HOT SPRINGS NATIONAL PARK,

ARKANSAS

WATER RESOURCES SCOPING REPORT

James C. Petersen and David N. Mott

Technical Report NPS/NRWRD/NRTR-2002/301

WATER RESOURCES DIVISION

National Park Service - Department of the Interior
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United States Department of the Interior • National Park Service

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November, 2002

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United States Department of the Interior
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Executive Summary

Hot Springs National Park (HOSP) is a park of about 5,450 acres that lies within and adjacent to the city of Hot Springs, Arkansas. Several hot springs are the primary natural resource of the park and are the source of water that was used by historic bathhouses along Bathhouse Row that are the primary cultural resource of the park. The hot springs at HOSP are a designated "significant thermal feature" in the Geothermal Steam Act Amendments of 1988 (P.L. 100-443). A thermal water distribution system consisting of covered concrete basins around the orifices most of the hot springs and collection and distribution lines has been in place for many years. Two cold water (relative to the temperature of the hot springs) springs, a few intermittent and perennial streams, and a few small lakes also occur within the boundaries of HOSP. The cold water springs (Whittington and Happy Hollow Springs) and thermal water fountains are used by the public as sources of drinking water.

This Water Resources Scoping Report describes the existing water resources conditions and issues at HOSP. Recommended actions to address these issues are included. The objectives of this report are to provide National Park Service (NPS) management with an overview of the existing hydrological information and water resources issues and to begin to identify data needs and management directions to assist NPS management in providing a greater level of water resources protection.

The flow system that yields thermal water to the hot springs of HOSP is not fully understood. A couple of theories prevail concerning flow and thermal dynamics of the system. The hot-springs water probably is of local, meteoric (i.e., atmospheric) origin from recharge of the Bigfork Chert and the Arkansas Novaculite. In one scenario water is suspected to slowly percolate (for a few thousand years) to depth, reside in the heated part of the system for a relatively short time (not more than a few hundred years), and then travel rapidly to the surface. The age of much of the water (i.e., the residence time under the ground) exceeds 4,000 years. Some geophysical and geological data suggest a somewhat different scenario—that the hot springs are located above the western edge of a large pluton (an igneous intrusion) with an upper surface about 4,000 feet below land surface that extends eastward from an igneous outcrop near Magnet Cove. Meteoric water has been suggested to percolate through a fracture zone (location unspecified) associated with the margin of the pluton and then (because the heat source is unknown) either is heated by the pluton, percolates below the pluton to depths of about 8,000 to 12,500 feet and is heated, or percolates below the pluton to a lesser depth and is heated by the underlying magma.

Approximately 47 hot springs emerge from the Hot Springs Sandstone in HOSP. Although most of the water from the hot springs is several thousand years old, a relative small (but unknown) percentage of the water is of recent age. Water from the hot and cold springs appears to be of good quality, but relatively few data are available for metals, pesticides, and other organic compounds.

Some water quality data are available for the streams and lakes of HOSP; most of these data are associated with sampling conducted between 1974 and 1978. Based on this data and data for nearby streams and lakes, water quality is expected to be good (low concentrations of nutrients, metals, and pesticides; low turbidity).

Although some unique organisms live in the hot springs, no terrestrial or aquatic species in HOSP are federally-listed threatened or endangered species. Between 13 and 17 species of blue-green algae thrive in the hot springs of HOSP. One species of blue-green algae, *Phormidium treleasei*, has been recorded from only five other places in the world. The Ouachita madtom (*Noturus lachneri*), which is endemic to areas near HOSP, recently (1992) was collected from the Middle Branch of Gulpha Creek about 1.25 mile southeast of HOSP. The madtom is considered to be a species of special concern by the State of Arkansas. Research conducted by scientists from the National Aeronautics and Space Administration (NASA) detected the presence of very small microbes (nanobacteria, or nannobacteria) in water from the hot springs. The nanobacteria presence is extremely important to the scientific community. NASA scientists are interested in the structures because of their resemblance to structures hypothesized to be fossilized nanobacteria found in the Mars meteorite that NASA designates as ALH84001.

The primary water resources issues of HOSP are related to (1) water quality of springs, (2) water quality of streams, and (3) flooding of Whittington, Hot Springs, and Gulpha Creeks. All of these issues are related to the potential effects of land use on the springs, streams, and lakes of HOSP.

