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National Park Service
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Water Resources Division
Natural Resource Program Center
Fort Collins, Colorado

WATER RESOURCES FOUNDATION REPORT
Ozark National Scenic Riverways

Natural Resource Report NPS/NRWRD/NRR—2007/363

ON THE COVER

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WATER RESOURCES FOUNDATION REPORT
Ozark National Scenic Riverways

Natural Resource Report NPS/NRWRD/NRR—2007/363

David L. Vana-Miller
National Park Service
Water Resources Division
P.O. Box 25287
Denver, CO 80225

April 2007

U.S. Department of the Interior
National Park Service
Water Resources Division
Fort Collins, Colorado

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EXECUTIVE SUMMARY

> This Water Resources Foundation Report is one of several planning products offered by the NPS Water Resources Division that assist national park units with achieving or maintaining water resource integrity.

Following the 2004 Park Planning Program Standards, parks are to prepare a *Foundation for Park Planning and Management* document (Foundation Document), which describes a park's purpose, significance, primary interpretive themes and special mandates, and identifies and analyzes those resources and values determined to warrant primary consideration (*Fundamental and Important Resources and Values*) in park planning and management. The Foundation Document may be developed as the first stage of a park's general management planning process or independently of a general management plan.

This *Water Resource Foundation Report* is designed to support development of the Foundation Document for Ozark National Scenic Riverways (OZAR) and extend as a reference for its general management plan. The primary objectives of this for OZAR are to: 1) provide background for water resources; and 2) identify and describe the fundamental water resources at OZAR, along with the identification of stakeholders and laws and policies that apply to those fundamental water resources.

Workshops were held to generate *Purpose Statements*, which describe the specific reason(s) for establishing the park and *Significance Statements*, which define what is most important about the park's resources and values, based on the park purpose.

The *Purpose Statements* for OZAR are:

- To preserve and protect unimpaired the unique scenic and natural values, processes, and unspoiled setting derived from the clear, free-flowing Current and Jacks Fork Rivers and springs, caves, and their karst origins and;
- To provide for and promote opportunities for the scientific and public understanding of the natural and cultural resources and;
- To provide opportunities for understanding and appreciation of the human experience associated with the Ozark Highlands landscape and;
- To provide for uses and enjoyment of the outdoor recreation opportunities consistent with the preservation of the park's resources.

The *Significance Statements* for OZAR that pertain to water resources are:

- The ancient Ozark Highlands is an important center of biodiversity in North America with over 200 endemic species. The large variety of species found within OZAR is due the integrity of its connected region and to the rich array of aquatic, terrestrial, and subterranean habitats concentrated within the river corridors. In particular, the park supports unique species found nowhere outside of this region.
- The impressive hydrogeologic character of the Ozark karst landscape supports an amazing variety of natural features in the park, including a spring system that is world-class and unparalleled in North America. The park features the largest spring in the national park system, a total of six first magnitude springs and spring complexes, and over 350 springs park wide. The cave system is equally impressive, with 338 recorded caves – one of the highest densities of any national park unit.
- OZAR contains 134 miles of clear, free-flowing spring-fed rivers. Both the Jacks Fork and Current Rivers within OZAR boundaries are Outstanding National Resource Waters (ONRW) because of their high water quality. Ozark NSR contains two of the three rivers designated as ONRWs in Missouri.

Building from the *Significance Statements*, five natural resources can be defined as fundamental resources at OZAR. Of these five fundamental natural resources, three are specific to water resources (*the fragile, karst-based hydrogeological system*; *the high density of caves and springs*; and *the high water quality and clarity in the free-flowing Current and Jacks Fork rivers*). The other two (*a significant diversity of high-quality ecosystems within the river corridors* and *the assemblage of unique plants and animals*) are an amalgamation of water and terrestrial resources. However, because of the importance and significant contribution of water resources, these two are considered fundamental water resources for the purposes of this document.

The importance of water resources at OZAR includes:

- The Ozark National Scenic Riverways is situated in a geologically and hydrologically complex area along the Current and Jacks Fork rivers. The combination of the geology of the two rivers' watersheds with an average annual precipitation of over 40 inches has created a karst landscape. The foundation of the Current and Jacks Fork watersheds and their dependent ecosystems is this karst landscape. Karst topography and structural features greatly affect water quantity and quality. In karst areas, water commonly drains rapidly into the subsurface at zones of recharge and then through a network of fractures, partings, and caves, emerges at the surface in zones of discharge at springs, seeps and wells. The ecosystems of these watersheds have developed in response to the karst and it is important that the quantity and quality of water moving through the karst system be maintained.

- The Ozarks region is perhaps the oldest continuously exposed land mass in North America. Because of the Ozarks central continental location, they have on multiple occasions served as refugia for organisms exposed to climatic extremes associated with glacial and geologic events. This influx of biota from different regions and high levels of habitat diversity have combined with the antiquity of the landscape to sustain relict populations and also allow for evolution of new species, making the Ozarks an important center of endemism in North America. The Current and Buffalo rivers of the Ozark Plateau between them contain the world's best know populations of 34 aquatic species of global conservation significance.

- The Jacks Fork and Current rivers are ideal for recreational use because the main channel gradients are steeper than gradients in other state rivers, thereby creating swifter currents. Additionally, the large amount of spring inflow (60 percent of the combined rivers' flow is from springs) produces large and stable flows, and tends to decrease water temperature, thus keeping the water cool through even the hottest months. Flow stability is at least partially attributable to the storage and transport capacity of the karst topography within the watersheds.

- Wetland types within OZAR include marshes, sinkhole ponds (doline lakes), bottomland forests, riparian areas, and ground water seeps. Groundwater seeps are relatively numerous and are most commonly found along the bases of hillsides in the Ozarks. In the Ozarks alkaline ground waters produce seeps known as fens. Because of their cool and wet microclimate, fens often contain plants more typical of more northern states. Many of these plants are rare or endangered in Missouri.

- A total of 43 species and subspecies of mussels are known from the Current River watershed, and 19 mussel species from the Jacks Fork watershed. Of these, two are both federally and state listed as endangered and three are former federal category-2 candidates. An additional eight species are listed as species of conservation concern.

- Fourteen species of crayfish are known from the Current River watershed and five species of crayfish occur in the Jacks Fork watershed, including the Salem cave crayfish (*Cambarus hubrichti*), a species of conservation concern. Crayfish are an aquatic invertebrate that play a major role in energy flow within the park ecosystem, acting as a keystone species that influences several trophic levels. Because crayfish play a major role as both consumers and prey, they are an important link in managing sportfish in the park as well as overall biodiversity. The Black River drainage, which includes the Jacks Fork and Current Rivers, was listed as one of the top conservation priorities in the Ozark Plateaus because of the taxonomic richness and diverse habitat requirements of its crayfish species.

- Subterranean aquatic karst passages are more commonly expressed than emergent cave passages. This is reflected in the regional karst fauna, with subsurface aquatic diversity being greater than subsurface terrestrial diversity – a total of 46 stygobite (obligate cave aquatic) species verses 31 troglobite (obligate cave terrestrial) species.

- Discrete recharge zones [which provide 42 percent recharge to springs (Alley 1978)] are areas where a substantial volume of groundwater recharge occurs but where there is no topographic expression of the recharge zone (such as a sinkhole). Even though we often cannot identify the location of these areas, the behavior of spring systems clearly demonstrates that they exist. There are numerous discrete recharge zones in and adjacent to the park and these non-surface expression features make up the largest percentage of discrete recharge features. The additional spring recharge areas add approximately 30 percent more acreage to the surface watershed. The surface watershed is approximately 1,161,589 acres and the watershed including the spring recharge areas outside the surface watershed adds an additional 348,477 acres.

- There are 338 recorded caves that exist as part of the karst system in the park. There are 60 caves with perennial streams in the park and 33 caves with intermittent water sources. Seven caves have lakes. The largest of the caves with lakes is in Devils Well Cave; the lake is about 400 feet long, up to 50 feet wide, and up to 200 feet deep. This is one of the largest cave lakes known in the U.S.

- OZAR ranks second only to Grand Canyon National Park for the greatest number of caves in a national park unit. However, OZAR has one of the highest densities of caves in the NPS.

- Five first-magnitude springs, which flow at more than 100 cubic feet per second, and at least 250 smaller springs are currently known to contribute flow to the rivers and their tributaries. Four springs within the park rank among the 10 largest in the state. The largest spring in the park is Big Spring, which is the largest spring in the U. S. west of Florida and east of Idaho and the largest freshwater spring within the national park system. Big Spring is a good example of the magnitude of interbasin transfer of groundwater in the area. Groundwater tracing studies have demonstrated straight-line groundwater flow distances to this spring of nearly 40 miles from outside of the Current River watershed. This complex underground network results in a huge recharge area for Big Spring, estimated to be 967 square miles.

- Typical lateral groundwater movement in many aquifers in the U. S. is only a few feet per year. Groundwater in the park has been shown to travel up to 3 miles per day. Therefore, interactions between surface and ground water processes are greatly enhanced in karst. This is the main reason that karst areas are so susceptible to pollution. Karst areas do not allow for effective filtration and absorption of pollutants from the surface water as it travels into the groundwater system. Also, faster travel rates provide less time for bacteria and viruses to die.

- All of the Jacks Fork and Current rivers are designated as Outstanding National Resource Waters (ONRW) because of their high overall water quality. ONRWs have national recreational and ecological significance and receive special protection against any degradation.

- Springs in the park supply most of the baseflow for the Current and Jacks Fork rivers – at least 60 percent of the combined rivers' flow is from springs. It is this large proportion of spring-derived flow, combined with the fact that most tributary flows do not reach the rivers because their flow is lost to the karst environment that contributes to the water clarity so prized in Ozark streams. In fact, with 134 miles of river with high water clarity OZAR is probably one of a handful of areas in the continental U. S. with the same size and clarity.

The current conditions and trends of water resources at OZAR include:

- Riparian zones are one of the most disturbed ecosystems in the Ozarks. Riparian zones of Ozarks streams are naturally dynamic, but rates of channel movement and deposition in the riparian zone have been accelerated in places by human-induced land-use changes, particularly land clearing and logging.

- Little is known about park wetlands and there is a great need for inventory and monitoring to determine size, extent and species composition of wetland types in the park.

- Stream channels in the park are changing via the accumulation of chert gravel; this accumulation may be due to historical land use changes in the riparian zone.

- No detailed analysis of trends involving fish diversity or density exists in the park.

- A 2004 study inventoried the mussel community within the park by re-surveying 19 sites from a 1982 study and surveying 17 new sites. The 2004 study suggested some trends in habitat characteristics related to the areas with high mussel concentrations

- Hellbender (a large, totally aquatic salamander) populations are declining throughout the Ozarks, particularly over the last 20 years. There has been little indication of consistent reproduction.

- Vegetated edgewater and forewater/backwater areas comprise only a small portion of the total stream area and are highly susceptible to degradation. Destruction of these habitats impacts an important trophic link between crayfish and other invertebrates as well as many fish species.

- There has not been any long-term monitoring of the benthic invertebrate community in park waters, but has been a large amount of research, short-term studies, and special projects.

- However, a draft monitoring protocol for benthic invertebrates was recently developed for the park.

- Because the karst environment is sensitive to changes in land use, the key to understanding trends in karst is understanding trends in land use. While there have been relatively small changes in land use in the last 30 years, the threat for major disruptions to the karst environment of the park still exist.

- Despite the critical role of water quality monitoring in protecting the park, the data are lacking in many respects. While there has been more consistent and increased monitoring activity in the last decade, data collection is limited to the recreation season (May-September). This limits statistical inferences regarding temporal trends in water quality.

- Overall water quality within the Current River watershed appears to be relatively good with the exception of an 7-mile section of the Jacks Fork River. This section of the Jacks Fork River was listed as impaired on Missouri's 2002 303(d) list due to excess fecal colifom bacteria. A TMDL was completed for his section in 2004 and determined the endpoint for fecal coliform under natural conditions. The U.S. Geological Survey conducted a three-phase study to better understand the extent and sources of microbiological contamination in the 7-mile impaired reach.

The current and potential threats to water resources at OZAR include:

- Groundwater contamination -- OZAR and its spring systems are more sensitive to land use practices than in other geologic regions because groundwater infiltration is quite rapid in karst terrain.

- Recreational use – Recreation has increased steadily since the park was established. Canoeing has always been popular. Technological advances in outboard jet motors now allow jet boaters access to areas that were previously unmotorized. Horseback riding is a significant use within certain areas of the park. In addition angling has also gained in popularity.

- Land use in the watershed – Because OZAR manages less than 3 percent of the total land within the Current River watershed, rivers are vulnerable to increased sedimentation and runoff from land use activities including grazing, deforestation, riparian zone clearing in tributaries, and road building.

- Loss of native species – The high species diversity that the park supports is part of its uniqueness. However, many species are threatened or endangered at the state and/or federal level and little is known about neither specific habitat requirements nor the role that water resources serve in maintenance or survival of species or communities.

- Exotic and invasive species – The presence of or close proximity of many invasive species threaten the viability of native species.

- Wastewater discharges – There are five municipal wastewater treatment plants that discharge into park watersheds. However, these plants do not treat for nitrates and phosphates. The rural characteristics of the park dictate that many people use septic tanks. Because of the karst landscape, the potential for contamination from septic systems is increased several fold.

- Mining – There are two areas where potential mining of lead and zinc occur within the watershed of the park. In addition, deposits are present beneath national forest and private land located in the Big Spring recharge area.

- Flow and channel alterations – Bridges, culverts, river accesses, and bank hardening divert flows and re-focus energy to adjacent stream reaches, causing scouring, sedimentation, and bank instability.

Interest of various stakeholders for OZAR includes:

Federal:

U. S. Forest Service
U. S. Fish and Wildlife Service
U. S. Environmental Protection Agency
U. S. Geological Survey
Army Corps of Engineers
Natural Resources Conservation Service
National Weather Service

State:

Missouri Department of Conservation
Missouri Department of Natural Resources

Regional:

Scenic Rivers Watershed Partnership

Non-Profit Groups:

The Nature Conservancy
The L-A-D Foundation

Advocacy Groups:

Missouri Coalition for the Environment
Conservation Federation of Missouri
Jacks Fork Watershed Committee
Friends of Ozark Riverways

INTRODUCTION

Ozark National Scenic Riverways (OZAR) was established by Congress in 1964 (Public Law 88-492). It was the nation's first federally protected national river and Congress used the experience gained from establishing OZAR to develop the National Wild and Scenic Rivers Act of 1968, using language contained in the enabling legislation with regard to the protection of a river's free-flowing condition. There were three popular state parks—Big Spring, Alley Spring, and Round Spring—that were donated to the federal government by the State of Missouri to help create Ozark NSR. These developed areas have continued to be popular recreation destinations and the park as a whole has seen considerable visitation increases, particularly from metropolitan areas within a day's drive of the park.

The park extends along 134 miles (approximately 80,000 acres) of the free-flowing Current River and one of its tributaries, the Jacks Fork River, in the Ozark Highlands of southeastern Missouri (Figure 1). The Current River flows 56 miles before its confluence with the Jacks Fork River and another 127 miles before it reaches the Black River in Arkansas. The park boundary encompasses 101 miles of the Current River. The Jacks Fork River flows 50 miles before its confluence with the Current River near Eminence, MO. The park boundary encompasses 34 miles of the Jacks Fork River. Boundary gaps of approximately 4 river miles each occur on the Current River at Van Buren, MO and Jacks Fork River at Eminence, MO. Sixty-four percent of the park is federally owned with an additional 12 percent controlled by federal easements. Other public lands and private land comprise 17 percent and 7 percent of the park, respectively.

The Ozark Highlands are characterized by karst topography and its attendant features, such as sinkholes, caves, and springs. The importance of these resources is readily apparent from the park's enabling legislation:

> For the purpose of conserving and interpreting unique scenic and other natural values and objects of historic interest, including preservation of portions of the Current River and the Jacks Fork River in Missouri as free-flowing streams, preservation of springs and caves, management of wildlife, and provisions for use and enjoyment of the outdoor recreation resources thereof...

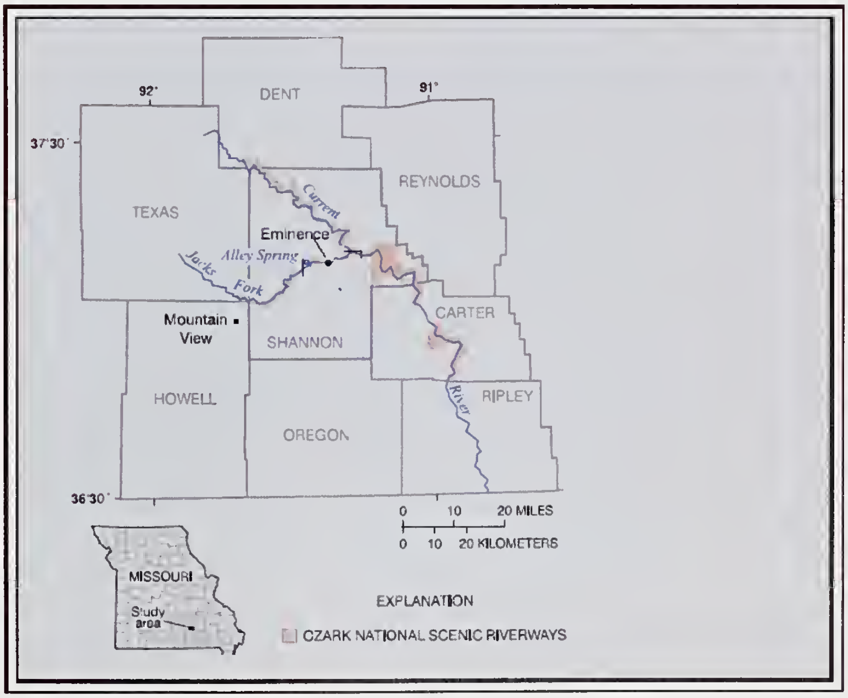


Figure 1. Location of Ozark National Scenic Riverways along the Current and Jacks Fork rivers (modified from Davis and Richards 2001).

Furthermore, The Nature Conservancy (2003) stated that the Current River watershed is probably the most significant middle-sized river in mid-continental North America primarily because it is a large, un-dammed cold water river system; has a high base flow fed from a set of the largest springs in central North America; and hosts an impressive 35 endemic or modal species, 25 of which have their most viable populations globally in the watershed.

Controversy surrounded not only the establishment of the park, but the development of the park's first general management plan (GMP) in 1984 and various administrative procedures designed to protect resources and manage public use. Today, many of the local population continue to resent the presence of the park. An updated GMP is needed to help foster better relations between the NPS and the local community. In addition, the current GMP provides little direction to guide park management with today's issues. Also, much of the 1984 GMP is no longer valid because of court cases and new legislation; some of its recommendations are not consistent with current NPS policies or the park's purpose and significance.

OZAR is following the 2004 Park Planning Program Standards during GMP planning process. This new planning framework begins with development of a *Foundation Document* (also referred to as the Foundation Statement). As a guide, the *Foundation Document* ensures that the most important objectives that are critical to achieving the park purpose and maintaining its significance are accomplished.

The GMP process began in November, 2005 with a planning workshop that produced Purpose Statements for park and Significance Statements for the park's resources (natural and cultural; see below). The purposes of the park are clear statements of why Congress established the park as a unit of the national park system. The significance statements define what is most important about the park's resources and values and is based on the purpose for which the park was created. To date, no changes have been made to the purpose or significance statements; however, given the iterative planning process, the final GMP may reflect revisions to these statements.

Purpose Statements

- To preserve and protect unimpaired the unique scenic and natural values, processes, and unspoiled setting derived from the clear, free-flowing Current and Jacks Fork Rivers and springs, caves, and their karst origins and;

- To provide for and promote opportunities for the scientific and public understanding of the natural and cultural resources and;

- To provide opportunities for understanding and appreciation of the human experience associated with the Ozark Highlands landscape and;

- To provide for uses and enjoyment of the outdoor recreation opportunities consistent with the preservation of the park's resources.

Significance Statements for Natural Resources

- The ancient Ozark Highlands is an important center of biodiversity in North America with over 200 endemic species. The large variety of species found within OZAR is due to the integrity of its connected region and the rich array of aquatic, terrestrial, and subterranean habitats concentrated within the river corridors. In particular, the park supports unique species found nowhere outside of this region.

