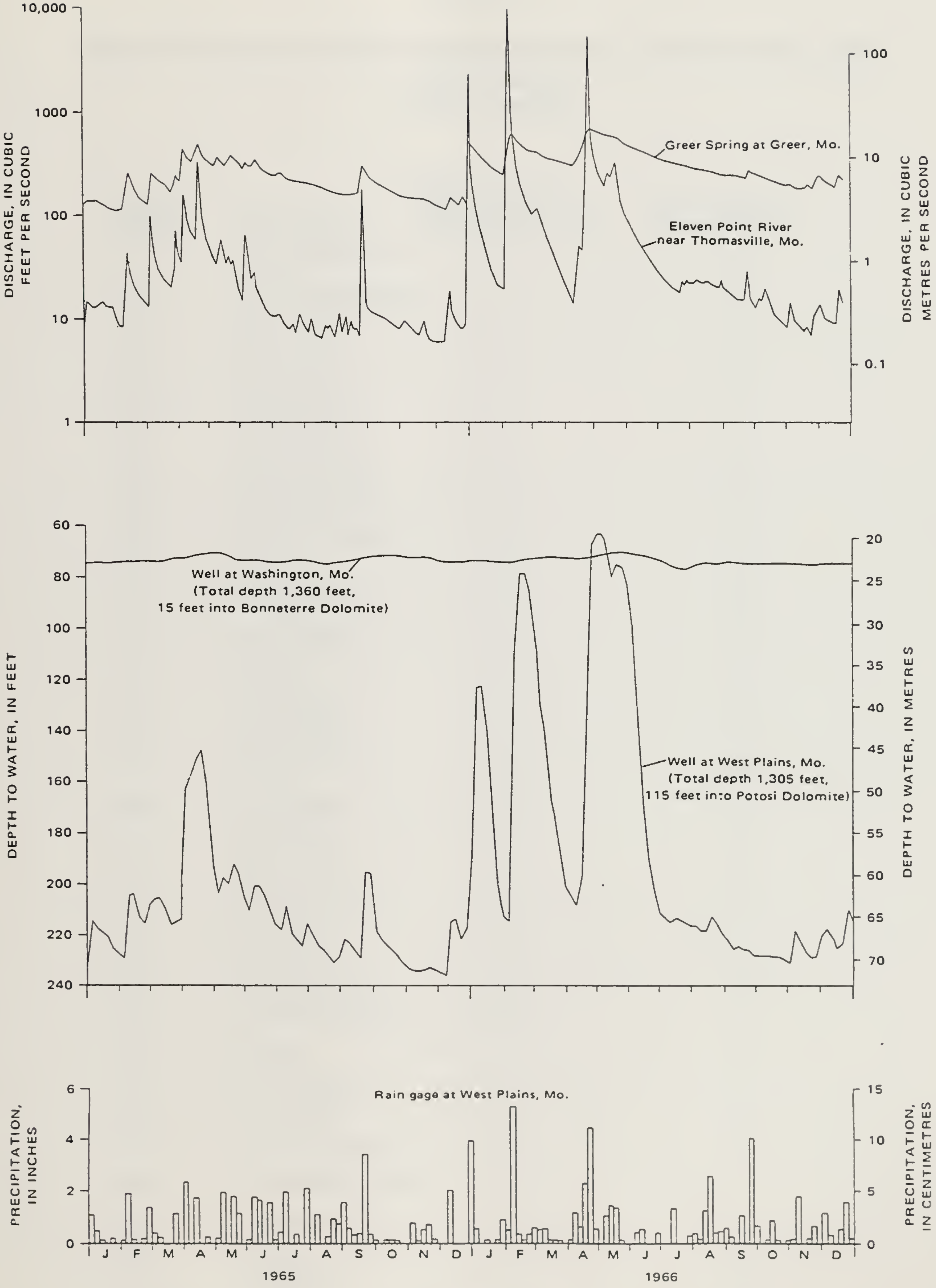


FIGURE 43

Comparison of Groundwater Response to Rainfall in Petitioned Area
(from: Gann et al., 1976)