The water quality of hot and cold springs is related to activities in the recharge area. The quality of the water that makes up the largest percentage of the water discharging from the hot springs (and Whittington Spring, which also is dominated by water that is several thousand years old) is not likely to be affected by any land-use changes for several thousand years. However, the locally derived, cold-water recharge that contributes some flow to the hot springs of HOSP is susceptible to contamination from surface input and some evidence suggests that shallow ground water in the area has been contaminated (based on elevated nitrate and chloride concentrations in water from some shallow wells in the area). The effect of this cold-water recharge on the quality of the hot spring water is likely to vary with differing hydrologic conditions; after rainstorms, or during wet periods, a greater percentage of the water that reaches the hot springs (and Whittington Spring) is more likely to be potentially contaminated. The influence of land use on water quality of the cold and hot springs is an important water resources issue. Delineation of recharge areas of the cold springs and the cold-water component of the hot springs will enhance management of the spring resource. For example, land-use changes in the recharge areas can be expected to affect quantity and quality of spring discharges by affecting the quantity (because of changes in impervious area) and quality of water recharging the aquifers. Accurate predictions of these land-use driven changes are more difficult without accurate delineation of the recharge areas and their associated land use.

A second water resources issue is water quality of streams. Although water quality of the small streams that flow through HOSP is expected to be fairly good, little is known about the water quality (or quality of streambed sediment) within the Park. Potential sources of contamination include land fills in the upstream parts of the Bull Bayou and Whittington Creek Basins, urban activities (including commercial activities, pest management, lawn care, fuel storage, and vehicle maintenance) in the Whittington, Hot Springs, and Gulpha Creek Basins, and portions of a golf course in the Gulpha Creek Basin.

Flooding is another primary issue. Since at least 1883, flooding along Hot Springs Creek and its tributaries has been a concern. The creek arch underneath Central Avenue (the street adjacent to Bathhouse Row) conveys the normal flow of Hot Springs Creek but does not have sufficient capacity to convey storm flows that exceed a recurrence interval of about 3 years. Flood water volumes that exceed the capacity of the arch flow down Central Avenue and adjacent areas. Bathhouse Row lies along part of the east side of Central Avenue, while several private businesses lie along the west side and other parts of the east side of Central Avenue. Flooding "has approached catastrophic proportions" in some events and three lives have been lost because of the flooding. The most recent flood (May 1990) caused an estimated $5.3 million damage.

Recommendations intended to address the primary identified issues are summarized in the following table:

Issue	Recommendation
Water Quality of Geothermal Springs	Implement long-term monitoring of priority water quality constituents through the National Park Service Inventory and Monitoring Program.
Determine Recharge Area of Cold Springs and Cold Water Components of Hot Springs	Secure funding for proposal developed by the Arkansas District of the USGS to address recharge delineation needs.
Effects of High-Flow Conditions on the Water Quality of Springs	HOSP staff should work with NPS and Regional ground water experts to develop a proposal to assess changes in water quality that result from precipitation generated proximal recharge.
Surface Water Sampling	Establish a USGS fixed-station water quality monitoring site on Bull Bayou through NPS or NPS/USGS partnership funding. Conduct long-term aquatic resource monitoring on Bull Bayou and Gulpha Creek through the NPS Inventory and Monitoring program.
Streambed Sediment Samples	Assess sediments within surface streams for the presence of elevated semi-volatile organic compounds.
Land-use Database	Conduct long-term land-use monitoring in the HOSP vicinity (especially in delineated recharge areas once established) under the auspices of the NPS Inventory and Monitoring Program.
Flooding	Monitor proposals to find an engineering solution to flooding along Central Avenue and consult with appropriate experts as needed.

Introduction

Hot Springs National Park (HOSP) lies within and adjacent to the city of Hot Springs (population about 33,000) in central Arkansas (fig. 1, fig. 2). HOSP has an area of about 5,450 acres (Stephen Rudd, National Park Service, oral commun., 2000). The Park is in a physiographic area known as the Ouachita Mountains, an area typified by intensely folded and faulted shales and sandstones that produce many east-west trending mountain ridges (Fenneman, 1938). HOSP was set aside as a federal reservation in 1832, and was established as a National Park in 1921. Several hot springs are the primary natural resource of HOSP, but unlike thermal features in other national parks such as Yellowstone National Park, they have not been preserved in their unaltered state. Instead, the springs have been managed to conserve the production of uncontaminated hot water for public use (National Park Service, 1986). From the early years of the reservation, pipes, flumes, and tanks were developed to collect, cool, and transport water from the springs. A thermal water distribution system (described more fully and diagrammed in National Park Service, 1986) consisting of covered concrete basins around the orifices of most of the hot springs and collection and distribution lines has been in place for many years. A group of bathhouses, built between 1892 and 1923 and currently known as the Historic Landmark District of

Bathhouse Row, is the primary cultural resource of the park. This group of bathhouses is one of the few collections of historic bathhouses remaining in the United States (National Park Service, 1997). Bathhouse Row lies along the east side of Central Avenue (Arkansas Highway 7) and immediately west or southwest of the hot springs.