- The impressive hydrogeologic character of the Ozark karst landscape supports an amazing variety of natural features in the park, including a spring system that is world-class and unparalleled in North America. The park features the largest spring in the national park system, a total of six first magnitude springs and spring complexes, and over 350 springs park wide. The cave system is equally impressive, with 338 recorded caves – one of the highest densities of any national park unit.

- OZAR contains 134 miles of clear, free-flowing, spring-fed rivers. Both the Jacks Fork and Current Rivers within OZAR boundaries are Outstanding National Resource Waters (ONRW) because of their high water quality. Ozark NSR contains two of the three rivers designated as ONRWs in Missouri.

What conditions account for the rich diversity of habitats and biota found at Ozark National Scenic Riverways? At various times in the past, the mid-continental location of the uplifted Ozark Plateau placed it at a crossroads of boreal, prairie, desert, deciduous forest, and alluvial floodplain ecosystems. Continental climate fluctuations then allowed or encouraged species movements to and from the surrounding regions. Simultaneously, the lack of glaciation or inundation of the Plateau for the past 230 million years permitted a land mass that was continuously available for species colonization and adaptation. Finally, during this timeframe, the soluble geologic material of the plateau was developing the complex karst terrain of springs, losing streams, caves and seeps, further diversifying the habitat available to plateau inhabitants.

This combination of factors set the stage for an interconnected system of terrestrial, aquatic, and subterranean microhabitats that encouraged high degrees of species endemism, refugia for relictual inhabitants, and habitat for edge-of-range species. Combined with the relative high-quality condition of the Current River watershed and its surrounding region, the Ozark National Scenic Riverways continues to provide an important center for conservation of the ecological framework and its processes that are native to and characteristic of the Ozark Plateau.

WATER RESOURCES PLANNING

The NPS Water Resources Division initiated a Water Resources Planning Program in 1991 that assists parks with their water resource planning needs. Recent changes in NPS general planning (2004 *Park Planning Program Standards*) and resources planning (draft *Director's Order 2.1: Resource Stewardship Planning*) required programmatic revision of the Water Resources Planning Program to assure that its products would support the new NPS planning framework. Within this new planning framework, six discrete levels of planning are represented by six planning-related documents (Figure 2).

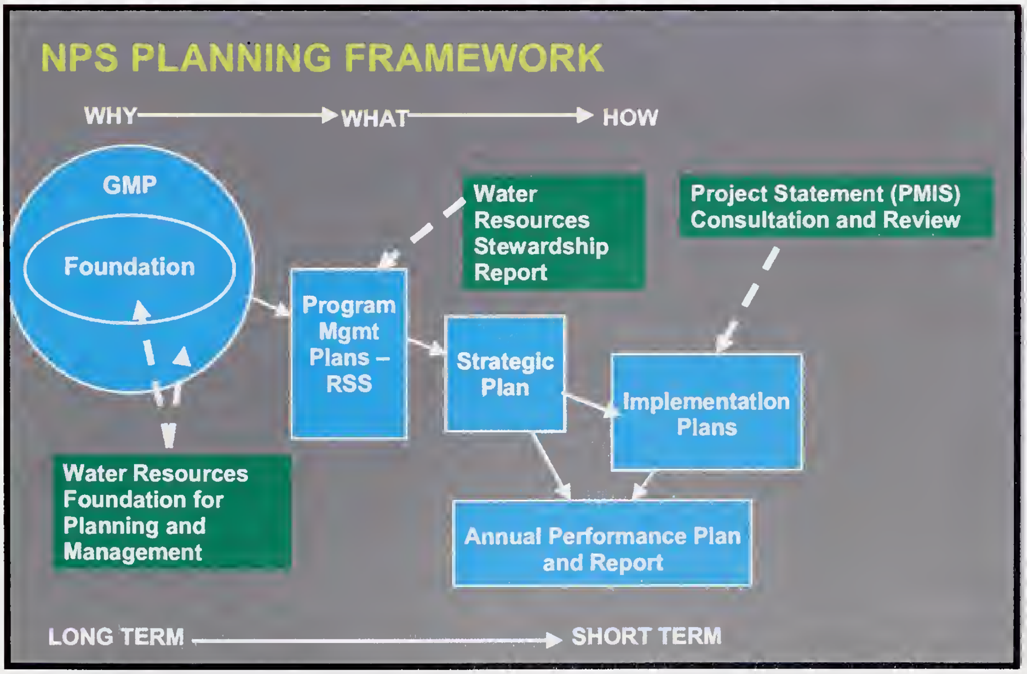


Figure 2. The 'new" NPS framework for planning and decision making (light blue). Green represents WRD planning products or technical assistance. RSS = Resource Stewardship Strategy, the program management plan for cultural and natural resources.

The *Foundation Document* defines the legal and policy requirements that mandate the park's basic management responsibilities, and identifies and analyzes the resources and values that are fundamental to achieving the park's purpose or otherwise important to park planning and management.

The *General Management Plan* (GMP) uses information from the Foundation report to define a broad direction for resource preservation and visitor use in a park, and serves as the basic foundation for park decision-making, including long-term direction for *desired conditions* of park resources and visitor experiences.

The *Program Management Plan* tiers off the GMP identifying and recommending the best strategies for achieving the desired resource conditions and visitor experiences presented in the GMP. Program planning serves as a bridge to translate the qualitative statements of *desired conditions* established in the GMP into measurable or objective indicators that can be monitored to assess the degree to which the *desired conditions* are being achieved. Based on information obtained through this analysis, comprehensive strategies are developed to achieve the *desired conditions*. The Program Management Plan component for natural and cultural resources is the Resource Stewardship Strategy (Figure 1).

The *Strategic Plan* tiers off the Program Management Plan identifying the highest-priority strategies, including measurable goals that work toward maintaining and/or restoring the park's *desired conditions* over the next five years.

Implementation Plans tier off the Strategic Plan describing in detail (including methods, cost estimates, and schedules) the high-priority actions that will be taken over the next several years to help achieve the *desired conditions* for the park.

The *Annual Performance Plan and Report* measures the progress of projects from the Implementation Plan with objectives from the Strategic Plan.

The *Water Resources Foundation Report* (WRFR) and the *Water Resources Stewardship Report* (WRSR) support this new planning framework. The WRFR (Figure 1) addresses the needs of either the *Foundation Document* or phase one of the GMP. The WRSR (Figure 1) is designed specifically to address the water resource needs in a park's Resources Stewardship Strategies.

Water Resources Foundation Report Objectives

The primary objectives of this *Water Resources Foundation Report* for OZAR are to: 1) provide background for water resources; and 2) identify and describe the fundamental water resources at OZAR, along with the identification of stakeholders and laws and policies that apply to these fundamental water resources. The water-related information contained in this report is designed to better assist OZAR with development of the Foundation Document, which ultimately supports the preparation of the new GMP for the park.

From: www.outdoorplaces.com/Destination/USNP/moozarkt/index.html

DESCRIPTION OF NATURAL RESOURCES

Climate

South-central Missouri has a temperate climate due to its mid-latitude, interior-continent location. Long summers and relatively short winters are characteristic for the area. January is the coldest month with mean minimum and maximum temperatures of 19-21° F and 43-44° F, respectively. July is the warmest month with mean minimum temperatures of 65-66° F and mean maximum temperatures of 90-92° F. Mean annual precipitation in the Current River basin is approximately 42-47 inches and showed an increasing trend from 1923-1994 (Figure 3a). March is the wettest month (approximately 5 inches) and January and February are the driest (< 3 inches); March through June is the wettest period of the year (Figure 3b). Geographically, precipitation increases within the Current Basin from north to south – mean annual precipitation in the headwaters is 41-42 inches, and 47-48 inches in the southern parts of the basin (Wilkerson 2003). Mean annual precipitation in the Jacks Fork River Basin is approximately 43-44 inches. Annual runoff ranges from 14 to 17 inches per year (Schroeder 1982).

Air Quality

Ozark National Scenic Riverways is designated a Class II air quality area under the prevention of significant deterioration program, as enacted by the Clean Air Act, amended on August 7, 1977. Wet deposition has been monitored at a National Atmospheric Deposition Program (NADP) site at Wappapello, Missouri (MO05), located 30 miles E of the park, since 1981. A visual analysis (http://www2.nature.nps.gov/air/Permits/ARIS/networks/docs/htlnAirQualitySummary.pdf) indicated an increasing trend in wet ammonium deposition, no obvious trend in wet nitrate deposition, and a decreasing trend in wet sulfate deposition from 1984-1999.

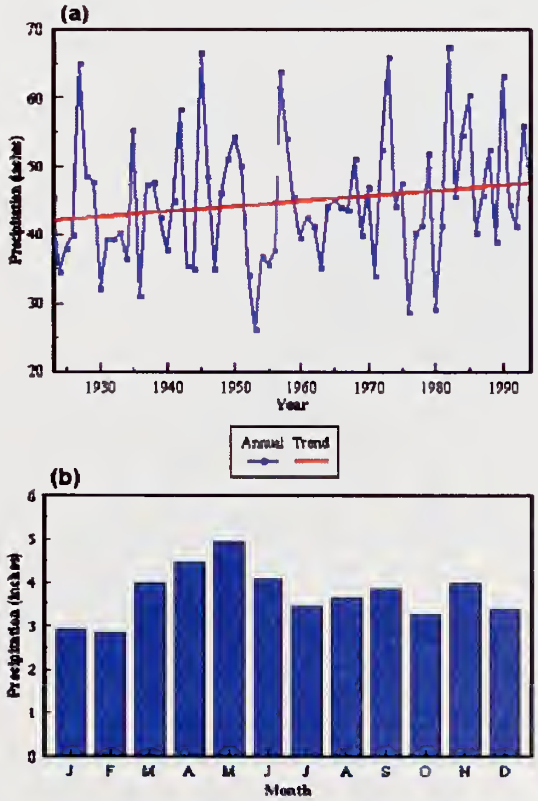


Figure 3. Estimated mean annual precipitation (a) and mean monthly precipitation (b) in the Current River basin, 1923 -1994 (from Wilkerson 2003).

Dry deposition has been monitored at the CASTNet site (CHE 185) on Cherokee Nation lands in Adair County, OK, located approximately 300 miles W/SW of Ozark NSR. For 2004 (most recent data), the annual dry nitrogen deposition at the Cherokee Nation site was 1.8 kg/ha, and the annual dry sulfur deposition was 1.2 kg/ha. A visual analysis indicated no obvious trend in dry nitrogen deposition, and a decreasing trend in dry sulfur deposition.

Physiography

Ozark National Scenic Riverways is located on the Salem Plateau of the Ozark Plateaus physiographic province in southeastern Missouri (Fenneman 1938). The Ozark Plateaus physiographic province covers an area of approximately 40,000 mi^2 and includes parts of four states. The underlying geology largely controls the physiography of this province – a structural dome underlies most of the province. Sedimentary rocks dip away from the center of the dome (igneous rocks) and form three distinct physiographic sections: the Springfield Plateau, the Salem Plateau, and the Boston Mountains (Fenneman 1938). The Salem Plateau is a dissected karst plain consisting of rolling uplands and rugged hills with deeply entrenched stream valleys. Streams and rivers in this sub province follow a dendritic pattern. The channel gradient on the Current River ranges from 8.3 ft/mi in the upper reaches to 3.2 ft/mi near the downstream end of the park. The upper Jacks Fork River has a gradient of

8.6 ft/mi and falls to 5.6 ft/mi near its confluence with the Current River (NPS 2005). Locally, elevations vary from about 510 ft on the Current River to 1,273 ft on Wildcat Mountain; however, relief rarely exceeds 350 ft (Fenneman 1938). There are abundant sinkholes, caves, springs, and losing streams.

Geology

The rocks of the Current River watershed (Salem Plateau) consist mainly of dolomites of Upper Cambrian and Lower Ordovician age (~ 520 Ma to 480 Ma). Structurally, the Salem Plateau is a dome, generally with older rocks (Cambrian) toward the center and younger rock further out. These Paleozoic rocks may be as much as 1,800 ft thick overlying an irregular basement surface of Precambrian age. The dolomites often contain units of chert, sandstone and orthoquartzite; in addition, shale, siltstone, and limestone are present in the subsurface. They are in turn overlain by unconsolidated Tertiary to Quaternary surficial deposits. Exposures of older rock are mainly from erosion and downcutting associated with the major stream valleys. The basement rock of Precambrian age (Middle Proterozoic - ~1,500 Ma) consists of volcanic rocks (rhyolites and tuffs) and some granite, and often appear as irregular knobs.

As is the case in most watersheds of the Ozarks, the geology of the Current River watershed (primarily consisting of water soluble rock such as limestones and dolomites), in combination with an average annual precipitation of over 40 inches has created a karst landscape within the watershed. This karst landscape is characterized, in part, by a close relationship between the surface water and groundwater systems. Within karst landscapes, points or areas of surface water/ground water interaction include losing streams, sinkholes, and springs.

Interactions between surface and ground water processes are greatly enhanced in karst. For example, typical lateral ground water movement in many U.S. aquifers is only a few feet per year (Aley 1975). However, ground water in the park travels up to 3 miles per day (Imes 2002). This is the main reason that karst areas are so susceptible to pollution (Veni *et al.* 2001). Karst areas do not allow for effective filtration and absorption of pollutants from surface sources as it travels into the groundwater system. Also, faster travel rates provide less time for bacteria and viruses to die. Polluted water that may have been on the surface yesterday could be in the groundwater system today and then discharge into the rivers from one of the major springs within a week.

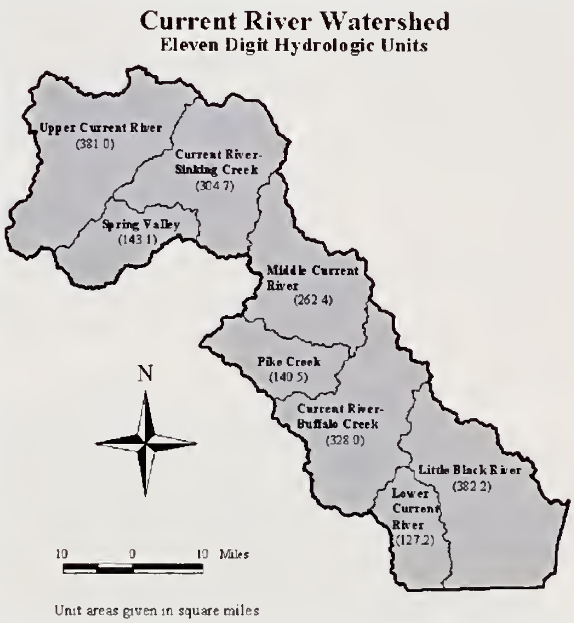


Figure 4. Eleven digit hydrologic units for the Current River watershed in Missouri (modified from Wilkerson 2003).

Soils

The Current River basin lies within the Current River Hills Subsection of the Ozark Highland Section (Missouri Department of Conservation 1997). This region lies on the southeastern flank of the broad Ozark uplift with strata dipping to the south. Underlying bedrock formations consist of Roubidoux sandstone and dolomite, Gasconade dolomite and Eminence dolomite. Small areas of Precambrian igneous occur in the central portion of the basin. Landforms consist of ridges, narrow crests, steep backslopes and narrow river valleys. Soils are related to the geologic formations and associated landforms. Upland soils are moderately well drained to well drained and widely formed in hillslope sediments dominated by gravelly silt overlying gravelly, clay residuum. Depth to bedrock ranges from very deep (>60 in) to very shallow (<10 in). A minor component of the upland soils formed in loess and the underlying colluvium and residuum. These occur on the most stable landforms and occasionally have fragipans, which restrict root penetration and limit water movement. They are moderately well drained. Terraces range from poorly drained to well drained and formed in loamy alluvium and while floodplains are dominated by sandy and gravelly alluvium and range from well to excessively well drained.

Hydrology

Watersheds

The Current River is formed by the confluence of Pigeon Creek and the Montauk Spring near Montauk, MO. The river flows approximately 184 miles in a southeasterly to southerly direction before flowing into the Black River near Pocahontas, AR. The total drainage area of the Current River watershed is 2,621 mi^2 (1,677,440 acres) and covers portions of nine counties (Texas, Dent, Reynolds, Shannon, Howell, Oregon, Carter, Butler, and Ripley) in Missouri and two counties in Arkansas (Randolph and Clay). Most of the watershed (95.9 percent) lies in Missouri. Wilkerson (2003) divided the watershed based on eleven digit hydrologic units. This resulted in 8 units (Figure 4). The largest units are the Little Black River and Upper Current River units which drain approximately 382.2 and 381.0 mi^2, respectively. The smallest is the Lower Current River unit, which drains 127.2 mi^2.

There are 5,285 miles of stream in the Current River watershed (Wilkerson 2001). Approximately 3,255 miles (62 percent) of this total are 1st order streams; 920 miles (17 percent) are 2nd order; 490 miles (9 percent) are 3rd order; 326 miles (6 percent) are 4th order; 128 miles (2 percent) are 5th order; 31 miles (<1 percent) are 6th order; and 135 miles (3 percent) are 7th order. Of the 5,285 stream miles in the watershed only 678 stream miles (13 percent) have permanent water.

The Current River watershed of Missouri and Arkansas has a total of 16 towns or cities within or partially within its boundary. Three of these have populations of > 1,000 persons: Doniphan, MO (1,713); Mountain View, MO (2,036); and Winona, MO (1,081).

The Jacks Fork River is formed by the confluence of the North Prong and South Prong of the Jacks Fork near Mountain View, MO. From this confluence the Jacks Fork River flows in an easterly direction for approximately 49 miles before joining the Current River northeast of Eminence, MO. The drainage area of the Jacks Fork watershed is 445 mi^2 (284,454 acres) and represents approximately 18 percent of the Current River watershed. Wilkerson (2001) divided the watershed into 12 units based on 14 digit hydrologic units (Figure 5). The largest of these units is the North Prong and Mahan's Creek which drain approximately 58.7 and 54.0 mi^2, respectively. The smallest units are Leatherwood and Jam Up Creek, both draining approximately 20 mi^2.

Wilkerson (2001) found a total of 1,189 miles of stream within the watershed – 743 miles (63 percent) are 1st order streams; 219 miles (18 percent) are 2nd order; 114 miles (10 percent) are 3rd order; 29 miles (3 percent) are 4th order; 21 miles (2 percent) are 5th order; and 49 miles (4 percent) are 6th order. Of the 1,189 stream miles approximately 152 stream miles (13 percent) within the watershed have permanent water.

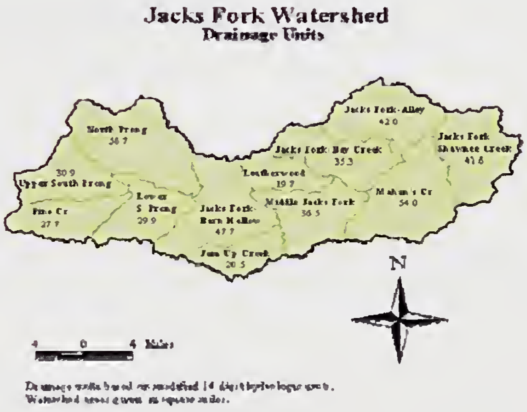


Figure 5. Fourteen digit hydrologic units for the Jacks Fork River watershed (modified from Wilkerson 2001).

The Jacks Fork watershed has two towns with populations exceeding 500 persons within or partially within its boundary – Eminence (573 persons) and Mountain View (2,036).

NPS (2005) lists the 160 named tributaries to the Jacks Fork and Current Rivers. As suggested by the low number of permanent stream miles, many of these tributaries are losing streams that flow only during and after rainfall events; however, this intermittency does not minimize their ecological importance to these watersheds. This suite of tributaries provides energy inputs (nutrients and woody debris); can be sources of contaminants; and, is likely the greatest source of sediments to the rivers, although springs provide the majority of the river's flows.

Jacobson and Primm (1997) summarized land use changes in these watersheds as follows:

> Different types of land use have taken place on different parts of the landscape, and to different times, resulting in a complex series of potential disturbances. Uplands have been subjected to suppression of a natural regime of wildfire, followed by logging, annual burning to support open range, patchy and transient attempts at cropping, a second wave of timber cutting, and most recently, increased grazing intensity. Valley side slopes have been subjected to logging, annual burning, and a second wave of logging. Valley bottoms were the first areas to be settled, cleared, and farmed; removal of riparian vegetation decreased the erosional resistance of the bottom lands. More recently, some areas of bottomland have been allowed to grow back into forest.

Furthermore, for this land-use scenario, it is difficult to separate anthropogenic from natural impacts on streams given the relations among land-use patterns, geology, and physiography (Panfil and Jacobson 2001).