FIGURE 45

Rate of Groundwater Movement in Petitioned Area From Successful Dye Traces

(from: Aley, 1975)

Reference Number	Name of Trace	Straight line travel rates for first recovery of tracer. ft/hr.	Straight line distances. (miles)
001	Blowing Spring--dye	374	17.0
002	Blowing Spring--spores	312	17.0
003	Leslie Spring	385	17.5
004	Dowler Sink	660	25.3
005	Johnson Spring	283	18.0
006	Wildcat Hollow	293	17.3
007	Stillhouse Spring	110	33.5
008	Middle Fork--dye	543	39.5
009	Middle Fork--spores	669	39.5
010	Goldmine	300	15.0
011	Mountain View	699	38.1
012	Nuttle Spring	504	27.5
013	Simpson	239	3.3
014	West Plains	367	25.0
015	Granny Myers	160	14.5
016	Mt. Zion	380	32.8
017	Pond Hollow	28	7.6
018	Davis Pond	193	3.5
019	Horse Trail Spr.	233	5.3
020	Summersville	605	11.0
021	Alton Dump	42	15.5
022	Dora Dump--dye	65	5.6
023	Dora Dump--spores	no data	5.6
024	Cureall	176	8.8
025	McGarr Spring	9	0.6
026	Under River	22	0.5
027	Sheep Ranch Hollow	33	1.5
028	Johnson Spr. to Hurr.	60	1.1
029	Hurricane Weir	32	1.0
030	Winona	470	19.2
031	Rough Hollow	330	2.8
Mean value		286	15.2

Note: Traces 032, 033, and 034 were not monitored as intensively as traces 001 through 031; data from these three traces are thus not fully comparable with the above values and are omitted.

Separation of Aquifers: There is one aquifer system in the petitioned area. It consists of an upper aquifer (sometimes called the Ozark Aquifer) and a lower aquifer. The upper aquifer extends from the surface of the land down to the top of the Davis Formation. The lower aquifer extends from the base of the Davis Formation down to the Precambrian basement. The Davis Formation, which separates the two aquifers, is not a productive aquifer, yet it is permeable and does connect the upper and lower aquifers into a single aquifer system. It is this complete aquifer system to which this petition applies.

There are differences of opinion as to the degree of hydrologic interaction between the upper and lower aquifers in this aquifer system. Some consider the aquifer above the Davis to be relatively independent of the aquifer below the Davis. Others believe there are sufficient hydrologic connections between the two units so that activities carried out in one will affect the other. Although there are presently not enough data to assess the degree of hydrologic interaction between the upper and lower units, arguments that the Davis is an effective aquitard are specious at best. There are enough data to show that a hydraulic connection is probable and there are certainly no data to demonstrate that the the upper and lower units are hydrologically independent.

references

The Missouri Division of Geology and Land Survey has records for a pair of wells in Shannon County, Section 36, T30N, R3W. Bear Creek Mining Test Hole #RC113 was plugged in the Davis member of the Elvins. Bear Creek Mining Test Hole #RC145 had casing set and grouted in the Davis, therefore producing from the Bonneterre Formation. The Bonneterre is that portion of the aquifer system acting as host rock for the principal lead-zinc deposits. There are no pump tests on the lower unit (Bonneterre) to demonstrate drawdown in the upper portions of the aquifer system; however, the potentiometric head in the lower aquifer is slightly less than in the upper aquifer and therefore the potential for downward movement exists. Water level fluctuations occur

in the lower aquifer.

Warner et al. (1974) state that although recharge to the deeper part of the aquifer system would conventionally be considered to occur at the outcrop of the Lamotte and Bonneterre Formations, that a) substantial amounts of recharge can occur through confining beds such as the Davis Formation in the presence of head differences across the beds and that pumping, and that b) pumping of the deep part of the aquifer system for mine dewatering produces a head difference across the Davis in the upper part of the aquifer system.