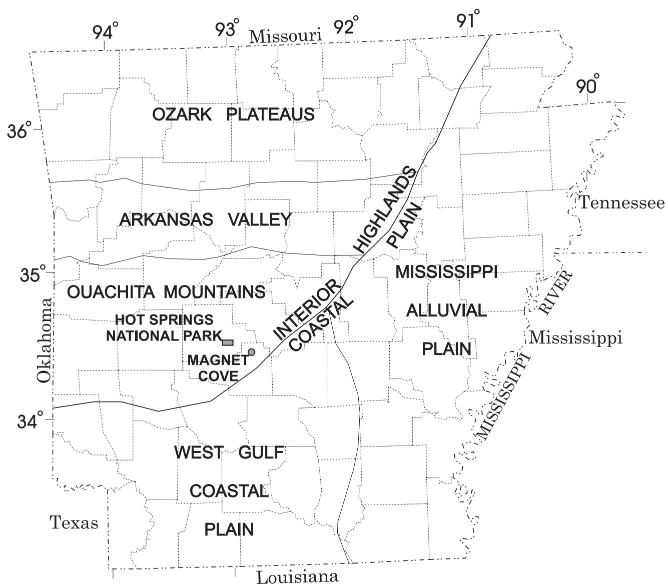

Figure 1. General location of Hot Springs National Park.