Rivers and Streams

The Current and Jacks Fork rivers are ideal for water recreational pursuits because:1) their gradients are steeper than gradients in other Missouri rivers; 2) large and stable flows are maintained by large spring inflows; and 3) the large spring inflow decreases water temperature, keeping river water cool even in the hottest months (Wilkerson 2001, 2003).
Presently, the U.S. Geological Survey (USGS) operates seven, real time discharge gaging stations within the Current River watershed, including three stations in the Jacks Fork River watershed:

	Station #	Station Name	Period of Record
Upstream			
↓	07064440	Current River at Montauk State Park, MO	2007- present
↓	07064533	Current River above Akers, MO	2001 - present
↓	07068000	Current River at Doniphan, MO	1904 - present
↓	07067000	Current River at Van Buren, MO	1921 - present
↓	07065200	Jacks Fork River near Mountain View, MO (HWY 17 Bridge)	2000 - present
↓	07065495	Jacks Fork River at Alley Spring, MO	1993 - present
↓	07066000	Jacks Fork River at Eminence, MO	1921 - present
Downstream			

In addition, seven other USGS gaging stations have been discontinued. These included three spring stations (Round Spring; Blue Spring; and Alley Spring) and four stream stations (Fudge Hollow; Big Creek; Current River; and Sycamore Creek) (NPS 2005).

Discharge data from the two longest running stations (Current River at Van Buren and Jacks Fork at Eminence) were used to generate daily discharge hydrographs for the 5-year period (October 2001 – October 2005; Figure 6). Both hydrographs are similar with regard to general tendencies of the annual hydrograph. That is, August through October may be considered the normal flow season (mean monthly flows in Current River over 1,000 cfs [cubic feet per second]); November through April the ascending flow season (mean monthly flows in Current River increasing from 1,720 to 3,380 cfs); and May through July the descending flow season (mean monthly flows in Current River decreasing from 3,090 to 1,310 cfs).

The Current River at Van Buren typically averages 2,006 cfs and ranges between with the highest recorded discharge (flood) of 72,000 cfs and the lowest recorded discharge of 476 cfs (Table 1). The flood discharge of 72,000 cfs was perceived by the public as a 100-year flood event, but it actually was less than a 25-year event (Table 2; Wilson 2001). Historically, floods appear uniformly distributed throughout the year except for a period in late August to early September; however, highest flows (i.e. flows exceeded 30 percent of the time) occur from April to May. Flows that are exceeded 10 to 30 percent of the time occur in November to December. For the Current River at Van Buren, a 25-year flood event has occurred only three times within the last 80+ years; a 50-year flood event (Table 2) has not occurred (NPS 2005).

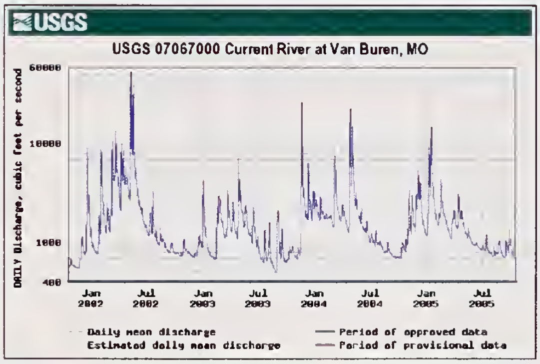
Similar statistics could probably be listed for the Jacks Fork at Eminence gaging station, given its close proximity and karst-based landscape.

Table 1. Flow statistics (cfs) for U.S. Geological Survey gaging stations within the Current and Jacks Fork river watersheds (modified from Wilkerson 2001, 2003).

Station	Median	Mean	Maximum Date	Minimum Date
07067000 (Current R. at Van Buren)	1,270	2,006	72,000 11/15/1993	476 10/8/1956
07068000 (Current R. at Doniphan)	1,940	2,815	90,000 3/12/1935	852 10/8/1956
07066000 (Jacks Fork at Eminence)	----	466	31,800 11/15/1993	67 9/16/1956
07065495 (Jacks Fork at Alley Spring)	----	308	23,300 11/14/1993	52 9/12/1993

Springs

Springs are the naturally occurring outlets of ground water systems. Spring flows account for the higher sustained flows (base flows) of the Current and Jack Fork rivers. More than 60 percent of the combined rivers' flow is from springs. Within the Current River watershed there are 248 known springs (1 spring /8.3 mi^2) (Wilkerson 2003); however, recent spring surveys by the park have located more than 170 additional springs in the lower watershed within the park boundary. Most of these springs have



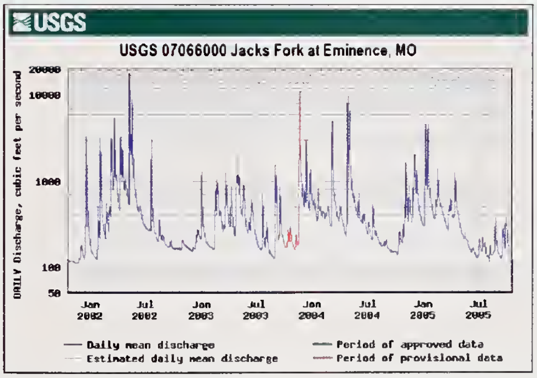


Figure 6. Hydrographs for 5-year period (October 2001-October 2005) for U.S. Geological Survey gaging stations on the Current River at Van Buren, MO and the Jacks Fork River at Eminence, MO. Based on data obtained from: http://www.usgs.gov.

discharges of < 1 cfs, although some discharges of 10 cfs have been found. Vineyard and Feder (1974) list discharges of 49 springs in the Current River watershed with 26 having discharges exceeding 1 cfs. The largest is Big Spring, the largest spring in the Ozarks Region and one of the largest in the world with a mean annual flow of 438 cfs (Table 3).

Table 2. Two to 100-year flood discharges (cfs) for selected U.S. Geological Survey gaging stations on the Current and Jacks Fork rivers (modified from Wilkerson 2001, 2003).

Station	Recurrence Interval in years (discharge in cfs)					
	2	5	10	25	50	100
07067000 (Current River at Van Buren, MO)	26,700	48,900	65,500	87,800	105,000	123,000
07068000 (Current River at Doniphan, MO)	27,300	50,700	68,700	93,500	113,000	185,000
07066000 (Jacks Fork at Eminence, MO)	11,900	24,200	34,100	48,200	59,500	71,500

Within the Jacks Fork watershed, Wilkerson (2001) determined there are 48 springs (1 spring/9.3 mi^2). Recent park surveys have identified more than 150 springs (> 1 spring/3 mi^2) in the watershed within the park boundary, most of which have a discharge < 1 cfs. Vineyard *et al.* (1974) listed discharges for nine springs in the watershed – four of these springs have discharges exceeding 1 cfs. The largest spring within the watershed is Alley Spring with a mean annual flow of 133 cfs (Table 3).

Table 3. Major springs of Ozark National Scenic Riverways and their approximate mean annual flow rate and recharge areas (modified from NPS 2005 and based on Aley and Aley 1987).

Name of Spring	Mean Annual Flow (cfs)	Spring Recharge Area (sq. miles)
Big Spring	438 *	967
Mill Creek Spring	30	30
Gravel Spring	35	35
Blue Spring (Current River)	140	107
Cove Spring (Powder Mill)	**	30.6
Alley Spring	133	125
Blue Spring (Jacks Fork)	25	24.5
Current River Springs *(in channel between Sinking Creek and mouth of Root Hollow, exact location unknown)*	125	125
Round Spring	45	45
Pulltite Complex	223	223
Cave Spring	42	41.4
Welch Spring	140	121
Montauk Spring (adjacent to park boundary)	100	100

* *Based on long-term continuous measurements;* ** *Insufficient data for estimate*

Six first-magnitude springs and spring complexes, those that flow at rates greater than 100 cfs, are within park boundaries (Table 3). Four of these springs rank among the 10 largest in the state (Vineyard *et al.*1974). In addition to the many springs which feed the rivers from spring branches, a number of springs emerge in the river channel. These springs cause changes in temperature, flow regime, and substrate that further diversify the aquatic habitat.

A defining feature of karst systems is that water entering the subsurface at a single point may sometimes discharge from multiple springs and wells. The discharge points are sometimes in different stream or river basins and may be separated from one another by a number of miles. That is, the topographic watershed boundary is not coincident with the groundwater watershed as is typical for non-karst areas (Veni *et al.* 2001). This is the case for many of the large springs in the park. For example, two of the major springs feeding the Current River, Big Spring and Blue Spring, have appreciable recharge areas that extend outside of the topographic boundaries of the watershed (Figure 7). At least six other springs receive smaller amounts of recharge from four other watersheds outside the surface watershed.

Springs are unique ecosystems because they tend toward a uniform temperature, usually the mean annual air temperature of the region. Therefore, springs provide uniform conditions in areas that are subject to seasonal changes. In these spring environments, relict species may have survived and many crenobionts (species confined to springs) can occur far outside their normal geographical range (Hynes 1970). Aquatic plants play a key role in spring ecosystem dynamics by providing organic matter and habitat – key functional and structural needs in these ecosystems. At least 38 animal species are found only in Ozark springs and subterranean waters (The Nature Conservancy 2003).

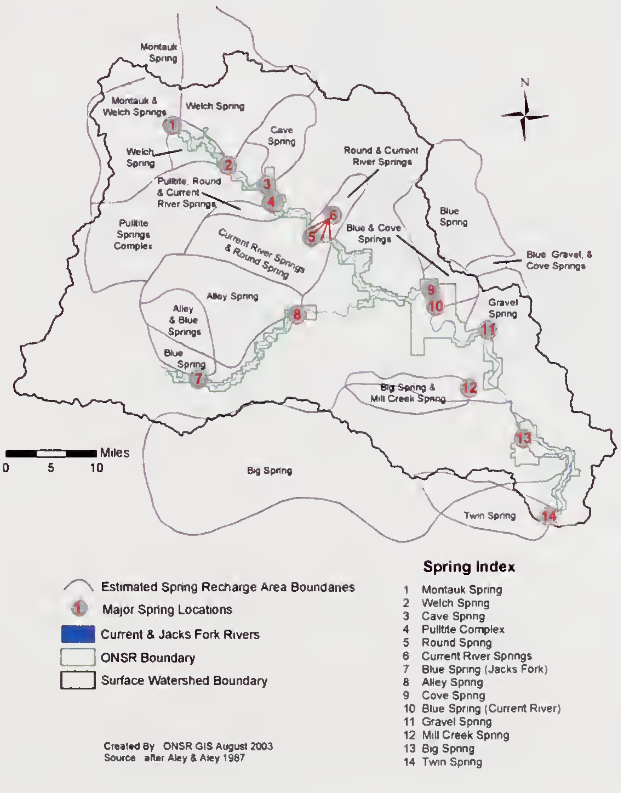


Figure 7. Selected spring locations in Ozark National Scenic Riverways and their estimated recharge areas (after NPS 2005).

Riparian Areas and Wetlands

Natural riparian zones are some of the most diverse, dynamic, and complex biophysical habitats in the terrestrial environment (Naiman *et al.* 1993). The riparian channel encompasses that stream channel between low and high watermarks and that portion of the terrestrial landscape from the high watermark toward the uplands where vegetation may be influenced by elevated water tables or flooding and by the ability of the soils to hold water (Naiman and Decamps 1997). Riparian zones are key systems for regulating aquatic-terrestrial linkages (Ward 1989) and they may provide early indications of environmental change (Decamps 1993).

Physically, riparian zones control mass movements of materials and channel morphology (Naiman and Decamps 1997). Ecologically, riparian zones: 1) provide sources of nourishment – terrestrial inputs to rivers; 2) control nonpoint sources of pollution, in particular, sediment and nutrients in agricultural watersheds; and 3) create a complex of shifting habitats (both in time and space), through variations in flood duration and frequency and concomitant changes in water table depth and plant succession (Naiman and Decamps 1997).

Other than a cursory understanding of the presence of riparian plant species (Lyons and Sagers 1996; Becker 1999), the riparian areas of the park are largely unstudied. In addition, wetlands exist throughout the riparian floodplain forests and bottomlands along the rivers (NPS 2005). Little is known about their composition. The U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI) has produced wetland maps that cover the entire park. These maps, based on USGS quadrangles that are at a scale of 1:24,000, are available as hard copies and as digital data that are easily customized using a wetlands mapper function available through the NWI website (http://wetlandsfws.er.usgs.gov/NWI/index.html). Figure 8 shows a portion of the Current River in OZAR and the locations of several riparian wetland types – it was generated using the wetlands mapper function. Such information can be used, at the least, to corroborate anecdotal evidence that suggests oxbow lakes and sloughs are more common on the lower Current River (NPS 2005). Because NWI maps are based on high altitude photography with minimal ground-truthing, they tend to omit smaller (< 1 acre) wetlands and wetlands with forest cover (potentially significant for OZAR). Most wetland classification errors are probably related to a misclassification of water regimes, or more importantly, gross lumping of habitat types due to small scales. Ongoing soils mapping will also assist in riparian wetland delineation.

Additional inventory and monitoring is needed to verify/determine the type, size and extent of extent of riparian wetlands in OZAR as well as determining and understanding their biotic communities.
The riparian zone and associated wetlands are some of the most disturbed ecosystems in the Ozarks (NPS 2005). For example, cane (*Arundinaria gigantea*) is a unique riparian plant (only genus of woody grass in Ozark region) that forms monotypic stands known as canebrakes. Historically, this species was widespread, but is now considered a critically endangered ecosystem that occupies < 2 percent of its original range (Noss *et al.* 1995).

The Current River watershed has 25 fens and 7 oxbows and sloughs listed in Missouri's natural heritage database; 5 fens, 2 deep muck fens, and one pond marsh are listed for the Jacks Fork watershed (Wilkerson 2001, 2003).

Ground Water

Ground water underlying OZAR is in the Ozark Aquifer of the Ozark Plateaus aquifer system (Miller and Appel 1997). The rocks of this aquifer are mostly dolomite and limestone, but some beds of sandstone, chert, and shale are included. The Ozark aquifer is the primary source of water in the Ozark Plateaus physiographic province. The main water-yielding formations in the Ozark aquifer are the Upper Cambrian Potosi Dolomite, Lower Ordovician Gasconade Dolomite, and Roubidoux formations. The Potosi Dolomite is the most permeable of the three formations. The Ozark Aquifer is less than 1,000 ft thick throughout the Salem Plateau, and is a karst aquifer. Caves, sinkholes, and other types of solution features characteristic of karst topography have developed in the carbonate-rock units that contain the aquifer. The Ozark Aquifer in the Salem Plateau is estimated to contain 208 trillion gallons of water or about 639 million acre-ft (Miller and Vandike 1997). This represents nearly 42 percent of Missouri's usable ground water.

The pattern in the potentiometric surface generally mimics the overlying topography. Precipitation recharges the unconfined aquifer nearly everywhere. Typically, ground water flows laterally from the higher altitudes to points of discharge in springs and seeps along streams. Well yields generally range from 50 -100 gal/min, but can be as much as 500 or 600 gal/min in the Roubidoux Formation or Potosi Dolomite (Imes and Emmett 1994).

Losing streams are common in areas overlying the Ozark Aquifer. These streams are sources of recharge to the ground water system. Results from ground water dye-tracing studies indicate that water recharging the aquifer from losing streams can discharge in springs in adjacent drainage basins. This is another example that ground water divides do not always coincide with surface water divides.

Dissolution of the rocks which comprise the Ozark aquifer allows deep circulation of the ground water. In south central Missouri municipal wells range from 1,300 to 1,500 ft deep. Despite these well depths, water

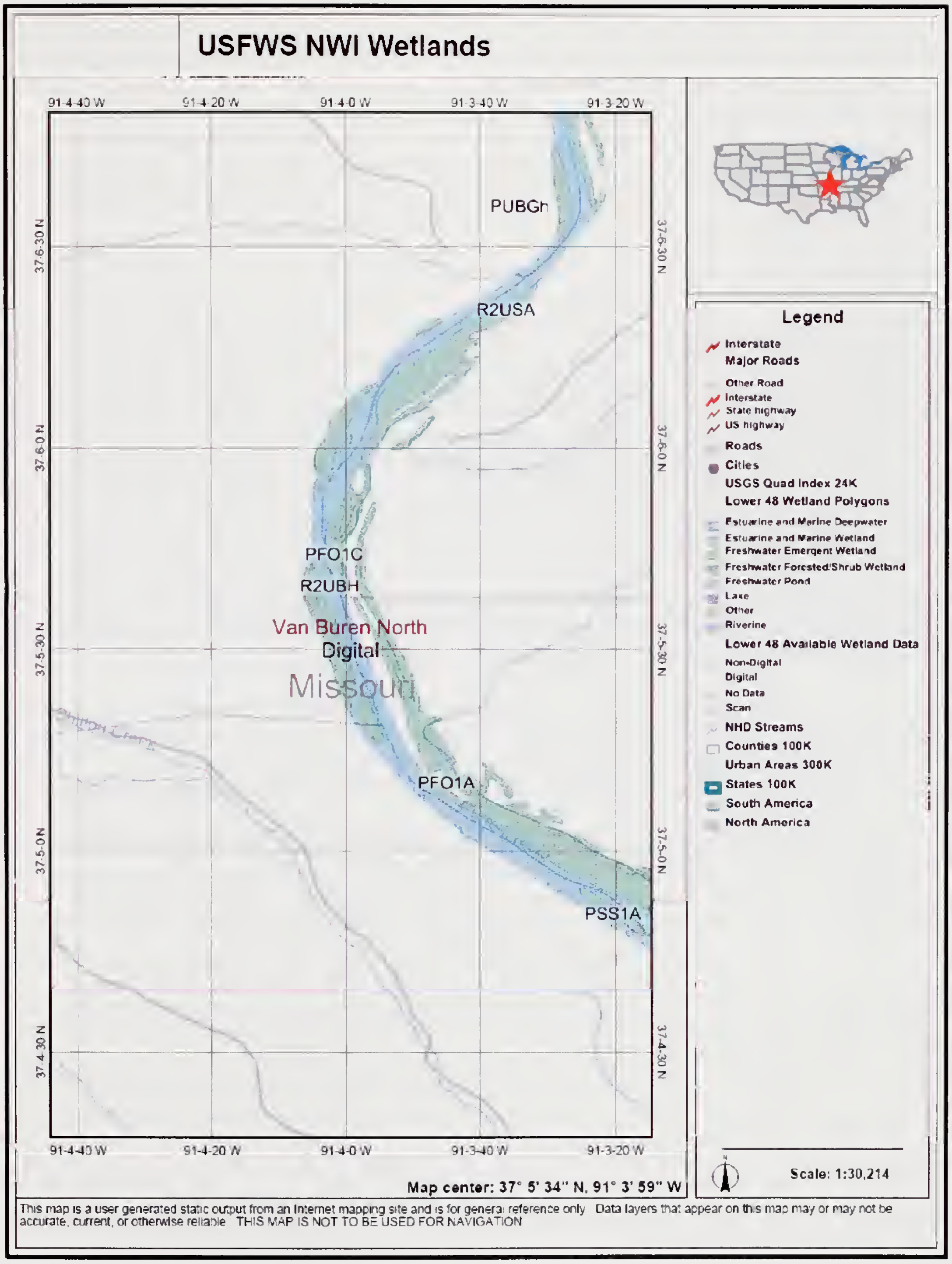


Figure 8. Example of National Wetland Inventory printout for a portion of the Current River in Ozark National Scenic Riverways. Letter/number codes refer to the wetland classification system of Cowardin *et al.* (1979) that is the standard for the NPS: PFO1A = palustrine, broad-leaved deciduous forested, temporarily flooded; PSS1A = palustrine, broad-leaved deciduous scrub-shrub, temporarily flooded; PFO1C = seasonally flooded (well drained) palustine, broad-leaved deciduous forested; PUBGh = diked, palustrine intermittently flooded unconsolidated bottom; R2USA = lower perennial riverine, temporarily flooded, unconsolidated shore; and R2UBH = lower perennial riverine, permanently flooded, unconsolidated bottom.

in some of the wells becomes turbid after a rainstorm, indicating that surface-recharged water rapidly circulates deep within sections of the aquifer (Harvey 1980).