Warner et al. (1974, p. 59) made an estimate of the rate of vertical leakage across the Davis under mining conditions. Using their estimates, the Davis would transmit about 160 acre feet of water per square mile per year into the lower aquifer unit. They note: ".......the selected value of permeability could be an order of magnitude greater or less, before mining; and, regardless of the initial value, it would be greatly increased by fracturing of the Davis Formation during mining."

Annual groundwater recharge to the petitioned area has been calculated to be approximately one acre foot per year (Aley, 1975). Of this, 25 percent could pass downward through the Davis using the numbers generated by Warner et al. (1974) for conditions in the New Lead Belt. Because of the thinner Davis Formation, it is likely that the percentage in the petitioned area would be larger. If 25 percent or more of annual groundwater recharge can pass through the Davis, then a single aquifer system truly exists.

A similar single aquifer system situation exists in the lead and zinc mines in the Tri-State mineral production area around Joplin, Missouri. Water-level measurements in the Joplin area indicate that the potentiometric surface of the deeper aquifer is lower than that of the shallower aquifer. This relationship has favored the downward leakage of water where faults, fracture

openings, and wells connect the shallower aquifer and the deeper aquifer across the separating aquitard which consists of the Northview Formation and Chattanooga Shale (Barks, 1977). Where the aquitard is breached, downward water movement occurs preferentially. The result is a single aquifer system comprised of two interacting aquifers.

The thickness of the Davis Formation in the petitioned area was not reported in the Environmental Impact Statement. This omission is unfortunate because data on the nature of the Davis are crucial in assessing the effect of mining on the aquifer system. The U. S. Geological Survey will soon publish on the hydrology of that part of Missouri inclusive of the petioned area which includes data on the Davis. The series of reports will be released as HA-711A through HA-711M and are scheduled for release by the end of 1989. Unfortunately, rough draft copies could not be released to the consultants preparing this application prior to publication; however, several observations were made when examining the rough draft maps at Rolla:

1) The aquitard, the Davis, contains less than 20% shale in the petitioned area. This is a lesser percentage of shale than occurs in the New Lead Belt where hydrologic interactions are known to occur across the Davis.

2) The Davis has a projected thickness ranging from only 200'-300' in the petitioned area as opposed to 300'-400' in the New Lead Belt.

Therefore, under optimal conditions of shale deposition, and at the maximum thickness of 300 feet, there can be expected to be less than 60 feet of shale in the Davis. However, this maximum of 60 feet of shale is not contained in one massive bed to act as a particularly efficient aquitard; the beds of shale are interspersed in some fashion with beds of siltstone, fine-grained sandstone, and dolomite. The often-used term Davis Shale is deceptive, for the formation is not truly a shale but

rather a highly diverse unit with appreciable amounts of soluble carbonates and sandstone. Additionally, as will be emphasized in following paragraphs, the Davis Formation has not been deposited everywhere. It may be either very thin or entirely absent over the upward projecting basement knobs which can be exploration targets for the mining industry. Greater than average permeability must be anticipated through the Davis near where the Davis contacts or is penetrated by the basement knobs.

Although there is no surface exposure for that portion of the aquifer below the Davis, apiezometric maps shoe an interaction between the rivers and the lower aquifer in the St. Francis Mountain area (J. Imes, U. S. Geol. Survey, Personal comm., 1989).

Further, Figure 10 depicted the pronounced thinning of the Elvins Group over the basement pinnacles in the vicinity of Winona. Over these pinnacles the Davis is probably absent with at most only the upper, shaleless Derby-Doe Run being present. Because one of the exploratory targets for the mining industry is the Bonneterre mineralized reefs that formed around pinnacles of this type, it can reasonably be assumed that more of these pinnacles breaching the Davis are located in the Mineral Leasing Study Area where the companies hope to mine.