Generally speaking, the predominant water type for the Ozark aquifer under the park is calcium bicarbonate or calcium magnesium bicarbonate (Adamski *et al.* 1995). Calcium is the dominant cation in the ground water of limestone aquifers and calcium and magnesium are dominant in ground water of dolomite aquifers. Bicarbonate is the dominant anion. Adamski *et al.* (1995) list the ranges of some chemical constituents in ground water of the Ozark aquifer: pH (7.0-7.2); chloride (<1-1,000 mg/L); sulfate (<1-500 mg/L); bicarbonate (166-332 mg/L); and dissolved solids (>200-10,000 mg/L). On a local basis, ground water quality for these and other water quality parameters is sensitive to changes in land use and the key to understanding trends in karstic ground water is understanding trends in land use.

Water Quality

Both the Jacks Fork and Current Rivers within park boundaries are designated as an Outstanding National Resource Waters (ONRW) because of their high overall water quality. ONRWs have national recreational and ecological significance and receive special protection against any degradation. In Missouri's water quality standards, ONRWs are classified as Tier Three Waters. For these waters, no degradation of water quality is allowed. For example, if the fecal coliform count that occurs naturally in a waterbody (based on previously collected data) is 25 col/100 ml (geometric mean), it then becomes the standard for that waterbody rather than the presently recognized standard of 200 col/100 ml (geometric mean). This more stringent standard combined with the concept of anti-degradation continues to protect the high overall water quality of these two rivers.

The State has adopted water quality standards intended to protect beneficial uses of water. These standards include designated use classifications for specific sections of the park (Table 4). Associated with each designated use are water quality criteria required to protect that use.

Water quality monitoring in the park has occurred for over 30 years; however, that monitoring has been generally limited to the recreational season. Current monitoring is no exception and occurs from May to

Table 4. Designated uses for the Current and Jacks Fork rivers in Ozark National Scenic Riverways.

Current River (state line to 24,31N,6W)	Outstanding Natural Resource Waters (starting at the northern Ripley County line), Irrigation, livestock and wildlife watering, protection of warm water aquatic life and human health-fish consumption, cool water fishery, whole body contact recreation, boating and canoeing
Current River (24,31N,6W to Montauk Spring)	Outstanding Natural Resource Waters, Livestock and wildlife watering, protection of warm water aquatic life and human health-fish consumption, cold water fishery, whole body contact recreation, boating and canoeing
Jacks Fork River	Outstanding Natural Resource Waters, Livestock and wildlife watering, protection of warm water aquatic life and human health-fish consumption, cool water fishery, whole body contact recreation, boating and canoeing

September. Additionally, there is limited information prior to the 1980's because of a general lack in consistency, including lack of sample site fidelity and choices in analytical methods and parameters.

Water quality data collected in the park from 1973-1995 were compiled and summarized by the NPS (1995). Raymond and Vache (2002) completed a detailed statistical analysis of data collected from 1973-1998. Huggins *et al.* (2005) further analyzed water quality data beyond the timeframes of those studies above. They limited their analyses to: 1) 'Level I' water quality parameters as identified by the NPS' Inventory and Monitoring Program; 2) priority concerns identified by the Heartland Inventory and Monitoring Network; and 3) potential concerns as determined via a comparison of data with water quality standards. The following trend observations come from these studies:

- ⇒ Springs as a group generally have higher total nitrogen levels when compared to river and tributary sites. In addition, the upper Current River showed high levels of total nitrogen.
- ⇒ Median concentrations for total phosphorus in the park are generally below the benchmark of 0.068 mg/L being considered for Region 7 of the U.S. Environmental Protection Agency. Additionally, an analysis of nitrogen:phosphorus ratios suggests that phosphorus is probably the limiting nutrient for algal growth.
- ⇒ Specific conductance, alkalinity, and pH increased in the downstream direction as expected because of the increased spring inflow.
- ⇒ Fecal coliform densities were generally below the state criterion for swimmable waters. The highest fecal coliform densities were consistently observed in the lower Jacks Fork River.

Studies conducted by the U.S. Geological Survey (Barks 1978), NPS and the Missouri Department of Natural Resources (MDNR 1998) suggested that heavy recreational use, primarily from horse trail rides, was causing the elevated fecal coliform bacteria densities that exceed the criterion. An 7-mile section of the Jacks Fork River immediately upstream of the confluence with the Current River is listed as impaired on Missouri's 2002 303(d) list due to excess fecal coliform bacteria (MDNR 2004). The result of this listing was the completion of a Total Maximum Daily Loads (TMDL) study for this impaired section (MDNR 2004) that determined that the endpoint for fecal coliform under natural conditions shall not exceed a 30-day geometric mean of 25 colonies per 100 ml nor should any single sample exceed 200 colonies per 100 ml (MDNR 2004). This endpoint is then used to determine waste load allocations for point sources and load allocations for nonpoint sources.

The U.S. Geological Survey conducted a three-phase study to understand better the extent and sources of microbiological contamination in the 7-mile impaired reach (Davis and Richards 2001, 2002; Davis and Barr 2006). Phase I determined the location and magnitude of the contamination; Phase II established a sampling network to further document and understand sources of contamination; and Phase III established sampling locations for routine, long-term monitoring.

Biological Resources

The Ozark region is one of the oldest continuously exposed land masses on earth and this fact has bearing on the region's high biodiversity (The Nature Conservancy 2003). The Ozarks, because of their location in the North American continent, have served as refugia on a number of occasions for species escaping glacial and geologic events. This biotic influx and high habitat diversity have combined with the antiquity of the landscape to sustain relict populations and also allow for evolution of new species, making the Ozarks an important center of endemism in North America (The Nature Conservancy 2003). For example, the Current and Buffalo Rivers of the Ozark Plateau between them contain the world's best known populations of 34 aquatic species of global conservation significance.

There are 169 species of conservation concern in the Current River watershed (Wilkerson 2003), including 117 species of plants; 7 insects; 5 crayfish; 10 mussels; 1 snail; 17 fish; 4 amphibians, 7 birds; and 6 mammals. Six species within the watershed are federally and state listed as endangered. These include the gray bat (*Myotis grisescens*), Indiana bat (*M. sodalis*), Curtis pearlymussel (*Epioblasma florentina curtisii*), pink mucket (*Lampsilis abrupta*), pondberry (*Lindera melissifolia)*, and running buffalo clover (*Trifolium stoloniferum*). The federally endangered red-cockaded wood pecker (*Picoides borealis)* is currently considered extirpated from the state. The federally threatened bald eagle (*Haliaeetus leucocephalus*) is common along the rivers. The Ozark hellbender (*Cryptobranchus alleganiensis bishopi*) was recently listed as a federal candidate endangered species, and is listed as endangered species by the State. Eight species are considered endangered by the State: Swainson's warbler (*Limnothlypis swainsonii*), harlequin darter (*Etheostoma histrio*), taillight shiner (*Notropis maculatus*), plains spotted skunk (*Spilogale putorius interrupta)*, elephantear (*Elliptio crassidens*), snuffbox (*Epioblasma triquetra*), ebonyshell (*Fusconaia ebena*), and the eastern prairie fringed orchid (*Platanthera leucophaea*).

The Jacks Fork watershed has 51 species of conservation concern (Wilkerson 2001), including 32 species of plants; 2 insects; 1 crayfish; 4 mussels; 5 fish; 2 amphibians, 3 birds; and 2 mammals. Listed species that occur within the watershed include the gray bat, and Bachman's sparrow (*Aimophila aestivalis*).

FUNDAMENTAL WATER RESOURCES AND VALUES

It is important for NPS units to identify the fundamental resources and values critical to achieving the park's purpose and maintaining its significance. The reasons for identifying fundamental and other important resources and values are:

1. To define and understand the most important resources and values that support the park's purpose and significance. If these resources and values are degraded or eliminated, they then jeopardize the park's purpose and significance.
2. To ensure that the park and public understand the key elements that sustain the park's purpose and significance.
3. To help planning and management activities focus on larger issues and concerns regarding protection of those resources and values that support the park's purpose and significance.
4. To facilitate development of alternative management concepts by estimating how they will influence the fundamental resources and values of the park.
5. To become the building blocks in creating a future vision and management strategy for the park while being responsive to the park's needs.


Courtesy of Ozark Natural Scenic Riverways

A Foundation for Planning and Management workshop was conducted at the park by the Denver Service Center-based planning team from October 31-November 3, 2005. The workshop developed draft purpose and significance statements as well as draft fundamental resources and values. I participated initially in a review and revision of the fundamental resources generated at the workshop. Of the five fundamental natural resources, three are specific to water resources (*the fragile, karst-based hydrogeological system*; *the high density of caves and springs*; and *the high water quality and clarity in the free-flowing Current and Jacks Fork rivers*). The other two (*a significant diversity of high-quality ecosystems within the river corridors* and *the assemblage of unique plants and animals*) are an amalgamation of water and terrestrial resources. However, because of the importance and significant contribution of water resources, these two are considered fundamental water resources for the purposes of this document.

Identifying the fundamental resources and values at OZAR helps ensure that all planning is focused on what is truly most significant about the park. The following sections follow a format provided by the NPS Denver Service Center (DSC) Planning Division that formed the analytical basis for the seminal *Water Resources Foundation Report* at Golden Gate National Recreation Area (Weeks 2005). That format includes five questions that are answered for fundamental water resources at the park. The first two questions are centered on water resources in general:

1. Who are the stakeholders who have an interest in OZAR's water resources and values?

2. Which laws and policies apply to OZAR's water resources and values, and what guidance do the laws and policies provide?

The remaining three questions focus on specific water resources at OZAR taking a look at the five fundamental water resources. For each fundamental water resource, the following questions are answered from existing resource information – together the answers form the justification as fundamental resources at OZAR:

3. What is the importance of these water resources and values?
4. What are the current state or conditions and the related trends of these water resources and values?
5. What are the current and potential threats to these water resources and values?

Because any existing or potential threat to water resources, in general, is a threat to any of the above fundamental water resources, with minor exceptions, all threats (Question #5) are discussed as common to all fundamental water resources.

Who are the stakeholders that have an interest in OZAR's water resources and values and what is the level of interest related to those resources?

Federal

U.S. Forest Service has a multi-use mission that ranges from managing wilderness areas to harvesting timber. The traditional mission has been strictly the commercial component; the multiple-use sustainable yield component was added in 1985. The Forest Service decides which acreage should be cut and how to cut it and conducts timber sales on USFS land. The Forest Service manages the Mark Twain National Forest in Missouri, which was established by Congress in 1939. Forty percent of the watershed (including spring recharge areas) is in the Mark Twain National Forest and much of that borders the Park.

U.S. Geological Survey collects and provides scientific information and research for the nation's natural resources. This information gathering effort supports management of water, biological, energy, and mineral resources. The USGS works in close partnership with the NPS conducting monitoring and research on parks throughout the country, including OZAR. There are several gages measuring water level and discharge in the park that are maintained by the USGS.

U.S. Environmental Protection Agency is a federal regulatory agency with a mission to protect both human health and the environment. The EPA develops and enforces regulations that implement the environmental laws enacted by Congress. The EPA is responsible for researching and setting national standards for a variety of environmental programs and delegates to the states the responsibility of issuing permits, monitoring and enforcing compliance. EPA can issue sanctions against states where national standards are not met. The EPA also conducts research on a wide array of environmental issues and provides financial assistance and grants to state environmental programs, such as the Missouri Department of Natural Resources.

Army Corps of Engineers administers the permit program for Section 404 of the Clean Water Act. A permit is required for discharge of dredged or fill materials in waters of the U.S., including wetlands.

U.S. Fish and Wildlife Service is dedicated to protecting threatened and endangered species and their habitats through enforcement and administration of the Endangered Species Act. OZAR is home to several federal threatened and endangered species as well as one federal candidate endangered species.

Natural Resources Conservation Service provides information to agribusiness and landowners regarding land use and Best Management Practices (BMPs) in the Current and Jacks Fork River watersheds and all agricultural regions. Its role is primarily advisory; helping landowners without any enforcement or regulatory power. The NRCS has funds to provide assistance to institute BMPs where they deem applicable.

National Weather Service (National Oceanic and Atmospheric Administration) obtains weather and climate information via monitoring within OZAR.

State
The Missouri Department of Conservation manages numerous conservation areas throughout the Current and Jacks Fork River watersheds with 14,062 acres within the park's boundary. The Department sets hunting seasons and regulations regarding Missouri wildlife resources. Its missions includes protecting and managing the fish, forest, and wildlife resources of the state; identifying and protecting state status species; as well as to facilitating public participation in resource management activities and providing opportunities for all citizens to enjoy the state's resources. It also supports private landowners and provides assistance for a variety of land and wildlife management projects through private landowners. The Missouri Natural Heritage Database provides detailed information about Missouri's status species. The agency is funded by the state of Missouri and was founded in 1937.

The Missouri Department of Natural Resources enforces Clean Water Act regulations regarding industrial, municipal, and agricultural practices, soils runoff, and any activities which could potentially cause degradation to the waters with the Current and Jacks Fork River watersheds. Its primary mission is to monitor pollution and associated ecological impact (s) and regulatory enforcement. OZAR resource management staff work with the Department in conjunction with the water quality monitoring program. In addition, the Department manages Missouri state parks, including Montauk State Park at the headwaters of the Current River which borders OZAR.

Regional
The Scenic Rivers Watershed Partnership was formed in April 1990 when park staff met with the County Commissioners from the eight counties within the watershed. Activities of that partnership include developing and adopting watershed management goals; educating the public on watershed issues; and protecting water quality for the benefit of fish and wildlife. Quarterly meetings are conducted with the park, Missouri Department of Conservation, U.S. Forest Service, the Missouri Department of Natural Resources, and U.S. Fish and Wildlife Service.

Non-Profit Groups
The Nature Conservancy is an international nonprofit agency that protects and preserves unique and biologically diverse landscapes. The Nature Conservancy manages two areas in the Current River watershed; the Chilton Creek preserve which is partially within the park (5,627 acres) and the Thorny Mountain preserve (960 acres) which borders OZAR. Within the park boundary, The Nature Conservancy manages 1362 acres.

The L-A-D Foundation is a non-profit foundation that recently acquired and now manages 144,000 acres of land in the Current River watershed within and adjacent to OZAR. This recently donated land, called the Pioneer Forest, was established by a private businessman named Leo Drey in 1951 in an effort to preserve forests while conducting sustainable single tree selection harvesting. This is the largest private land holding in Missouri. The L-A-D Foundation owns and manages over 4500 acres within OZAR.

Advocacy Groups
The Missouri Coalition for the Environment works to preserve, protect, and enhance an environment that is livable, healthful, and sustainable through a comprehensive program of education, citizen action, and legal defense.

The mission of the Conservation Federation of Missouri is to educate, inspire, and empower individuals and organizations to take action to conserve and to support the sustainable harvest and wise use of fish, wildlife, forest and other natural resources, to help protect our planet's environment, and to nourish an ethic of stewardship and enjoyment of our natural world.

The Jacks Fork Watershed Committee is a local organization that works to educate, preserve, protect, and promote water quality and recreation of the Jacks Fork River and watershed. It includes the NPS, Missouri Department of Conservation, Missouri Department of Natural Resources, Natural Resources Conservation Service and various conservation entities.

The Friends of Ozark Riverways was created in 2003 by individuals and organizations that highly value the natural, cultural, and recreational resources of the Ozark National Scenic Riverways. This organization works under the auspices of the Missouri Coalition for the Environment and is not a formal Friends Group as typically associated with national parks.

The Missouri Stream Team program organizes concerned citizens to address stream problems. Stream Teams tackle stream problems at the local level. Collectively, Stream Team members learn to monitor water quality on a geographic scale far beyond what government agencies can do. They also work to plant trees, stabilize stream banks, and improve fish and wildlife habitats in or near streams. The Scenic Rivers Stream Team Association represents a collection of local stream teams working throughout the Ozark National Scenic Riverways, such as the Stream Team #1571 (Upper Current River) and Stream Team #713 (Jacks Fork).

2. What are the relevant laws and policies that guide the management of the park's water resources and values and what guidance do they provide?

The park management of water resources is guided by many federal and state laws and policies.

Park-specific

A bill was signed into law by President Johnson in 1964 declaring the Current and Jacks Fork Rivers protected under the Ozark National Scenic Riverways. This was the first legislation of its kind and paved the way for the Wild and Scenic Rivers Act of 1968. The park was officially dedicated in 1972.

The U. S. Congress broadly defined the water resource management objectives of in the park's enabling legislation. The principle purpose for establishing the park is contained in Section 1 of P.L. 88-492, 88th Congress, dated August 27th, 1964:

> *That, for the purpose of conserving and interpreting unique scenic and other natural values and objects of historic interest, including preservation of portions of the Current River and the Jacks Fork River in Missouri as free-flowing streams, preservation of springs and caves, management of wildlife, and provisions for use and enjoyment of the outdoor recreation resources thereof by the people of the United States, the Secretary of Interior (hereinafter referred to as the "Secretary") shall designate for establishment as the Ozark National Scenic Riverways...*

NPS policies require that each unit of the national park system develop and implement a General Management Plan (GMP) to provide a basis for the overall management of the unit's natural and cultural resources, public use, and facilities. Initially, a Master Plan was drafted soon after the Park was established. Questions related to the intent of the legislation delayed its completion. A General Management Plan was approved in 1984 in its place. The park's General Management Plan (NPS 1984) outlines the objectives of natural resource management in the park. The overall objective is to "...maintain a diverse natural environment..." through ... "ecosystem management." Specifically, protection of caves, springs, riparian soils and vegetation, the aquatic ecosystem, and water quality are priorities. A primary goal stated in the GMP for resource management is to "ensure a stable quality and quantity of water". Also, the GMP expressed a need to develop a comprehensive watershed management plan to preserve existing quality and quantity of surface and underground waters.

The Current and Jacks Fork rivers are listed on the Nationwide Rivers Inventory (NRI). In partial fulfillment of Section 5(d) (Wild and Scenic Rivers Act) requirements, the NPS has compiled and maintains an NRI, a registry of river segments that potentially quality as national wild, scenic or recreational river areas (see www.nps.gov/rtca/nri).

Federal

- The *National Park Service Organic Act* of 1916 created the NPS and includes a significant management provision stating that the NPS *shall promote and regulate the use of the federal areas known as national parks, monuments, and reservations by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for future generations*. The Organic Act also authorizes the NPS to *regulate the use* of national parks and develop rules, regulations and detailed policies to implement the broad policies provided by Congress. Rules and regulations for the national park system are described in the *Code of Federal Regulations* (Title 36).

- The *General Authorities Act* of 1970 strengthened the 1916 *Organic Act*, stating that lands in all NPS units, regardless of title or designation, shall have a common purpose of preservation. All water resources in the national park system, therefore, are equally protected by federal law. It is the primary duty of the NPS to protect those resources unless otherwise indicated by Congress.

- The *Redwood National Park Act* of 1978 amended the *General Authorities Act* of 1970, identifying the *high public value and integrity of the national park system* as reason to manage and protect all park system units. The act further stated that no activities should be allowed that will compromise the *values and purposes for which these various areas have been established*, except where specifically authorized by law or provided for by Congress.

- The *National Parks Omnibus Management Act* of 1998 outlined a strategy to improve the ability of the NPS to provide high-quality resource management, protection, interpretation and research in the national park system by:

    - Fostering the collection and application of the highest quality science and information to enhance management of units of the national park system;
    - Authorizing and initiating cooperative agreements with colleges and universities, including but not limited to land grant schools, along with creating partnerships with other Federal and State agencies, to construct cooperative study units that will coordinate multi-disciplinary research and develop integrated information products on the resources in national park system units and/or the larger region surrounding and including parks;
    - Designing and implementing an inventory and monitoring program of national park system resources to collect baseline information and to evaluate long-term trends on resource condition of the national park system, and;
    - Executing the necessary actions to fully and properly apply the results of scientific study to park management decisions. Additionally, all NPS actions that may cause a significant adverse effect on a park resource must conduct unit resource studies and administratively record how study results were considered in decision making. The trend in resource condition in the national park system shall be a critical element in evaluating the annual performance of the NPS.

- *Safe Drinking Water Act* (42 USC 3001 et seq.) applies to developed public drinking water supplies. It sets national minimum water quality standards and requires testing of drinking water.

    - *2006 NPS Management Policies*: These policies cover water supply systems; wastewater systems; and recreational waters. Specific guidance is provided by Director's Order 83: Public Health and its associated Reference Manuals – 83A1 (Drinking Water Standards); 83A2 (Cross Connection Control); 83A3 (Water System Security); 83B1 (Wastewater Systems); and 83B4 (Sewage Spill Response Notification).

- The 1972 *Federal Water Pollution Control Act*, also known as the *Clean Water Act*, strives to restore and maintain the integrity of U.S. waters. The Clean Water Act grants authority to the states to implement water quality protection through best management practices and water quality standards. It is in the discussion of water quality standards that the concepts of Outstanding Natural Resource Waters and anti-degradation are discussed. Section 404 of the act requires that any dredged or fill materials discharged into U.S. waters, including wetlands, must be authorized through a permit issued by the U.S. Army Corps of Engineers, which administers the Section 404 permit program. Additionally, Section 402 of the act requires that pollutants from any point source discharged into U.S. waters must be authorized by a permit obtained from the National Pollutant Discharge Elimination System (NPDES). All discharges and storm water runoff from major industrial and transportation activities, municipalities, and certain construction activities generally must be authorized by permit through the NPDES program. NPDES permitting authority typically is delegated to the state by the U.S. Environmental Protection Agency.

Section 303 discusses the requirement that states provide a regular, updated listing of its impaired waters and the reasons for impairment. This section also discusses the Total Maximum Daily Load (TMDL) process that is implemented to improve impaired waters.

- *2006 NPS Management Policies*: The NPS will determine the quality of park surface and ground water resources and avoid, whenever possible, the pollution of park waters by human activities occurring within and outside of parks.

    - Work with appropriate governmental bodies to obtain the highest possible standards available under the Clean Water Act for the protection of park waters.
    - Take all necessary actions to maintain or restore the quality of surface waters and ground waters within the parks consistent with the Clean Water Act and all other applicable federal, state, and local laws an regulations; and
    - Enter into agreements with other agencies and governing bodies, as appropriate, to secure their cooperation in maintaining or restoring the quality of park water resources.

- *2006 NPS Management Policies:* The NPS will manage watersheds as complete hydrologic systems, and will minimize human disturbance to the natural upland processes that deliver water, sediment, and woody debris to streams. The NPS will protect watershed and stream features primarily by avoiding impacts on watershed and riparian vegetation and by allowing natural fluvial processes to proceed unimpeded.

- *Executive Order* 11990: *Wetlands Protection* requires the NPS to 1) exhibit leadership and act to minimize the destruction, loss, or degradation of wetlands; 2) protect and improve wetlands and their natural and beneficial values; and 3) to refrain from direct or indirect assistance of new construction projects in wetlands unless there are no feasible alternative to such construction and the proposed action includes all feasible measures to minimize damage to wetlands.

    - *2006 NPS Management Policies:* The NPS will manage wetlands in compliance with NPS mandates and the requirements of Executive Order 11990 (Wetland Protection), the Clean Water Act, and the Rivers and Harbors Appropriation Act of 1899, and the procedures described in Director's Order 77-1. The service will 1) provide leadership and take action to prevent the destruction, loss, and degradation of wetlands; 2) preserve and enhance the natural and beneficial values of wetlands; and 3) avoid direct and indirect support of new construction in wetlands unless there are not practicable alternatives and the proposed action includes all practicable measures to minimize harm to wetlands. The NPS will implement a "no net loss of wetlands" policy.

- *Executive Order* 11988: *Floodplain Management* has a primary objective *...to avoid to the extent possible the long- and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative.* For non-recurring actions, the order requires that all proposed facilities must be located outside the boundary of the 100-year floodplain. Barring any feasible alternatives to construction within the floodplain, adverse impacts are to be minimized during the design phase of project planning. NPS guidance for this executive order can be found in D.O. 77-2.

    - *2006 NPS Management Policies:* In managing floodplains on park lands, the NPS will 1) manage for the preservation of floodplain values; 2) minimize potentially hazardous conditions associated with flooding; and 3) comply with the NPS Organic Act and all other federal laws and executive orders related to the management of activities in flood-prone areas, including Executive Order 11988

(Floodplain Management), NEPA, applicable provisions of the Clean Water Act, and the Rivers and Harbors Appropriation Act of 1899. Specifically the NPS will:

- Protect, preserve, and restore the natural resources and functions of floodplains;
- Avoid the long-and short-term environmental effects associated with the occupancy and modifications of floodplains; and
- Avoid direct and indirect support of floodplain development and actions that could adversely affect the natural resources and functions of floodplains or increase flood risks.

When it is not practicable to locate or relocate development or inappropriate human activities to a site outside and not affecting the floodplain the NPS will:

- Prepare and approve a statement of findings, in accordance with procedures described in Director's Order 77-2 (Floodplain Management;
- Use nonstructural measures as much as practicable to reduce hazards to human life and property while minimizing the impact to the natural resources of floodplains;
- Ensure that structures and facilities are designed to be consistent with the intent of the standards and criteria of the National Flood Insurance Program (44 CFR Part 60).

- *2006 NPS Management Policies*: Natural shoreline processes (such as erosion, deposition, dune formation, shoreline migration) will be allowed to continue without interference. Where human activities have altered the nature or rate of natural shoreline processes, the NPS will, in consultation with appropriate state and federal agencies, investigate alternatives for mitigating the effects of such activities or structures and for restoring natural conditions. New developments will not be placed in areas subject to wave erosion or active shoreline processes unless 1) the development is required by law; or 2) the development is essential to meet the parks' purposes, as defined by its establishing act of proclamation, and

  - No practicable alternative locations are available,
  - The development will be reasonably assured of surviving during its planned life span, without the need for shoreline control measures, and
  - Steps will be taken to minimize safety hazards and harm to property and natural resources.

- *Federal Cave Resources Protection Act* of 1988 requires protection of "significant caves" on federal lands and fosters increased cooperation and exchange of information between governmental authorities and those who utilize caves located on federal lands for scientific, education, or recreational purposes. Significant caves possess one or more of the following features, characteristics, or values: 1) biota; 2) cultural; 3) geologic/mineralogic/paleontologic; 4) hydrologic; 5) recreational; and 6) educational or scientific. However, all caves on NPS administered lands are deemed to fall within the definition of "significant caves."

  - *2006 NPS Management Policies*: As used here, the term "caves" includes karst (such as limestone and gypsum caves) and non-karst caves (such as lava tubes, littoral caves, and talus caves). The Service will manage caves in accordance with approved cave management plans to perpetuate the natural systems associated with the caves, such as karst and other drainage patterns, air flows, mineral deposition, and plant and animal communities. Wilderness and cultural resources and values will also be protected.

    No developments or uses, including those that allow for general public entry, such as pathways, lighting, and elevator shafts, will be allowed in, above, or adjacent to caves until it can be demonstrated that they will not unacceptably impact natural cave conditions, including sub-surface water movements. Developments already in place above caves will be removed if they are impairing or threatening to impair natural conditions or resources.

Parks will strive to close caves or portions of caves to public use, or to control such use, when such actions are required for the protection of cave resources or for human safety. Some caves or portions of caves may be managed exclusively for research, with access limited to permitted research personnel. All recreational use of undeveloped caves will be governed by a permit system.

  - *2006 NPS Management Policies*: The NPS will manage karst terrain to maintain the inherent integrity of its water quality, spring flow, drainage patterns, and caves. Local and regional hydrological systems resulting from karst processes can be directly influenced by surface land use practices. If existing or proposed developments do or will significantly alter or adversely impact karst processes, these impacts will be mitigated. Where practicable, these developments will be placed where they will not have an effect on the karst system.

- The *Clean Air Act* of 1970 (as amended in 1990) regulates airborne emissions of a variety of pollutants from area, stationary, and mobile sources. The amendments to the act were added primarily to fill gaps in earlier regulations pertaining to acid rain, ground level ozone, stratospheric ozone depletion and air toxics, and also to identify 189 hazardous air pollutants. The act directs the U.S. Environmental Protection Agency to study these pollutants, identify their sources, determine the need for emissions standards and develop and enforce appropriate regulations.

- The *National Environmental Policy Act* (NEPA) of 1969 requires that any action proposed by a federal agency that may have significant environmental impacts shall *utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and in decision making which may have an impact on man's environment.*

- The *Endangered Species Act* of 1973 requires the NPS to identify all federally listed endangered, threatened and candidate species that occur within each park unit and promote their conservation and recovery. The act requires that any activity funded by federal monies that has the potential to impact endangered biota must be consulted through the Secretary of Interior. It requires agencies to protect designated critical habitats upon which endangered and threatened species depend. Although not required by law, it also is NPS policy to identify, preserve and restore state and locally listed species of concern and their habitats.

- *Invasive Species* (Executive Order 13112): enhances and furthers the existing authority of the federal government to assist in preventing and controlling the spread of invasive species.

State of Missouri

Code of State Regulations

Title 3

Division 10 – Conservation Commission – this contains the wildlife code for Missouri and cites constitutional authorities and provisions, endangered species, permits for hunting and fishing, sport-fishing and hunting regulations, taking of wildlife (including fish), etc.

Title 10

Division 20 – Clean Water Commission, Chapters 1-2 Role of Clean Water Commission, Chapter 7 Water Quality – specifies standards for water quality in streams, lakes and reservoirs. Standards are based on designated uses assigned to water bodies.

Division 40 – Land Reclamation Commission, Chapter 10 – contains the permit and performance requirements for in-stream sand and gravel operations.

Division 60 - Safe Drinking Water Commission.

Missouri Revised Statutes (2006)

MRS 64.975 This statute explains provisions to adopt Natural Streams. The majority of voters must approve in county or counties in which the stream is located; provisions may be resubmitted for vote in two years if not passed initially.

MRS 252.210 Contamination of streams - a misdemeanor for dumping, draining, or placing a deleterious substance into waters in sufficient quantity to injure, stupefy, or kill fish.
MRS 256.405 Purpose is to develop information for future water resource management needs. It is intended to provide an important part of the information required in the technical assessment of current and future requirements for the regulation of water use or consumption, or both, on a regional or statewide basis, as may be required.

MRS 256.410 Major water users withdrawing or diverting water required to file registration with division.

MRS 256.621 All persons engaged in groundwater or surface water tracing, for any purpose, shall register with the division. This registration shall be renewed annually. The registrant shall report in writing all proposed injections of tracers to the division prior to actual injection. Written and graphical documentation of traces shall be provided to the division within thirty days of completion of each trace. The division shall maintain records of all injections and traces reported and will provide this information to interested parties upon request at the cost of reproduction.

MRS 304.013 All-terrain vehicles, prohibited on highways, rivers and streams of the state except for landowners operating on their own land, official vehicles, or at designated road system crossings.

MRS 306 – Watercraft regulation and licensing – State Water Patrol.

MRS 578.200 Cave Resources Act. This act includes definitions of caves and sinkholes. Entry or defacing without permission is illegal, introduction of any substance or structure that will or could violate any provision of the Missouri Clean Water Law (present and future) is prohibited.

MRS Chapter 640.4 Water Resources Law. Includes definitions, interstate use, provision for surface and groundwater monitoring, inventory to be maintained on ground and surface water uses (quantity and users), provides for development and periodic revision of a state water plan, and special water protection areas.

MRS Chapter 644 Missouri Clean Water Law. Provides for establishment and operations of the Missouri Clean Water Commission, which is responsible for administration of the law.

Missouri Water Rights

Water rights, whether federal or state law-based, are needed by the park to meet the water needs of park personnel and visitors, and to protect water-dependent resources. Authorities for NPS water rights at OZAR include applicable Missouri law, NPS Organic Act, and park-specific enabling acts. The NPS will obtain and use water in accordance with these legal authorities, and, on a case-by-case basis, will pursue those that are most appropriate to accomplish the purposes and protect water-related resources at OZAR. While preserving its legal remedies, the NPS will work with appropriate water resource entities to protect park resources and, if conflicts amongst multiple water users arise, will seek their resolution through good faith negotiations.

Missouri, like most eastern and Midwestern states, follows English common law doctrines for allocating water in surface watercourses and groundwater without any diversion permit system. Any property owner whose land abuts a watercourse is a riparian and is entitled to riparian rights. Overlying landowners are entitled to withdraw ground water. Surface and ground water, including underground streams, are allocated between users by the common law doctrine of riparian rights. Allocations are made subject to comparative reasonable use interpretations, that is, no one party may divert or use all of the flow to the detriment of other riparians. Reasonable use determinations are made by the court on a case-by-case basis, considering factors such as the volume of water in the stream, climatic conditions, nature of the use and needs of other riparians. Ground water can be used off-site, so long as the off-site use does not deprive neighbors of ground water necessary to the benefit and enjoyment of their land. Except for diversions averaging at least 100,000 gallons per day, which must be reported annually, Missouri does not supervise water diversions, uses, or wells.

From: http://photo.itc.nps.gov/storage/images/ozar/ozar-thumb.00001.html

Specific Fundamental Water Resources

A Significant Diversity of High-Quality Ecosystems within the River Corridors

What is the importance of a diversity of water-related ecosystems?

The karst terrain in southern Missouri is the foundation of the entire two-river system and dependent ecosystems (Covington 2002). Karst topography (springs, sinkholes, and losing streams) and structural features (folds, faults, and fractures) greatly affect water quantity and quality. In karst areas, water commonly drains rapidly into the subsurface at zones of recharge and then through a network of fractures, partings, and caves, emerges at the surface in zones of discharge at springs, seeps and wells (Veni *et al.* 2001). The present ecosystem has developed in response to the karst and it is important that the quantity and quality of water moving through the karst system be maintained.

Much of the aquatic biodiversity in the Current River basin results from heterogeneity of its physical habitat. A mosaic of habitat types defined by different combinations of depth, velocity, substrate and cover have been recognized in park stream channels –a variety of pool and edgewater types and riffles and runs (Rabeni and Jacobson 1993a, b). They combine several ecological and physical habitat requirements in appropriate combinations, allowing for management decisions and restoration efforts to focus on a particular habitat unit rather than a single, isolated aspect of a habitat unit that a fish or other species may not respond to independently (Rabeni and Jacobson 1993a). McKenney (1997) documented the processes and rates of habitat type formation and destruction as well as what controls those processes in Ozark streams. Such information is important in evaluating habitat sensitivity to anthropogenic disturbances, designing long-term ecosystem monitoring programs, and implementing mitigation strategies. Generally speaking, stream channel morphology is highly significant in the river corridor ecosystem of the park – it provides the physical habitat template for the ecosystem in general (Covington 2002).

The Jacks Fork and Current rivers are ideal for recreational use because the main channel gradients are steeper than gradients in other state rivers, thereby creating swifter currents. The Jacks Fork at Eminence and the Current River at Van Buren have gradients of 9.50 and 5.92 ft/mi. Statewide, basins with similar sized drainage areas have an average gradient of 5.80 and 3.45 ft/mi; similar basins in northern Missouri have average gradients of 4.29 and 2.71 ft/mi (Wilson 2001). Additionally, the large amount of spring inflow (60 percent of the combined rivers' flow is from springs) produces large and stable flows, and tends to decrease water temperature, thus keeping the water cool through even the hottest months. Flow stability is at least partially attributable to the storage and transport capacity of the karst topography within the watersheds.

Natural riparian zones are some of the most diverse, dynamic and complex biophysical habitats in the terrestrial environment. Attributes of riparian zones suggest that they are key systems for regulating aquatic-terrestrial linkages and that they may provide early indications of environmental change. Riparian communities perform an array of important ecosystem functions, including stream bank stabilization, thermal regulation of streams, filtering and retention of nutrients, maintenance of ecosystem stability, provision of important wildlife habitat, migration corridors for animals, and organic matter to the aquatic food web. Because OZAR is a long, linear park, understanding the structure and function riparian ecosystems is an essential element of river management. For example, cane (*Arundinaria gigantea*) is the only genus of woody grasses in the Ozark region and forms monotypic stands known as canebrakes. Once widespread, particularly in alluvial floodplains, canebrakes are now regarded as a critically endangered ecosystem reduced to less than 2 percent of its former range (Noss *et al.* 1995). Canebrakes provide important habitat for a number of unique or rare species; they are the most common location of the Swainson's warbler (Missouri endangered species) and are also known habitat for black bears (*Ursus americanus)*, spotted skunks (*Spirogale putorius*), golden mice (*Ochrotomys nuttalli,* Missouri species of concern*)*, swamp rabbits (*Sylvilagus aquaticus*, Missouri rare species), white-tailed deer (*Odocoileus virginianus)*, and gray squirrels (*Sciurus carolinensis)* (Murray 1991).

Wetland types within OZAR include marshes, sinkhole ponds (doline lakes), bottomland forests, riparian areas, and ground water seeps. Groundwater seeps are relatively numerous and are most commonly found along the bases of hillsides in the Ozarks. In the Ozarks alkaline ground waters produce seeps known as fens. Because of their cool and wet microclimate, fens often contain plants more typical of more northern states. Many of these plants are rare or endangered in Missouri.

Springs are unique ecosystems because they tend toward a uniform temperature, usually the mean annual air temperature of the region. Therefore, springs provide uniform conditions in areas that are subject to seasonal changes. In these spring environments, relict species may have survived and many crenobionts (species confined to springs) can occur far outside their normal geographical range (Hynes 1970). Aquatic plants play a key role in spring ecosystem dynamics by providing organic matter and habitat – key functional and structural needs in these ecosystems. At least 38 animal species are found only in Ozark springs and subterranean waters (The Nature Conservancy 2003).

In the Current River watershed, there are the following natural features as listed in the Missouri's natural heritage database: 25 fens; three examples of Ozark creeks and small rivers; four examples of Ozark headwater streams; seven oxbows and sloughs; and six springs/spring branches. Natural features in the Jacks Fork watershed include: 23 caves; one example of Ozark creeks and small rivers; two deep muck fens; five fens; and one pond marsh.

What are the current state or conditions and the related trends of the diverse water-related ecosystems?

Riparian zones are one of the most disturbed ecosystems in the Ozarks. Historically, riparian areas in the Ozarks were generally forested but were heavily logged during the late 1880's to 1900's. Riparian zones of Ozarks streams are naturally extremely dynamic, but rates of channel movement and deposition in the riparian zone have been accelerated in places by human-induced land-use changes, particularly land clearing and logging (Saucier 1983, Jacobson and Primm 1997). This excessive channel migration causes bank erosion and loss of riparian habitat.

Lyons and Sagers (1996) assessed riparian vegetation in the park and found that disturbed sites were much different in species composition and structure compared to undisturbed mesic bottomland forests. Disturbed sites (including campsites and pastures) were 54 percent lower is species richness compared to mesic bottomlands. Of the five most important tree species in mesic bottomland forests (white oak, bur oak, sugar maple, box elder, and sycamore) only sycamore was common at disturbed sites and white oak, bur oak, sugar maple were missing from disturbed sites. Species richness of shrubs decreased by 90 percent and of the species that occurred at these sites, exotic species were found at a much higher abundance than other forest types. The study also found a high loss of organic matter content in soils at disturbed sites. The soils were generally higher in sand content and lower in silt content.

Several studies in the park have identified successional stages in riparian vegetation, described the structure, diversity and dynamics of these fluvial systems but focused on the physical environment, and identified strong relationships between riparian vegetation and environment along the rivers. More recently an ecological classification system was developed that linked vegetation to physical factors within the riparian zone via four ecological land types (Buck *et al.* 2001).

There has been some inventory of canebrakes but park managers are in need of a more extensive assessment of canebrake distribution, structure, and composition over time along the rivers to help preserve this unique riparian community.

NPS (2005) states that little is known about park wetlands and there is a great need for inventory and monitoring to determine the size, extent and species composition of wetland types in the park. National Wetland Inventory (U.S. Fish and Wildlife Service) maps provide a starting point to determine wetland types and their sizes that exist in the park. However, these maps have limitations associated with the use of high altitude photography with minimal ground-truthing. Additional inventory and monitoring is needed to verify the type, size and extent of extent of riparian wetlands in OZAR as well as determine and understand their biotic communities.

Stream channels in the Ozarks, including the park, are changing via the accumulation of chert gravel (Jacobson and Primm 1997). There are two theories for this gravel overload. Saucier (1983) posits that the gravel is a result of massive erosion on hill slopes from the extensive logging during the late 19th and early 20th centuries as well as the introduction of grazing on the cleared lands. Jacobson and Primm (1997) suggested that historical land use changes in the riparian areas are the more likely cause of the increased gravel accumulation. They concluded that open range grazing and land clearing activities in the riparian corridor reduced the amount of soil stabilizing vegetation causing channel instability and redistribution of gravel from upstream and floodplain sources. Observations of streambed aggradation and degradation (Jacobson 1995) indicate that gravel, liberated from upstream drainage channels, has been accumulating in waves towards downstream parts of the drainage basin. The result of this wave is an increase in shallow runs at the expense of pool and riffle habitat. The habitat becomes more uniform, losing diversity and structure. Less biologically productive habitats replace habitats that are more productive and the quality of habitats that are retained is degraded (Rabeni and Jacobson 1993a,b).