Faulting undoubtedly exists in the area and can provide a connection between groundwaters above and below the Davis. A number of workers have recognized that lineaments and fractures tend to be favorable sites for the location of water wells. Hanson (1973) in his studies in Arkansas noted that 96% of the springs were associated with mapped linear trends. Further, he noted that springs located at the intersection of two or more lineaments possessed flows 8 to 100 times those situated along single trends, and that all springs which exhibited discharges of greater than or equal to 700 gpm occur at the intersection of two or more lineaments. If permeabilities along lineaments are important conduits for transporting water to major karst springs it is reasonable to assume that

they will be major conduits for the transport of pollutants and are corridors along which the integrity of the Davis aquitard is particularly questionable on a regional basis. Figure 13 showed those major lineaments within the petitioned area that are persistent for at least 15 miles; there are many other lineaments and fracture traces of lesser linear extent in the petitioned area.

Lead deposits may be localized by the same fractures, faults, and lineaments which are associated in the localization of groundwater flow paths. Aley (1975) mapped some of these flowpaths to springs in the petitioned area and concluded (Aley and Aley, 1987) that the large springs as well as many of the losing stream segments of the region are typically located on or near one or more of the lineaments. We believe that there is ample evidence to suggest that the Davis may be breached by faulting. If true, the Davis cannot be considered an efficient aquitard let alone an aquiclude and hydrologic interaction between groundwaters above and below the Davis is probable.

In summary, there is ample evidence to indicate that the Davis Formation is an ineffective aquitard and that the upper and lower aquifer units are part of the same aquifer system. These are:

1. There is a slight downward hydraulic gradient between the upper and lower aquifer units with the potentiometric elevation in the lower unit fluctuating from year to year.

2. Arguments that the Davis Formation is an effective aquitard are specious at best.
    a. The Davis contains minor amounts of shale intermixed with major amounts of coarse clastics and soluble carbonates.
    b. The Davis is not deposited everywhere and can be absent or quite thin over and around the upward protruding Precambrian basement knobs and pinnacles. The areas around these knobs and pinnacles are frequently exploration targets

for mining. Greater than average permeability must be anticipated through the Davis near where the Davis contacts the sides of the basement knobs.

c. Calculations by Warner et al. (1974) and this report indicate that 25 percent or more of the annual groundwater recharge could pass through the Davis from the shallow aquifer unit to the deeper aquifer unit of the aquifer system if a head differential created by mining or other major water extraction existed. This amounts to 160 acre feet per square mile per year.

3. Both the presence of faulting and the greater than average permeability on the Davis around the basement pinnacles, which are the exploration targets for the mining companies, makes it highly likely that dewatering activities in the lower aquifer unit affects the groundwater in the upper aquifer unit.

4. Because of the deep solution of overlying carbonates, the Davis is not protected and is subject to the same solutional activity as the overlying units.

5. Prospecting, lease evaluation, and mining causes increased interactions between the upper and lower aquifer units of the aquifer system. This has been demonstrated in the New Lead Belt where sinkhole collapse and loss of water wells are commonly associated with the drilling of prospect holes, vents, and shafts and mine dewatering activities.

Public Health Hazards:

The preceding discussion has demonstrated that the geohydrologic regime in the petitioned area is such that if activities which produce contaminants or pollutants occur in the recharge area as

outlined, those contaminants or pollutants can enter the aquifer system of the area. Dye traces and traces using *Lycopodium* spores performed by T. Aley over the past 16 years have proven that ineffective natural filtration occurs and that many contaminants can readily be transported into and through the groundwater system in the petitioned area.

That contamination of the petitioned aquifer is possible is proven because it has happened in the past. In 1920, Big Spring was contaminated by chemical wastes (probably isopropyl alcohol) discharged into the dry valley of Davis Creek (now called Pike Creek) by the Midcontinent Iron Company, a few miles north of Fremont and about 10 miles from Big Spring (Bridge, 1930; Aley, 1975). The contaminants disappeared in the channel of Pike Creek and reappeared at Big Spring - a straight-line travel distance of about 9 miles. During the same period that Big Spring was discharging the Midcontinent wastes into the Current River, the municipal water supply for Doniphan, 35 miles downsteam, was also the Current River. Doniphan brought legal action against the Midcontinent Iron Company, the company went out of business in 1921, and the problem ceased.