A theoretical model of the process by Jacobson and Gran (1997) suggests that in the Current River, downstream of the confluence with the Jacks Fork, waves of gravel will probably continue to grow and move downstream. Because these waves of gravel are from widespread, historical riparian disturbances, they will have a persistent effect on channel instability even in the absence of additional land-use change. Indications are that the primary wave of instability has passed small streams in the Ozarks. The gravel wave is thought to be in the middle portions of the park now, with the upper sections recovering and lower sections not yet impacted (Jacobson and Primm 1997, Jacobson 1995).

Some caves contain streams and some provide habitat for important and environmentally sensitive aquatic cave fauna, including stygobitic crayfish, fish, and various invertebrates. Two bat species that are listed as federally endangered, the gray bat (*Myotis grisescens*) and the Indiana bat (*Myotis sodalis*), reside in numerous caves in the park. At least 28 caves have known gray bat populations and 13 caves have known Indiana bat populations (House 2004). The rare grotto salamander (*Typhlotriton spelaeus*), also known as the Ozark blind salamander, is found in most park caves that contain streams or pools of water. This salamander is listed as a species of conservation concern in Missouri (Missouri Natural Heritage Program 2005). There are 20 caves with recorded grotto salamander populations (House 2004). According to an inventory of 86 caves, Aley (1981) reported at least six caves with populations of the southern cavefish (*Typhlichthys subterraneus*) and House (2004) reports three caves with southern cavefish populations. This fish is also listed a species of conservation concern in Missouri.

The Assemblage of Unique Plants and Animals

What is the importance of the high aquatic-based biodiversity?

A major factor to the Ozark region's high biological diversity is that the region is perhaps the oldest continuously exposed land mass in North America and one of the oldest on earth (230 MYA). Because of the Ozarks central continental location, they have on multiple occasions served as refugia for organisms exposed to climatic extremes associated with glacial and geologic events. This influx of biota from different regions and high levels of habitat diversity have combined with the antiquity of the landscape to sustain relict populations and also allow for evolution of new species, making the Ozarks an important center of endemism in North America (The Nature Conservancy 2003). For example, the Current and Buffalo Rivers of the Ozark Plateau between them contain the world's best know populations of 34 aquatic species of global conservation significance.

Previous samplings (1930-2000) of the fish community in the Current River watershed include a total of 124 species representing 24 families (Wilkerson 2003). Nine species of game fish (as defined by the Missouri Dept. of Conservation) with significant fisheries occur in the watershed. Four species are considered exotic. Collections of the fish community from 1980-2000 showed a substantial decrease in the number of species from collections between 1930 and 1979. Of the species not observed during this timeframe, one is a state endangered and nine are considered species of conservation concern. However, the determination of actual species decline in the Current River watershed is problematical because of inconsistent use of sampling gear and differences in the number and pattern of collections.

The Current River supports a significant trout fishery [rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*), both nonnative species] in its upper reaches (Wilkerson 2003). Montauk State Park, one of Missouri's four trout parks, is at the head of the Current River. Approximately 3 miles of trout stream exist within the state park. An additional 16.7 miles of the Current River below the state park and in OZAR are managed for trout. Currently, the state stocks both rainbow and brown trout in the upper Current River. Introductions of nonnative trout into headwater streams can have numerous effects on the receiving stream ecosystems, potentially threatening native species and disrupting key ecological processes. Dunham *et al.* (2004) list seven key issues for assessing the biological and economic consequences of nonnative trout in headwater ecosystems: 1) effects of nonnative trout can span multiple biological domains; 2) effects of nonnative trout can extend beyond waters where they are introduced; 3) nonnative trout do not travel alone; 4) not all habitats are equal; 5) ecosystems vary in their resistance and resilience to nonnative trout; 6) prioritization can improve management of nonnative trout; and 7) economic costs of recreational fisheries in headwater ecosystems can be substantial. Addressing these issues could provide more effective guidance for determining where recreational fisheries for nonnative trout are justified in headwater ecosystems and where they might be terminated to support other ecosystem values.

Fish collection records (1941-1997) in the Jacks Fork River watershed include a total of 67 species in 16 families (Wilkerson 2001). Collections prior to 1981 included a total of 66 species whereas collections from 1981-1997 included only 50 species. A total of 17 species were observed prior to 1981 but not observed after 1980. Nearly all of these were only observed in one or two collections. In addition, not all sites which harbored these species previously were sampled after 1980.

A total of five species of sport fish (as defined by Missouri Department of Conservation) occur in the Jacks Fork watershed (Wilkerson 2001). There is no state or federal stream stocking efforts in the Jacks Fork watershed.

Within the United States, mussels are the most rapidly declining animal group and constitute the largest group of federally endangered or threatened invertebrates (Jennings 1998). Mussels provide an important middle link in the freshwater ecosystem food chain. They continuously filter water for phytoplankton and microorganism food sources, they are eaten by muskrats (*Odotra zibethicus*), raccoons (*Procyon lotor*), herons (Aredidae), birds, waterfowl, and other terrestrial and aquatic animals (Jennings 1998). They also provide an important bridge between primary and secondary energy production. By filtering and consuming phytoplankton, they are able to rapidly convert energy produced from photosynthesis into the higher trophic levels.

A decline in abundance, diversity, or the disappearance of species can indicate water quality problems and habitat loss. Some mussels also have a unique life stage when the larvae (called glochidia) become free swimming and must attach to a host fish as an obligate parasite. This stage makes mussels even more sensitive to ecosystem disruptions because they are dependent upon a particular host fish species for reproduction (Jennings 1998).

A total of 43 species and subspecies of mussels are known from the Current River watershed (Wilkerson 2003). Of these, two are both federally and state listed as endangered – Curtis pearlymussel and pink mucket. The ebonyshell, elephantear, and snuffbox are state listed as endangered. An additional eight species are listed as species of conservation concern.

A total of 19 species of mussel occur in the Jacks Fork watershed (Wilkerson 2001). Of these, three species are former federal category-2 candidates – elktoe (*Alsmidonta marginata*), Ouachita kidneyshell (*Ptychobranchus occidentalis*), and purple lilliput (*Toxolasma lividus*). Mussel species currently listed as species of conservation concern include the Arkansas brokenray and the three species above.

Fourteen species of crayfish are known from the Current River watershed and five species of crayfish occur in the Jacks Fork watershed, including the Salem cave crayfish (*Cambarus hubrichti*), a species of conservation concern (Wilkerson 2001, 2003). Starting in 1991, a research project focusing on crayfish has been ongoing in the Jacks Fork River. It is probably the longest running, most intense study of crayfish ever in North America (Wilkerson 2001).

Crayfish are an aquatic invertebrate that play a major role in energy flow within the park ecosystem, acting as a keystone species that influences several trophic levels (Whitledge and Rabeni 1997). Because crayfish play a major role as both consumers and prey, they are an important link in managing sportfish (Probst *et al.* 1984, Rabeni 1992b) in the park as well as overall biodiversity. The Black River drainage, which includes the Jacks Fork and Current Rivers, was listed as one of the top conservation priorities in the Ozark Plateaus because of the taxonomic richness and diverse habitat requirements of its crayfish species (Crandall 1998).

DiStefano (2002) determined that of the five habitats surveyed, vegetated edgewaters and forewater/backwater areas had the highest crayfish densities. These habitats have already proven important to aquatic invertebrate species richness (Dosiy *et al.* 1997) as well as a nursery and habitat for young of year fishes (Rabeni and Jacobson 1993b).

Twenty-five species of snails have been identified in the Current River. One species, the rough hornsnail, is a stated listed species of conservation concern (Wilkerson 2003).

Three hundred taxa of aquatic invertebrates have been collected in the Current River watershed and two hundred taxa of aquatic invertebrates have been collected in the Jacks Fork watershed (Wilkerson 2001, 2003). Five species are listed as species of conservation concern – *Stenonema bednariki* (Ephemeroptera-mayflies), *Allocapia pymaea* (Plecoptera-stoneflies), *Hydropsyche piatrix* (Trichoptera-caddisflies), *Ophiogomphus westfalli* (Odonata-dragonflies), and *Tachopteryx thoreyi* (odonata-dragonflies).

Subterranean aquatic karst passages are typically better expressed than emergent cave passages. This is reflected in the regional karst fauna, with subsurface aquatic diversity being greater than subsurface terrestrial diversity – a total of 46 stygobite (obligate cave aquatic) species verses 31 troglobite (obligate cave terrestrial) species (The Nature Conservancy 2003). Distributional patterns of karst fauna are related more to subsurface bedrock and aquifer patterns than to surface topography.

Within the Current River watershed, 169 aquatic species of conservation concern have been identified, including seven insects, five crayfish, ten mussels, one snail, seventeen fish, and four amphibians (Wilkerson 2003). Within the Jacks Fork watershed there are 51 species of conservation concern including two insects, one crayfish, four mussels, five fish and two amphibians (Wilkerson 2001).

An exclusively aquatic giant salamander, the Ozark hellbender, was recently listed as a new federal candidate endangered species. Endemic to the Black and White River drainages in Arkansas and Missouri (including the Ozark National Scenic Riverways), this species is believed to be declining throughout its range, and no populations appear to be stable (U.S. Fish and Wildlife Service 2001).

From: www2.nature.nps.gov

Ozark National Scenic Riverways is home to several endangered terrestrial species which depend on its aquatic resources. Several are directly linked to the aquatic resources of the park. The Indiana bat and the gray bat are both listed as federally endangered under the Endangered Species Act. They reside in caves along the Current and Jacks Fork Rivers, foraging for emergent aquatic insects from the rivers, tributaries, and springs. Most of the caves that serve as important habitat units are closed to public access. Moved from federally endangered to threatened status in 1994, the bald eagle is common along the park, feeding on fish and spending the winter along the river. The bald eagle is still considered a state endangered species. The Swainson's warbler, a state endangered species, is dependent on giant cane for nesting habitat. Cane habitat is rapidly declining throughout the United States and the park supports this important riparian habitat. There are numerous other aquatic species of state or global conservation concern found in the park.

What are the current state or conditions and the related trends of the aquatic-based biodiversity?

No detailed analysis on trends involving diversity or fish density exists in the park. Data generally consist of focused research projects, early inventory data related to the parks establishment, and other surveys related to angling and game fish management actions. Fish community collections date back to 1930 and various collections have continued, with increased focus in the 1960's when the park was established. The Missouri Conservation Department compared data from these various collections but could not determine any trends due to different collection periods, different types of gear, and unclear explanations of sample methodology (Wilkerson 2003)

McClane Environmental Services (2004) conducted an inventory of the mussel community within the boundaries of the park in 2002. The inventory included re-surveying 19 sites previously sampled by the Missouri Conservation Department in 1982 (Buchanan 1996) in addition to 17 new sites. Of the 36 sites, five sites were in the Jacks Fork, the remaining were in the Current River. Eighteen species were found and of these, 13 species were collected only as dead specimens. The population was dominated by 5 species, which made up 96 percent of the total sample size. These included, in order of abundance: Ozark broken-ray (*Lampsilis reeviana brevicula*), Ouachita kidneyshell, rainbow (*Villosa iris*), Ozark pigtoe (*Fusconaia ozarkensis*), and purple wartyback (*Cyclonaias tuberculata*).

In 1982, 1,788 specimens were collected from the 19 sites and in the 2002 inventory, about half as many were collected, 890 specimens. The 1982 study actually collected more at the 19 original sites than the 2002 inventory did at all 36 sites. In 1982, Powder Mill and Two Rivers on the Current River and Hwy 17 Bridge and Bay Creek on the Jack Fork had the highest diversity. In 2002, Logyard and Weymeyer on the Current had the highest diversity per site. The same species were most abundant for both surveys with the exception of *C. tuberculata,* which was not an abundant species in the 1982 inventory. In summary, out of the 22 known historical or current species found within the park, 14 species were collected live in 2002. Sampling the additional sites that were not included in the 1982 inventory resulted in collection of two species not collected in the 1982 survey. Both species were found at Big Tree Slough, a side channel in the Current River.

Although no statistical analyses were done, the McClane Environmental Services (2004) suggested some trends in habitat characteristics related to the areas with high mussel concentration. Some common habitats noted to have more abundant mussel populations include the following: near shore runs with water less than four feet deep, areas where submerged aquatic macrophytes were growing, areas downstream of instream shelters such as vegetated gravel bars or near shore islands but also with sufficient velocity to prevent sediment deposition, and areas wedged among boulders and large cobbles.

Hellbender populations are declining throughout in the Ozarks, particularly over the last 20 years. The hellbender population is also getting older with little indication of consistent reproduction. There is a lack of juveniles in the population which indicates that reproduction may have been limited for some time. The population within the park has not been well studied in the past although some inventory information does exist and additional inventory and monitoring occurred in 2005.

Vegetated edgewaters and forewater/backwater areas comprise only a small portion of the total stream area and are highly susceptible to degradation related to land use in riparian areas. Destruction of these habitats impacts an important trophic link between crayfish and other invertebrates as well as many species of fish.

There has not been any long-term monitoring of the benthic invertebrate community in park waters, but there has been a large amount of research, short-term studies, and special projects (Doisy and Rabeni 2002). The common theme throughout this body of work is the dependence of the benthic invertebrate community on the overall ecological integrity of the Current and Jacks Fork Rivers. The health of the benthic invertebrate community should reflect ecological change in park waters. A draft monitoring protocol for benthic invertebrates in OZAR was recently developed (2006) (www.nature.nps.gov/im/htln/monitoring/projects/aquatic_invertebrates.htm).

More recent benthic macroinvertebrate studies determined the importance of habitat diversity. Doisy *et al.* (1997) sampled each of the habitat types previously discussed. Chironomids were the dominant family in the summer, making up 46 percent of the total specimens but only 14 percent in the fall sample. From the 139 taxa collected, other dominant families included Heptageniidae, Tricorythidae, Baetidae, Hydropsychidae, and Elmidae. This study also collected a rare caddisfly species (*Hydropsyche* [*Ceratopsyche*] *piatrix*) that is on the Missouri endangered species list, as well as two new species to the park – an un-described subterranean dytiscid beetle (*Haideoporus spp.*) from Big Spring and a mayfly (*Baetisca gibbera),* heretofore found only in several eastern states. The finding of new and rare species indicates the importance of habitat diversity in maintaining species diversity.

Doisy *et al.* (1997) also identified the importance of vegetated edgewaters, particularly water willow (*Justicia sp.*), to the benthic invertebrate community. These areas had the highest number of species of the habitat types sampled. Vegetated edgewaters also had the greatest number of rare taxa (12) compared to nonvegetated edgewater, which only had one rare taxon. The habitat types with the highest diversity of invertebrate species were the high gradient riffle, the coarse run, and low gradient riffle.

Rabeni *et al.* (2002) showed that fast water channel units (high gradient riffles) had the most consistent taxa over time, with higher densities and less variability compared to the other habitat units. This is an important finding for designing a biomonitoring program; focused quantitative sampling on high gradient riffles is warranted rather than more time consuming and expensive multiple habitat quantitative sampling protocols.

The Fragile, Karst-Based Hydrogeological System

What is the importance of this hydrogeological system and its values?

The Ozark National Scenic Riverways is situated in a geologically and hydrologically complex area along the Current and Jacks Fork Rivers. The combination of the geology of the two rivers' watersheds (soluble rock formations of dolomites and limestones) with an average annual precipitation of over 40 inches has created a karst landscape (Wilkerson 2001, 2003). The karst landscape is characterized, in part, by a close relationship between the surface and ground water systems, via sinkholes, losing streams, caves, and underground drainage (http://pubs.usgs.gov/fs/fs50-97).

In karst areas like the park, water infiltrates the soil and moves down to the groundwater system by one of two paths. The first path is by diffuse recharge. Water seeps slowly and is spread out and filtered by the soil as it moves toward the water table. The second path is by discrete recharge, which is a concentrated and relatively rapid flow. Substantially greater quantities of water per unit area enter the groundwater system through discrete recharge zones than through diffuse recharge areas.

Once the water reaches the groundwater, it exists as either water in storage or water in transit. In many groundwater systems, once water infiltrates the surface and recharges the groundwater, it is referred to as water in storage. Typical lateral groundwater movement in many aquifers in the United States is only a few feet per year (Aley 1975). Groundwater in the park has been shown to travel up to 3 miles per day (Imes 2002). It is likely that in the park, integrated conduit systems exist at substantial distances beneath the water table. Therefore, interactions between surface and ground water processes are greatly enhanced in karst. This is the main reason that karst areas are so susceptible to pollution (Veni *et al.* 2001). Karst areas do not allow for effective filtration and absorption of pollutants from the surface water as it travels into the groundwater system. Also, faster travel rates provide less time for bacteria and viruses to die. Polluted water that may have been on the surface yesterday could be in the groundwater system today and then discharge into the rivers from one of the major springs within a week.

Discrete recharge is the most common form of recharge in OZAR – 63 percent of recharge to springs (Aley 1978). Sinkholes, losing streams, and discrete recharge zones provide the conduits for water to reach the subsurface through discrete recharge. Sinkholes (which provide 10 percent recharge to springs) are natural depressions in the surface of the land that drain directly into the groundwater system. The density of sinkholes in and near the park ranges from 1 to more than 10 per 100 square miles (Adamski *et al.* 1995). The density of sink holes along the Jack's Fork River ranges from less than 1 sink hole per 100 square miles at the park's far west boundary, to more than 10 within a north-south trending band that crosses the river farther downstream, and extending approximately to Eminence, MO.

Losing streams (which provide 11 percent recharge to springs) are surface streams that lose significant quantities of water into the subsurface in segments within the stream (Aley 1978). The stream seems to disappear into the ground and then reappear, often many times along its course. Many of the surface streams in and adjacent to the park are losing streams. Gladden Creek and Pike Creek are two examples of large losing stream basins in the park area. Hurricane Creek, which is tributary on the surface to the Eleven Point River, but provides water to Big Spring on the Current River via the groundwater system, is a major losing stream. Logan Creek, another losing stream that drains surface water to the Black River yields interbasin flow to Blue Spring on the Current River (Aley and Aley 1987).

Losing streams are one manner in which surface water is transported or lost to the ground water system. Within the Current River and Jacks Fork watersheds there are 211 miles and 8 miles, respectively, of streams that have been designated as losing according to rules of the Missouri Department of Natural Resources (Wilkerson 2001, 2003). The definition of a losing stream in these rules is specific in nature and many more streams in these watersheds, which possibly lose large amounts of flow to the ground water system, have yet to be surveyed or classified.

Discrete recharge zones (which provide 42 percent recharge to springs) are areas where a substantial volume of groundwater recharge occurs but where there is no topographic expression of the recharge zone (such as a sinkhole) (Aley 1978).. Even though we often cannot identify the location of these areas, the behavior of spring systems clearly demonstrates that they exist. There are numerous discrete recharge zones in and adjacent to the park and these non-surface expression features make up the largest percentage of discrete recharge features.

Big Spring is a good example of the magnitude of interbasin transfer of groundwater (see Figure 7). Dye work has provided evidence of a large groundwater trough that extends from Big Spring to Hurricane Creek, 25 miles west of the spring and outside of the Current River topographic watershed. Hurricane Creek is part of the Eleven Point River surface drainage network. This trough indicates the presence of a large conduit system that supplies groundwater to Big Spring from the Eleven Point River topographic basin. Groundwater tracing studies (Aley and Aley 1987) have demonstrated straight-line groundwater flow distances to this spring of nearly 40 miles. The dye introduced in the losing stream was first detected at Big

Spring 16 days later (Wilkerson 2003). This complex underground network results in a huge recharge area for Big Spring, estimated to be 967 square miles (Aley and Aley 1987).

The additional spring recharge areas add approximately 31 percent more acreage to the surface watershed. The surface watershed is approximately 1,161,075 acres and the watershed including the spring recharge areas outside the surface watershed adds an additional 362,985 acres. The extended watershed (surface watershed + additional spring recharge areas) is 1,524,060 acres.

Unlike other landscapes, groundwater recharge into karst aquifers carries substantial amounts of dissolved and suspended materials underground (Veni *et al.* 2001). Great volumes of sediment are transported underground in karst areas, sometimes resulting in openings becoming clogged. The karst landscape of the region tends to produce a bimodal sediment load; clay and silt are flushed from these streams whereas chert gravel moves slowly, resulting in land-use induced aggradation in streams by coarse rather than fine sediment.

A Geoindicator Scoping Report for OZAR (Covington 2002) identified 16 geoindicators that were applicable to the park. Karst activity was one of three that were identified has having the most importance to park ecosystems, the greatest impact from human influence, and the highest level of management significance to the park.

What are the current state or conditions and the related trends of the karst-based hydrogeological system?

Many water quality problems in a karst environment are due to the interaction of surface and subsurface waters. The key to protecting water quality is to prevent contamination from entering the ground water system. For example, because infiltration into groundwater is quite rapid in karst terrain, the park and its spring systems are more sensitive to land use practices than in other geologic regions. Chemicals and waste products deposited on the land can be rapidly washed into sink holes and conduits, polluting springs and rivers in the Riverways. In July of 2001, a spill at the Mountain View Wastewater Treatment Plant introduced 50,000 gallons of untreated sewage into a losing stream that recharges Big Spring, which feeds directly to the Current River and is the largest spring in the state of Missouri. The volume of water discharging from Big Spring was 3,900 times greater than the amount of wastewater that was discharged into Jam Up Creek so the contamination was diluted by the time it reached Big Spring (Imes and Fredrick 2002). Had this type of accident occurred in a recharge area of a smaller spring in the park with less dilution of the contamination, severe ecological damage and public health threats could have occurred both in the spring branch and in the Current River.

Because the karst environment is sensitive to changes in land use, the key to understanding trends in karst is understanding trends in land use. In the last 30 years, upland land-use changes have involved moderate acreage increases, particularly with increased timber production from second growth forests and increased land clearing for cattle pasture. Bobbitt (1995) concluded that overall land use changes for the Jacks Fork and Current River basins had been small. Forested areas decreased slightly in the Current River watershed but increased minimally in the Jacks Fork River watershed and agriculture and barren lands increased slightly in both watersheds.

While there have been relatively small changes in land use in the last thirty years, the threat for major disruptions to the karst environment of the park still exist. The karst landscape that generally surrounds the park is similar in characteristic to the karst landscape protected with the park boundary. Ecological functioning is still dependent upon the broad landscape scale and its natural characteristics. Urban encroachment, larger scale industrial or agricultural development, or new mining operations are examples of land use threats to the karst landscape. Such land uses and their attendant impacts would have significant impacts on the structure and functioning of the karst environment.

<u>The High Density of Exceptional Caves and Springs</u>

What is the importance of a high density of caves and springs?

Caves in OZAR represent both hypogenic and epigenic types. Hypogenic caves form in and follow strata beneath impermeable sandstone horizons. These caves were formed below the water table, in confined aquifers, and possibly under enhanced hydrostatic pressure. In contrast, epigenic caves are formed in strata above sandstones from water percolating down into unconfined aquifers and flowing along the top of the sandstone units. Epigenic caves represent the majority of all caves.

In a mature cave system like OZAR, an underground branching, tree-like drainage network develops that resembles surface stream systems (Veni *et al.* 2001). The flow of water is concentrated in large conduits and typically emerges at a few springs with high rates of discharge. At this stage, the karst groundwater system is a coherent part of the hydrologic cycle. Water passes downward from the surface, through this efficient system of natural pipes and emerges elsewhere at the surface as seeps and springs.

From: http://mdc.mo.gov/areas/natareas/p126-1.htm

There are 338 recorded caves that exist as part of the karst system in the park (House 2004). Some of these caves, such as Round Spring Cavern, are extensive. While there are numerous caves in the park, many of the openings have little or no accessible cave passage located behind their large entrances. Other caves may have passages but they are buried beneath slabs of rock which have collapsed off the entrance ceiling, blocking the passageway. According to House (2004), there are 60 caves with perennial streams in the park and 33 caves with intermittent water sources. Aley (1981) noted seven caves with lakes. The largest of these caves is in Devils Well Cave; the lake is about 400 feet long, up to 50 feet wide, and up to 200 feet deep. This is one of the largest cave lakes known in the United States.

OZAR ranks second only to Grand Canyon National Park (GRCA; estimated total of 1000 caves) for the greatest number of caves in a national park unit (Ronal Kerbo, NPS, pers. comm. 2006). However, OZAR has the highest density of caves in the NPS, approximately 1 cave per 239 acres. GRCA has, at best, about 1 cave per 1,217 acres.

Within OZAR there are eight caves and an open sinkhole that are designated as outstanding natural features. Four OZAR provide priority habitat for federally endangered Indiana and gray bats (http://www.nps.gov/ozar).

Springs are the naturally occurring outlets of ground water systems. Spring flows account for the higher sustained flows (base flows) of the Current and Jack Fork rivers. At least 60 percent of the combined rivers' flow is from springs. Within the Current River watershed there are 248 known springs (1 spring /8.3 mi^2, Wilkerson 2003) with more being documented through recent inventories. Vineyard and Feder (1974) list discharges of 49 springs in the watershed with 26 having discharges exceeding 1 cfs. The largest is Big Spring with an average flow of 276 million gallons/day and peak flows of 800 million gallons/day. Big Spring is the largest spring in the Ozarks Region and one of the largest in the world. It has been calculated that a daily average of 175 tons of calcium carbonate is removed from underground in solution through Big Spring. As a result, in one year the total volume of cave openings increases by 30 feet x 50 feet x 1 mile or 7,920,000 cubic feet (http://pubs.usgs.gov/fs/fs50-97/).

Within the Jacks Fork watershed, there are 48 springs (1 spring/9.3 mi^2) (Wilkerson 2001). Survey results conducted within park boundaries in the watershed indicate that significantly more springs exist than those displayed on USGS topographic maps. Vineyard *et al.* (1974) list discharges for nine springs in the watershed – four of these springs have discharges exceeding 1 cfs. The largest spring within the watershed is Alley Spring which has an average flow of 80 million gallons/day.

Six first-magnitude springs and spring complexes, which flow at more than 100 cfs, and at least 250 smaller springs are currently known to contribute flow to the rivers and their tributaries. Four springs within the park rank among the 10 largest in the state (Vineyard *et al.*1974). The largest spring in the park is Big Spring, which is the largest spring in the United States west of Florida and east of Idaho and the largest freshwater spring within the National Park System. In addition to the many springs which feed the rivers from spring branches, a number of springs emerge in the river channel. These springs cause changes in temperature, flow regime, and substrate that further diversify the aquatic habitat.

What are the current state or conditions and the related trends of these caves and springs?

From the standpoint of numbers and densities of caves and springs, the current condition can be considered exceptional. Given the dynamic nature of karst environments, we can probably expect to see the discovery of new caves and springs in the future.

Caves and springs of the park are the most visible expressions of the karst environment and as such will respond to changing conditions via land use changes. Therefore, the discussion of conditions and trends under the karst-based hydrogeologic system would be applicable to caves and springs.

<u>High Water Quality and Clarity in the Free-Flowing Current and Jacks Fork Rivers</u>

What is the importance of high water quality and clarity in these rivers?

All of the Jacks Fork and Current rivers are designated as Outstanding National Resource Waters (ONRW) because of their high overall water quality. ONRWs have national recreational and ecological significance and receive special protection against any degradation.

Springs in the park supply most of the baseflow for the Current and Jacks Fork Rivers – 60 percent of the combined rivers' flow is from springs (Wilson 2001). It is this large proportion of spring-derived flow, combined with the fact that most tributary flows do not reach the rivers because their flow is lost to the karst environment that contributes to the water clarity so prized in Ozark streams (NPS 2005). In fact, with 134 miles of river with high water clarity OZAR is probably one of a handful of areas with such clarity in the continental U. S.

Springs also maintain the temperature of the rivers in a narrower, year-round range than that of runoff-based streams. This speaks to a biologically important fact – a river that is cool in summer because it is spring-fed is warmer in winter than streams fed by run-off. This is a contributing factor in the collection of the unique aquatic biota.

A Geoindicator Scoping Report for OZAR (Covington 2002) identified 16 geoindicators that were applicable to the park. Three of these were identified has having more importance to the ecosystem of the park, the greatest impact from human influence, and the highest level of management significance to the park – surface water quality was one of these three. The quality of water in the two rivers is of utmost importance both for the ecosystem and for visitor enjoyment. And it is the excellent water quality that draws people to the park and is responsible for a diverse aquatic ecosystem.

The Heartland Inventory and Monitoring Network, of which OZAR is a member, recently determined that the following specific water resources are key resources for the park (Debacker *et al.* 2004); perennial streams; intermittent/ephemeral streams; cold springs; seeps; caves; riparian wetlands; cave invertebrate communities; fish communities; mussel communities; stream macroinvertebrate communities; and karst features.

Debacker *et al.* (2004) also determined the following monitoring vital signs for OZAR: 1) for rivers and streams – discharge, water clarity, stream pathogens, nutrient loading, stream macroinvertebrates, stream core elements, fish community, stream habitat quality, and metal contaminants; 2) for springs – discharge; and 3) for wetlands – amphibians. The high number of water-based vital signs is indicative of the importance and significance of water resources to OZAR.

What are the current state or conditions and the related trends of water quality and clarity in the parks?

Despite the critical role of the water quality monitoring in protecting the park, the data are lacking in many respects. There is limited information prior to the 1980's because few sites were consistently monitored for water quality, including inconsistencies in sampling locations, analytical methods, and parameters sampled. While there has been more consistent and increased monitoring activity in the last decade, data collection is still limited to the recreation season (May-September). The lack of seasonal water quality data limits statistical inferences regarding temporal trends in water quality. There is also lack of data regarding high flow events in the park. High flow event data could provide important insight into the land use impacts occurring in the park watershed.

Overall water quality within the Current River watershed appears to be relatively good (Wilkerson 2003). With the exception of a 7-mile section of the Jacks Fork River (see below), overall water quality of the Jacks Fork watershed would also appear relatively good (Wilkerson 2001).

Water quality data collected in the park from 1973-1995 were compiled and synthesized by the NPS (1995). Raymond and Vache (2002) completed a detailed statistical analysis of data collected from 1973-1998. The following trend observations come from these studies.

Increased nitrogen levels in streams are often associated with human activities such as waste disposal and urbanization. Concentrations of total nitrogen are relatively low in the park; however, concentrations during spring and summer have shown an increasing trend in recent years (NPS 2005).

Springs as a group are significantly higher in nitrates compared to river and tributary sites: Alley Spring has the highest nitrate levels of all the sites (Raymond and Vache 2002). Numerous studies indicate that karst aquifers are susceptible to nitrate leaching into the groundwater in the Ozarks, so springs often show the effects of land use in the watershed when the tributaries and main stem river do not (Austin and Steele 1990; Adamski 1987; Edwards and Daniels 1992). The upper Current River was also higher in nitrates than all the other sites except Alley Spring (Raymond and Vache 2002). Barks (1978) noted a similar high concentration of nitrates in the upper Current, possibly related to the close proximity of Montauk Springs and a trout hatchery at the headwaters of the river.

Total phosphorus levels in the park are generally below the threshold (0.03 mg/L) that would cause concern (NPS 2005). Less than 3 percent of the total phosphorus measurements from the park exceeded this threshold and there was no evidence of increasing annual phosphorus trends at any monitoring site. Alley Spring and the Upper Current River both showed significantly higher levels of total phosphorous than other sites in the park, with Alley Spring showing the highest concentration (Raymond and Vache 2002).

The N:P ratio is an indication of which nutrient likely limits freshwater algal growth. Phosphorus limits algal growth when N:P ratios > 16, and N limits growth when the ratio is <16. Data from the Riverways suggest that P is most likely the limiting nutrient for algal growth (NPS 2005). Low phosphorus in park waters is not surprising given the infertile soils in the watershed. Anthropogenic increases in total N may not result in more frequent or intense algal blooms, because the system is P-limited. However, park waters may be sensitive to small increases in P that could cause nuisance algal blooms. As might be expected, the upper Current River had higher levels of chlorophyll-*a*, a measure of plant material abundance indicative of higher nitrogen and phosphorus levels (Raymond and Vache 2002).

Raymond and Vache (2002) determined that an upper Jacks Fork River site showed an increasing trend in total nitrogen and total phosphorous based on visual inspections of scatter plots. This was not a statistically significant trend but in combination with generally increasing levels of chlorophyll-*a* concentrations on the Jacks Fork, a change in the system could be occurring (NPS 2005).

Specific conductance, alkalinity, and pH increased in the downstream direction in both the Current and Jacks Fork rivers (Raymond and Vache 2002). This is an expected trend due increased spring seepage into the river channel bringing higher concentrations of bicarbonates into the system (NPS 2005). However, some of the major spring branches flowing into the Current and Jacks Fork rivers had lower specific conductance, pH, and alkalinity than the river and tributaries. This could be related to a fast transport time for groundwater in these systems. Springs with high conductance and alkalinity generally show longer residence times for the water in transport, allowing more time for the bicarbonates to dissolve in the water. This low residence time in the major springs indicates the vulnerability of park waters to rapid contamination from groundwater as pollutants move quickly through spring systems and into the rivers (NPS 2005).

Studies conducted by the USGS (Barks 1978), NPS and the Missouri Department of Natural Resources (1998) have suggested that heavy recreation use is causing adverse impacts on the water quality of the Jacks Fork River, including elevated fecal coliform bacteria densities that exceed the standard for whole body contact recreation. A 7-mile section of the Jacks Fork River immediately upstream of the confluence with the Current River was listed as impaired on Missouri's 2002 303(d) list due to excess fecal coliform bacteria (Missouri Department of Natural Resources 2004). That is, the 2002 Missouri standard for Whole Body Contact Recreation of 200 colonies/100 ml was often exceeded and these high counts are not attributed to natural causes.

Because the impaired section is part of the ONRW there can be no degradation under any conditions. States are required to establish Total Maximum Daily Loads (TMDLs) for the identified pollutant. A TMDL specifies the maximum amount of the identified pollutant allowed to be present in a water body, allocates allowable pollutant loads among sources, and provides the basis for attaining or maintaining the water quality standard within the affected waterbody. The TMDL for this impaired section of the Jacks Fork River was completed late in 2004 and determined that the endpoint for fecal coliform under natural background conditions shall not exceed a 30-day geometric mean of 25 colonies per 100 milliliters (Missouri Department of Natural Resources 2004). Nor shall any single sample exceed 200 colonies/100 milliliters. This endpoint is used to determine waste load allocations for point sources and the load allocation for nonpoint sources. However, the applicable bacterial standard to the Jacks Fork or any other water body in the park is confusing as Table 5 suggests. This is, in part, due to revisions to the water quality standards by the State of Missouri in 2005 and a movement away from fecal coliform bacteria towards *E. coli* as the preferred indicator of bacterial contamination. For example, the State of Missouri 2006-2008 bacterial standard eliminates the single sample standard and does not specify the number of samples nor timeframe for the geometric mean standard. This is less restrictive. Additionally, the fecal coliform standard will be phased out in 2009. Finally, the current NPS standard for *E. coli* recognizes a single sample standard; whereas, the State of Missouri does not.

The USGS conducted a three-phase study to better understand the extent and sources of microbiological contamination in the 7-mile impaired reach. Davis and Richards (2001) found fecal coliform densities were generally larger in the 7-mile reach and that the standard was exceeded at some sites. Data from Phase II (Davis and Richards 2002) indicated that, after accounting for wet-weather flow, the largest densities were during trail rides – this occurred in both water and streambed sediment samples. Although it is evident from 5 years of sampling that fecal coliform densities tend to increase to sometimes unacceptable levels during trail rides, the exact causes for the increase and the sources of the bacteria have not been positively identified. Phase III was an attempt to determine the causes and sources. Results from Phase III (Davis and Barr 2006) include: 1) generally, bacterial densities tended to decrease or stay constant as the number of canoes, kayaks and tubes passing a site increased. However, during trail rides, the bacterial densities tended to increase as the number of horses crossing the river increased, and decrease with a decrease in the number of horses crossing the river; 2) fecal coliform bacteria densities in streambed sediment have no relation with season or recreational activity; 3) A total of 501 fecal coliform bacteria isolates were analyzed via a methodology that identifies presumptive sources of fecal bacteria in the Jacks Fork River – 70 isolates were from sewage, 132 to horses, 118 to cattle, and 181 unknown.

What are the Current and Potential Future Threats to the Fundamental Water Resources?

The Draft Water Resources Management Plan (NPS 2005) discusses in some detail the following threats to the park's water resources:

- Groundwater Contamination

Because infiltration into groundwater is quite rapid in karst terrain, the park and its spring systems are more sensitive to land use practices than in other geologic regions. Groundwater tracing studies in the park indicate that groundwater travel is routinely on the order of thousands of feet per day (Aley and Aley 1987). Septic tank effluent can travel though soil to karst aquifers and finally to springs in just hours

(Crawford 1998). Chemicals and waste products deposited on land can rapidly wash into sink holes and ground water conduits, polluting springs and rivers in the park. In addition, over 40 percent of the annual allocation of water recharging springs in the park is from features that are not coincident with the topographic surface so their location is unknown. Aley and Aley (1987) identified the following activities that pose threats to groundwater quality: agricultural and forestry activities; sewage disposal facilities,

Table 5. Bacterial standards applicable to the Current and Jacks Fork rivers and tributaries (pers. comm., Victoria Grant, Ozark National Scenic Riverways 2006). Abbreviations are: Geomean = geometric mean; WBC-a = whole body contact for primary contact recreation waters; WBC-b = whole body contact for secondary contact recreation waters; TMDL = total maximum daily load; and USPHS/NPS = U.S. Public Health Service/National Park Service.

		Standard					
		Anti-degradation	TMDL Jacks Fork Only	Statewide 2005	Statewide 2006-2008	Statewide 2009	USPHS/NPS
Fecal Coliform colonies/ 100mL	**All WBC waters**	No degradation	25 Geomean* and 200 Single Sample	200 Single Sample	_____	_____	_____
	WBC-a	No degradation	25 Geomean * and 200 Single Sample	_____	200 Geomean **	_____	_____
	WBC-b	No degradation	_____	_____	1800 Geomean **	_____	_____
E. coli colonies/ 100mL	**WBC-a**	No degradation	_____	_____	126 Geomean **	126 Geomean **	126 Geomean *** or 235 Single Sample
	WBC-b	No degradation	_____	_____	548 Geomean **	548 Geomean **	_____

* Geometric Mean of 4 equally spaced samples in a 30-day period year round
** Geometric Mean of an undefined number of samples over an undefined period of time during the recreational season
*** Geometric Mean of 5 weekly samples (based on National Park Service Director's Order 83).

dumps, landfills, and salvage yards; industrial sites; transportation routes including major pipelines; petroleum storage sites; and chemical storage sites.

Groundwater contamination from underground storage tanks (gasoline) has occurred in Eminence and Van Buren. A timber post treatment plant in Winona, near a major losing stream, has been designated as a Superfund site due to the danger of groundwater contamination.

In July 2001, a spill at the Mountain View Wastewater Treatment Plant introduced 50,000 gallons of untreated sewage into Jam Up Creek, a losing stream. The 'lost' surface water in the stream eventually discharges at Big Spring, a distance of 38 miles.

Most spring recharge areas are outside of the park boundary; therefore, the protection of water quality in the Current and Jacks Fork Rivers will necessarily involve interagency cooperation and landowner education.

- Recreational Use

Recreational use has increased steadily since the park was established. In 1972, approximately 60,000 canoes floated the river and in 1979, nearly 148,000 canoes floated the river (NPS 1989). Since 1980, new motor technology has advanced to include more sophisticated outboard jet motors. This technology has increased the number of jet boat users compared to propeller motors – a 1993 survey found 90 percent of motorboat users at Big Spring had jet motors (Phillips and Chilman 1995). In addition, jet motors increase access to areas that were previously unmotorized because of boating hazards. Horseback riding is a significant use within certain areas of the park. Angling has gained in popularity with an estimated average of 148,983 anglers from 1995 to 2000. Other uses such as off-road vehicles, hunting, primitive camping and hiking have also increased, but there is limited data regarding amount of use and its distribution (NPS 2005).

Information on the impacts of recreation activity in the park is limited to the following: 1) boating disturbance caused some fish species to leave their nests thus increasing the risk of predation; 2) herons and kingfishers were displaced from the main channel where canoes and boats traveled; 3) bodily wastes from animals is a major contamination threat to the park as well as a human health risk; 4) increased use of jet boats has created a more constant level of disturbance to aquatic and riparian animals as well as physical disturbance to bank and bottom substrates; 5) foot traffic in the river and on banks can destroy young vegetation and physically dislodge substrate; and 6) increased sport fishing and gigging can lead to changes in ecological processes, including population reduction of popular species through over harvest.