Leakage of municipal sewage at Winona and Mountain View has been demonstrated by Aley (1975) to have contributed sewage effluent to Big Spring. The distance from Mountain View to Big Spring is nearly 40 miles. Further, in May, 1978, a sinkhole developed under the West Plains sewage lagoon and the lagoon collapsed. This collapse contaminated Mammoth Spring in Arkansas, polluted wells in the area, and caused several hundred people to become ill (Craun, 1984). Collapse can also happen to tailings ponds. The preceding demonstrates that aquifer pollution has happened in the past and can happen in the future if the recharge area for the the petitioned aquifer is not protected.

Further, the pollution resulting from tailings leachates or tailings pond collapse entering the groundwater system could be more serious than the above examples. Leachates from the lead-zinc mines in the Tri-State area have been measured to contain 9,400 to 200,000 micrograms per liter of zinc, 400 micrograms per liter of lead, and 1,400 micrograms per liter of cadmium (Barks, 1977). This is many times the maximum allowable concentrations for drinking water supplies and for the protection of aquatic life. Contaminants leaching from the tailings can enter the groundwater system in a matter of hours. Barks (1977) also reports that mine-water discharges increase dissolved zinc concentrations in receiving streams from a background of about 40 micrograms per liter to about 500 micrograms per liter during periods of low flow. The zinc concentration in bottom sediment increases from a background of about 100 micrograms per gram to about 2,500 micrograms per gram and increases the lead concentration in bottom materials from about 20 micrograms per gram to about 450 micrograms per gram.

Metals are discharged from the milling operations associated with the mining along with other tailings material and should a tailings impoundment receiving such heavy materials fail, heavy metals will be introduced into the groundwater system. Exposure to these heavy metals can result in acute toxicity or nervous disorders. Metals limits, most often for zinc, are already exceeded in the effluent from tailings impoundments in the New Lead Belt (Hardrock Mineral Leasing, Draft EIS, 1987).

Mines often have ore-concentration mills associated with them. Some of the milling reagents which can escape or be discharged to streams or groundwater are (Hardrock Mineral Leasing, Draft EIS, 1987):

Methyl Isobutyl Carbinol
Propylene Glycol Methyl Ether
Isopropyl Ethylthionocarbamate

Sodium Diethyldithiophosphate

Sodium Ethyl Xanthate

Zinc Sulfate

Sodium Cyanide

Copper Sulphate

Calcium Hydroxide

Anionic Dissodiumsulfosuccinate

Long-chain Aliphatic Alcohols

Sodium Isopropyl Xanthate

Sodium Dichromate

Sulfur Dioxide

Starch

Sodium Dioxide

Although some of the above chemicals are of negligible concern, others are highly toxic to both humans and aquatic life and can adversely impact water quality. This has happened in the New Lead Belt. Proliferatons of algal growth, probably caused by the toxicity of milling reagents to algal grazers, polluted several streams and when the algae died the odor of massive decay was added to that of the milling reagents (Hardrock Mineral Leasing, Draft EIS, 1987). This should not be allowed to happen to the Ozark National Scenic Riverways or to other waters in the petitioned area. Even if the mill effluent were continuously pumped back through the mill for use as processing water, the danger of impoundment failure would exist.

Our summary of past water quality problems associated with lead mining in the Missouri Ozarks provides insight into possible and probable water quality impacts in the petitioned area should similar mining and milling occur there. Utilization of newer mining and milling

methodologies may alter or lessen adverse impacts, yet, it is unreasonable to assume that such activities can be conducted in the petitioned area without significant groundwater impacts. Designation of the petitioned aquifer system as a Sole Source Aquifer is sought as an important step toward insuring that groundwater quality in the area will be sufficiently protected.

If mining occurs, the conduit nature of subsurface flow in the subject area assures that there will be ineffective natural removal of these contaminants and that, in the event of impoundment failure, or sinkhole collapse where wastes have been placed near mines, these contaminants will be conducted to water wells and to springs of the petitioned area. The resulting water quality impacts would occur rapidly and will likely persist for long periods of time. This would not only deny some of the residents their only source of drinking water but also would degrade features of the Ozark National Scenic Riverways.

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