- Land Use in the Watershed

The NPS manages less than 3 percent of the total land within the Current River watershed, leaving the rivers vulnerable to increased sedimentation and runoff from land use activities including overgrazing, deforestation, riparian zone clearing in tributaries, and road building.

Historic clearing of riparian areas and deforestation of lowlands along river channels have created chert gravel deposits in the Current and Jacks Fork rivers that were either absent or not as common in pre-settlement times (Jacobson and Prim 1997). River changes are continuing to adjust to these legacy impacts via the downstream waves of gravel accumulation resulting in channel instability (Jacobson and Primm 1997; Jacobson and Gran 1997).

Roads are a great threat to streams because of sediment loading. Heavily used gravel roads can contribute 100 times more sediment than paved or abandoned roads (Reid and Dunne 1984). Dirt and gravel roads within the Ozarks in general are the largest source of sediments to streams, outweighing the combined impacts of pasture erosion, logging, and natural erosion (USDA 1986).

Riparian zone clearing along tributaries results in increased runoff to streams especially during storm events. During non-storm times, reduced water storage capacity in the soil creates lower water levels (Doisy and Rabeni 2002). These changes in flow regime can have impacts on the aquatic biota. In addition riparian clearing can lead to increased erosion, channel area and width to depth ratios.

Increased runoff may bring increased nutrients into the river system. Numerous studies indicate that karst aquifers are susceptible to nitrate leaching into the groundwater in the Ozarks so springs often show the effects of land use in the watershed when the tributaries and main stem river do not (Austin and Steele 1990).

- Loss of Native Species

Part of the uniqueness of the park is the high species diversity it supports. Many species are threatened or endangered at the state and/or federal level. Other than general habitat descriptions and location data, little is known about specific habitat requirements and the relationship or role that water resources serve in the survival and maintenance of many species and communities.

Some of the species of special concern as related to water resources include river cane and cave communities, mussels and the Ozark Hellbender. There are also 14 species of fish, one crayfish, one snail, and 28 benthic invertebrates that are species of special concern in Missouri (Missouri Natural Heritage Program 2005). There are four mussel species found in the park that are also species of special concern.

- Exotic and Invasive Species

The Asian clam (*Corbicula fluminea*) is present in the park and may be increasing its abundance and range. Because of its life history it may compete with native mussel species.

The Current River in OZAR (upper 16.7 miles) is managed by the state as a trout fishery [rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*), both nonnative species] that is maintained via stocking. There is little information on the ecological impacts of nonnative trout species on native communities in the Current River.

Other exotics that could potentially have negative effects on native species and the ecological integrity of the rivers include zebra mussels, Eurasian watermilfoil (*Myriophyllum spicatum*), and purple loosestrife (*Lythrum salicaria*). Gravel bar habitats in some areas of the park are threatened by Sericea Lespedeza (*Lespedeza cuneata*). Potential threats exist from exotic crayfish in neighboring watersheds and possible forest vegetation changes caused by gypsy moths.

- Wastewater Discharges

There are five municipal wastewater treatment plants that discharge into park watersheds. These plants all treat at the secondary level, reducing pathogens, oxygen consuming materials, and sediment loads in the discharged waters, but not treating for nitrates and phosphorus. Such nutrients in excessive amounts cause ecological harm. Most facilities in the park watershed are designed to bypass all treatment during significant storm events because they cannot handle the volume of waste/storm water delivered to them under such conditions. Mountain View, MO has built a new wastewater system in 2005 and a storm water system is being installed.

The rural characteristics of the park and low population density indicate that many people use septic tanks rather than tie-ins to wastewater treatment facilities. Aley (1972, 1974) suggested that the potential for contamination by septic systems is increased in areas with soluble bedrock such as the park and identified sewage disposal as a groundwater pollution hazard.

An emerging issue is the organic chemicals that arise from household chemicals, pharmaceuticals and biogenic hormones that are passed through wastewater treatment facilities. Although in minute quantities measured in parts per billion, there is growing evidence that these chemicals can cause harm to the aquatic biota.

- Mining

There are two areas where potential mining of lead and zinc may occur within the watershed of the park. There may be economically viable lead deposits on Missouri Department of Conversation lands within the Current River basin. Many of these lands are within recharge areas for major springs on the Current River upstream of the confluence with Jacks Fork River.

In addition, deposits are present beneath National Forest and private lands located in the Big Spring recharge area – the mining area is about 20 miles south and west of Big Spring.

The important issue, in addition to potential aquifer contamination and alteration of the hydrogeology, is the disposal of waste rock and processed rock residues (tailing piles). These wastes still contain significant quantities of heavy metals that can be leached into waters passing over them. A common dispersal approach is to fill valleys with such materials. If this is done in a losing stream it will adversely impact groundwater quality. In addition, dissolved metals may have direct toxic effects on aquatic organisms.

➢ Flow and Channel Alterations

Although it is unlikely that the flow regime of park rivers would be altered within the watershed by dams on the main stem rivers, other types of alterations are possible. Bridges, culverts, river accesses, and bank hardening divert flows and re-focus stream energy to adjacent stream reaches, which alters the hydrologic regime downstream. Local disruptions of flow can cause scouring, sedimentation, and bank instability.

Gravel mining is another activity occurring in the park's watershed that can alter channel structure and influence flow regime. Gravel mining operations may result in head cutting, channel incision and lateral instability, increasing stream gradient, channel relocation, and scouring and erosion (Femmer 2002). Removal of large gravel and the bed sediment disturbance release fine sediments into the stream system. Fine sediment deposits degrade the habitat for species requiring a variety of substrate particle sizes.

Since 1998, there have been four permitted gravel removal operations in the Jacks Fork watershed and since 1994 there have been 42 permitted sand and gravel removal operations in the Current River watershed, although those in the Current River watershed are below the park boundary (Wilkerson 2003).

Finally, fish communities have been impacted by conditions beyond the watershed scale. Atmospheric deposition of mercury has resulted in a fish consumption advisory statewide in Missouri, issued by the Missouri Department of Health and Senior Services. Mercury is released into the atmosphere when coal or municipal trash is burned. The mercury travels great distances in the atmospheres and transforms through a series of chemical reactions to methylmercury, a form of mercury that can accumulate in the living tissue of aquatic organisms as it settles into the water. Fish higher on the food chain, particularly largemouth bass, accumulate the highest levels of mercury. The recently updated (2007) consumption advisory is for largemouth bass over 12 inches long and it is recommended that women who are pregnant, who may become pregnant, who are nursing, and children 12 years or younger should not consume these fish.

Literature Cited

Adamski, J. 1987. The effects of agriculture on quality of groundwater in a karstified carbonate terrain, northwest Arkansas. M.S. thesis. University of Arkansas, Fayetteville, AR.

Adamski, J., J. Petersen, D. Friewald and J. Davis. 1995. Environmental and hydrologic setting of the Ozark Plateaus study unit, Arkansas, Kansas, Missouri, and Oklahoma. Water-Resources Investigations Report 94-4022, U.S. Geological Survey, Little Rock, AR.

Aley, T. 1975. A Predictive hydrologic model for evaluating the effects of land use and management on the quantity and quality of water from Ozark springs. Ozark Underground Laboratory. Springfield, Missouri. 185 p. (Reprinted in Missouri Speleology, Vol. 18 as the entire volume).

Aley, T. 1978. Hydrologic studies of springs in the Ozark National Scenic Riverways, Missouri. Ozark Underground Laboratory, Protem, Missouri.

Aley, T. 1981. Cave management investigations, Ozark National Scenic Riverways, Phase 2. Ozark Underground Laboratory, Protem, Missouri.

Aley, T. and C. Aley. 1987a. Groundwater study, Ozark National Scenic Riverways - Volume 1. Ozark Underground Laboratory. Protem, Missouri.

Aley, T. and C. Aley. 1987b. Groundwater study, Ozark National Scenic Riverways - Volume 2. Ozark Underground Laboratory. Protem, Missouri.

Allgood, F. and I. Persinger. 1979. Missouri general soil map and soil association descriptions. United States Department of Agriculture, Soil Conservation Service State Office, Columbia, Missouri.

Austin, A. and Steele, K. 1990. Nitrate concentrations of groundwater, northern Madison County, Arkansas. Misc. Publication No. 75, Arkansas Water Resources Research Center. Fayetteville, AR.

Barks, J.. 1978. Water quality in the Ozark National Scenic Riverways, Missouri. Water Supply Paper 2048, U.S. Geological Survey, Little Rock, AR.

Becker, C. 1999. Multifactor classification of intermittent creeks in the Southeast Missouri Ozarks. M.S. thesis, U. of Missouri, Columbia.

Bobbitt, K. 1995. A physiographic/geomorphic classification of the Current River valley; a basis for aquatic resources management. Department of Geology, Carleton College, Northfield, Minnesota.

Buchanan, A. 1996. Distribution of naiades in select streams in southern Missouri: a survey conducted during 1981-1982. Missouri Department of Conservation. Columbia, MO.

Buck, C., K. Grabner and T. Nigh. 2001. Ecological classification of riparian areas in the Ozark National Scenic Riverways. Missouri Department of Conservation, Columbia, MO. Also available from Ozark National Scenic Riverways, Van Buren, MO.

Covington, S. 2002. Geoindicator Scoping Report for Ozark National Scenic Riverways. National Resource Program Center, Geologic Resources Division, National Park Service, Denver, CO.

Crandall, K. 1998. Conservation phylogenetics of Ozark crayfishes: assigning priorities for aquatic habitat protection. Biological Conservation 84: 107-117.

Crawford, R. 1998. Water auality investigation of the Jacks Fork River. Missouri Department of Natural Resources. Stream Survey Sampling Report, Columbia, MO.

Davis, J. and M. Barr. 2006. Assessment of possible sources of microiological contamination and water-quality characteristics of the Jacks Fork, Ozark National Scenic Riverways, Missouri – Phase III. U.S. Geological Survey, Scientific Investigations Report 2006-5161.

Davis, J. and J. Richards. 2001. Assessment of microbiological contamination of the Jacks Fork within the Ozark National Scenic Riverways, Missouri--Phase I. U.S. Geological Survey Fact Sheet 026-01.

Davis, J. and J. Richards. 2002. Assessment of possible sources of microbiological contamination and water quality characteristics of the Jacks Fork River, Ozark National Scenic Riverways, Missouri—Phase II. Water-Resources Investigations Report 02-4209, U.S. Geological Survey.

Davis, P. 1982. Eastern water diversion permit statutes: precedents for Missouri? Missouri Law Review Vol. 47: 429-470.

DeBacker, M. and many others. 2004. Heartland inventory and monitoring network and prairie cluster prototype monitoring program vital signs monitoring plan, phase III report. National Park Service, Midwest Regional Office, Omaha, NE. Available at: http://www1.nature.nps.gov/im/unites/htln.

Decamps, H. 1993. River margins and environmental change. Ecol. Appl. 3:441-225.

DiStefano, R. 2002. Macrohabitat partitioning among three crayfish species in two Missouri Ozarks streams. Missouri Department of Conservation, Dingell-Johnson Project F-1-R-42, Study S-41, Job 2, Final Report. Columbia, Missouri.

Doisy, K., C. Rabeni and D. Galat. 1997. The benthic insect community of the lower Jacks Fork River. Transactions Missouri Academy of Sciences Vol. 31: 19-36.

Doisy, K., and C. Rabeni. 2002. Ozark riparian and aquatic systems: a literature review and information synthesis: a report to the National Park Service. Missouri Cooperative Fish and Wildlife Research Unit, University of Missouri. Columbia, MO.

Dunham, J., D. Pilliod, and M. Young. 2004. Assessing the consequences of nonnative trout in headwater ecosystems in western North America. Fisheries 29(6):18-26.

Edwards, D. and T. Daniel. 1992. Environmental impacts of on-farm poultry waste disposal. Bioresource Technology v. 41.

Femmer, S. 2002. Instream gravel mining and related issues in southern Missouri. U.S. Geological Survey.Fact Sheet 012-02.

Fenneman, N. 1938. Physiography of eastern United States, McGraw-Hill Book Co., Inc., New York.

Harvey, E. 1980. Ground water in the Springfield-Salem Plateaus of southern Missouri and northern Arkansas. Water-Resources Investigations Report 80-101, U.S. Geological Surey.

House, S. 2004. Missouri Cave Database, last updated September 8th, 2004.

Huggins. D., R. Everhart, D. Baker, and R. Hagen. 2005. Water quality analysis for the Heartland Inventory and Monitoring Network of the U.S. National Park Service, Ozark National Scenic Riverways. Central Plains Center for BioAssessment, Kansas Biological Survey, University of Kansas, Lawrence, KS.

Hynes, H. 1970. The ecology of running waters. University of Toronto Press, Canada.

Imes, J. 2002. Geohydrological and biological investigations associated with a new lead-zinc exploration area near Winona, Missouri, and the Viburnum Trend of Southeastern Missouri. U.S. Geological Survey Fact Sheet 005-02.

Imes, J. and L. Emmett. 1994. Geohydrology of the Ozark Plateaus aquifer system in parts of Missouri, Arkansas, Oklahoma, and Kansas. Professional Paper 1414-D, U.S. Geological Survey.

Jacobson, R. 1995. Spatial controls on patterns of land-use induced stream disturbance at the drainage-basin scale -- an example from gravel-bed streams of the Ozark Plateaus, Missouri. American Geophysical Union, Geophysical Monograph Vol. 89: 219-239.

Jacobson, R. and A. Primm. 1997. Historic land-use changes and potential effects on stream disturbance in the Ozark Plateaus, Missouri. Water-Supply Paper 2484, U.S. Geological Survey.

Jacobson, R. and K. Gran. 1997. Gravel sediment routing from widespread, low-intensity landscape disturbance, Current River basin, Missouri. U.S. Geological Survey, Rolla, MO.

Jennings, Sue. 1998. Needs in management of native freshwater mussels in the national park system, Technical Report NPS/NRWRD/NRTR-97-147. National Park Service, Water Resources Division, Fort Collins, CO.

Lyon, J. and .C. Sagers. 1996. Inventory and characterization of the riparian zone of the Current and Jacks Fork Rivers. Final Project Report, Project No. OZAR-N-022. Ozark National Scenic Riverways, Van Buren, MO.

McClane Environmental Services. 2004. Ozark National Scenic Riverways 2002 freshwater mussel inventory. Final Report to Ozark National Scenic Riverway, Van Buren, MO.

McKenney, R. 1997. Formation and maintenance of hydraulic habitat units in the streams of the Ozark Plateaus. Ph.D. Dissertation.,Pennsylvania State University, University Park, PA.

Miller, D. and J. Vandike. 1997. Groundwater resources of Missouri. Missouri Department of Natural Resources, Water Research Rept. 46, Rolla, MO.

Miller, J. and C. Appel. 1997. Ground water atlas of United States. U.S. Geological Survey Report HA-730-D. Available at: http://www.capp.water.usgs.gov/gwa/ch_d/index.html.

Missouri Department of Conservation. 1997. Ozark Region Resource Inventory. Jefferson City, MO.

Missouri Department of Natural Resources. 1998. Section 303(d) waters, State of Missouri, September 23 1998. http://www.dnr.state.mo.us/wpscd/wpcp/tmdl/tmdl_list.pdf.

Missouri Department of Natural Resources. 2004. Total maximum daily loads for Jacks Fork River, Shannon County, Missouri. Missouri Department of Natural Resources, Columbia, MO.

Missouri Natural Heritage Program. 2005. Missouri species and communities of conservation concern checklist. Missouri Department of Conservation. Jefferson City, MO.

Murray, D. 1991. Mammals of Ozark National Scenic Riverways. University of Missouri, Columbia. MO.

Naiman, R., H. Decamps, and M. Pollock. 1993. The role of riparian corridors in maintaining regional biodiversity. Ecol. Appl. 3:209-212.

Naiman, R. and H. Decamps. 1997. The ecology of interfaces: riparian zones. Ann. Rev. Ecol. Syst. 28:621-658.

National Park Service. 1989. River Use Management Plan. Ozark National Scenic Riverways, Van Buren, MO.

National Park Service. 1995. Baseline Water Quality Data Inventory and Analysis, Ozark National Scenic Riverways, Vol. II & I. Technical Report NPS/NRWRD/NRTR-95/70. United States Department of the Interior. Washington, D.C. 561 p.

National Park Service. 2005. Draft Water Resources Management Plan. Ozarks National Scenic Riverways, Van Buren, MO.

Noss, R., E. Laroe, and J. Scott. 1995. Endangered ecosystems of the United States: A preliminary assessment of loss and degradation. Biological Report 28, U.S. National Biological Service. Washington, D.C.

Panfil, M., and Jacobson, R. 2001. Relations among geology, physiography, land use, and stream habitat conditions in the Buffalo and Current River systems, Missouri and Arkansas: U.S. Geological Survey Biological Sciences Report, USGS/BRD/BSR-2001-0005.

Phillips, D. and K. Chilman. 1995. River Use Monitoring 1994. Lower Current District, Ozark National Scenic Riverways, Van Buren, MO.

Probst, W., C. Rabeni, W. Covington and R. Marteney. 1984. Resource use by stream-dwelling rock bass and smallmouth bass. Trans. Am. Fish. Soc. 113: 238-294.

Rabeni, C. 1992. Trophic linkages between stream centrarchids and their crayfish prey. Can. J. Fish. Aquat. Sci. 49: 1714-1721.

Rabeni,C., K. Doisy and D. Galat. 2002. Testing the biological basis of a stream habitat classification system using benthic invertebrates. Ecological Applications 12:782-796.

Rabeni, C. and R. Jacobson. 1993a. The relation of fluvial hydraulics to fish habitat in low gradient alluvial streams. Freshwater Biology 29: 211-220.

Rabeni, C. and R. Jacobson. 1993b. Geomorphic and hydraulic influences on the abundance and distribution of Sream centrarchids in Ozark USA. Streams.Polskie Archiwum Hydrobiologii: Polish Archives of Hydrobiology 40: 87-99.

Raymond, R. and K. Vache. 2002. Analysis of water quality trends for select stations on the Current and Jacks Fork Rivers, Ozark National Scenic Riverways. E&S Environmental Chemistry. Corvallis, OR.

Saucier, R. 1983. Historic changes in Current River meander regime. Rivers '83, Waterway, Port, Coastal and Ocean Division, ASCE. New Orleans, LA. Pages 180-190.

Schroeder, M. 1982. Missouri water atlas. Missouri Department of Natural Resources, Columbia, MO.

The Nature Conservancy. 2003. Ozarks Ecoregional Conservation Assessment. The Nature Conservancy Midwestern Resource Office, Minneapolis, MN.

U.S. Department of Agriculture. 1986. A study of erosion, animal wastes, and nutrient transport associated with agricultural areas within the Beaver Lake Watershed, Arkansas.

U.S. Fish and Wildlife Service. 2001. Candidate and Listing Priority Assignment Form*(Cryptobranchus alleganiensis bishopi).* 17 pp.

Veni, G. and many others. 2001. Living with Karst. American Geological Institute. Available at: http://www.agiweb.org.

Vineyard, J.D., and Feder, G.L., 1982, Springs of Missouri: Missouri Department of Natural Resources, Division of Geology and Land Survey, Water Resources Report 29.

Vineyard, J. G. Feder, W. Pflieger, and R. Lipscomb. 1974. Springs of Missouri with sections on fauna and flora. Missouri Geological Survey, Rolla, MO.

Weeks, D. 2006. Water Resources Foundation Report for Golden Gate National Recreation Area. National Park Service, Water Resources Division Tech. Rept. NPS/NRWRD/NRTR-2006/348.

Whitledge, G. and C. Rabeni. 1997. Energy sources and ecological role of crayfishes in an Ozark stream: insights from stable isotopes and gut analysis. Can. J. Fish. Aquati. Sci. 54: 2555-2563.

Wilkerson,T., Jr. 2001. Jacks Fork River Watershed Inventory and Assessment. Missouri Department of Conservation. http://www.conservation.state.mo.us/fish/watershed/jcksfork/contents/160cotxt.htm.

Wilkerson, T., Jr. 2003. Current River Watershed Inventory and Assessment. Missouri Department of Conservation. http://www.conservation.state.mo.us/fish/watershed/current/contents/080cotxt.htm.

Wilson, G. 2001. Streamflow information for the Jacks Fork and Current River in the Ozark National Scenic Riverways, South-Central Missouri. U.S. Geological Survey Fact Sheet 092-01.

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National Park Service
U.S. Department of the Interior

Water Resources Division
1201 Oak Ridge Dr., Suite 250
Fort Collins, CO 80525

www.nature.nps.gov/water