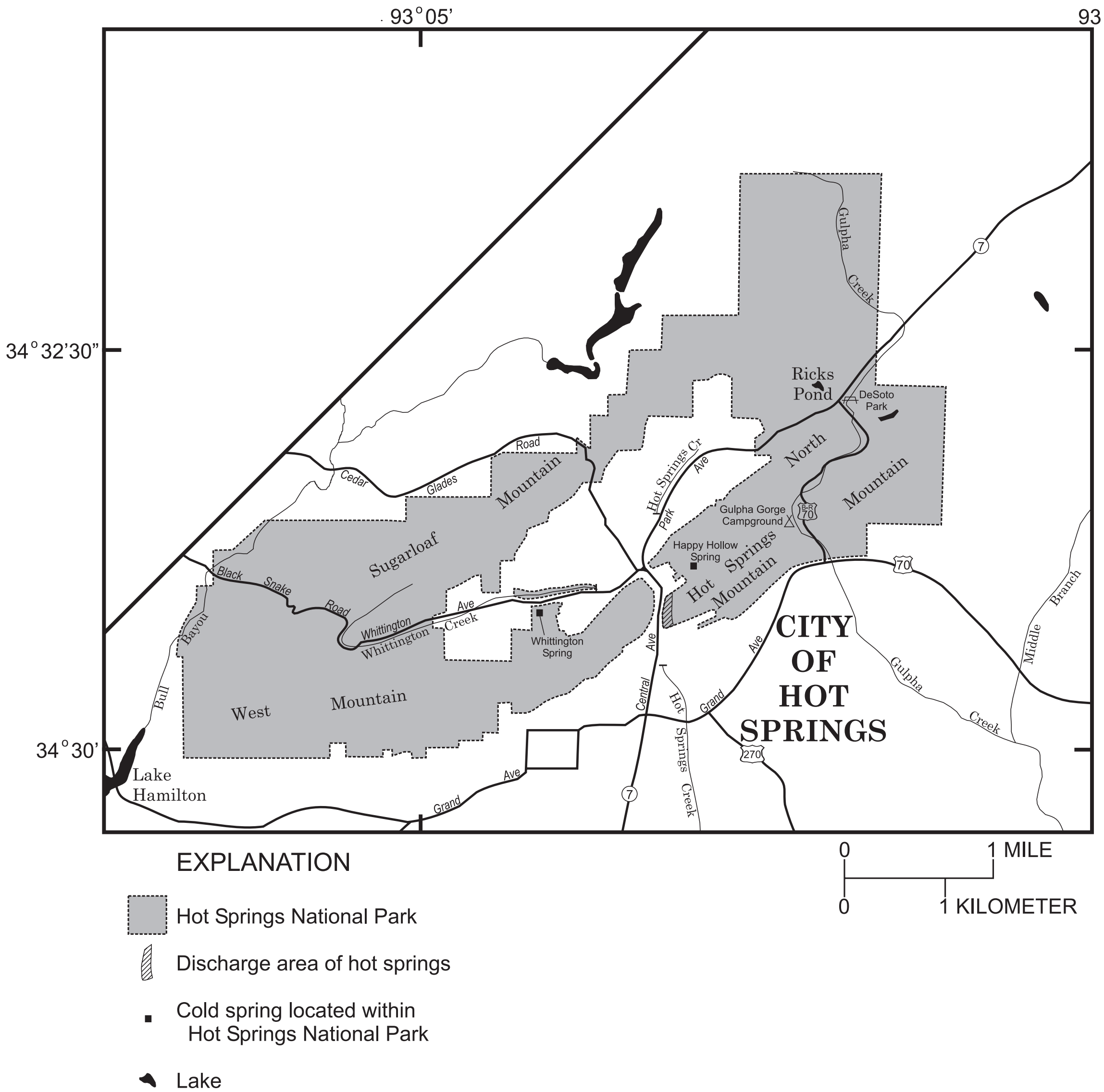

Figure 2. Water resources of Hot Springs National Park.

This Water Resources Scoping Report describes the existing water resources conditions and issues at HOSP. Recommended actions to address these issues are included. The objectives of this report are to provide National Park Service (NPS) management with an overview of the existing hydrological information and water resources issues and to begin to identify data needs and management directions to assist NPS management in providing a greater level of water resources protection.

Legislation and Executive Orders Related to Management

Several legislative acts and executive orders exist that are related to management of the water resources of HOSP. Congress established Hot Springs Reservation on April 20, 1832 to protect hot springs flowing from the southwestern slope of Hot Springs Mountain. Hot Springs Reservation became Hot Springs National Park by a Congressional name change on March 4, 1921. Some additional legislation and executive orders that help guide management of HOSP's aquatic resources include the following:

> The *National Park Service Organic Act* of 1916 established the NPS and mandated that it "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 wildlife therein and to provide for the enjoyment of future generations."
>
> The *General Authorities Act* of 1970 reinforced the 1916 *Organic Act* – all park lands are united by a common preservation purpose, regardless of title or designation. Hence, federal law protects all water resources in the national park system equally, and it is the fundamental duty of the NPS to protect those resources unless otherwise indicated by Congress.
>
> Congress passed the *National Environmental Policy Act* (NEPA) in 1969, which requires that federal actions which 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 *Clean Air Act* of 1970 (as amended) regulates airborne emissions of a variety of pollutants from area, stationary, and mobile sources. The 1990 amendments to this act were intended primarily to fill the gaps in the earlier regulations, such as acid rain, ground level ozone, stratospheric ozone depletion and air toxics. The amendments identify a list of 189 hazardous air pollutants. The U.S. Environmental Protection Agency must study these chemicals, identify their sources, determine if emissions standards are warranted, and promulgate appropriate regulations.
>
> The 1972 *Federal Water Pollution Control Act*, more commonly known as the *Clean Water Act*, was designed to restore and maintain the integrity of the nation's waters. States implement the protection of water quality under the authority granted by the Clean Water Act through best management practices and through water quality standards. Section 404 of the act requires that a permit be issued for discharge of dredged or fill materials in waters of the United States, including wetlands. The U.S. Army Corps of Engineers administers the Section 404 permit program. Section 402 of the act requires that a National Pollutant Discharge Elimination System (NPDES) permit be obtained for the discharge of pollutants from any point source into the waters of the United States. In general, all discharges and storm water runoff from major industrial and transportation activities, municipalities, and certain construction activities must be permitted by the NPDES program. The U.S. Environmental Protection Agency usually delegates NPDES permitting authority to the state.
>
> The *Geothermal Steam Act Amendments of 1988* (P.L. 100-443) require the NPS to establish and maintain a monitoring program for all units of the NPS in which thermal features qualify as significant according to the provisions of the Act. Currently, sixteen

NPS units, including HOSP, are listed in the Act as containing significant thermal features.

The *Endangered Species Act* of 1973 requires the NPS to identify and promote the conservation of all federally listed endangered, threatened, or candidate species within any park unit boundary. This act requires all entities using federal funding to consult with the Secretary of Interior on activities that potentially impact endangered flora and fauna. It requires agencies to protect endangered and threatened species as well as designated critical habitats. While not required by legislation, it is NPS policy to also identify state and locally listed species of concern and support the preservation and restoration of those species and their habitats.

The *Redwood National Park Act* (1978) amended the *General Authorities Act* of 1970 to mandate that all park system units be managed and protected "in light of the high public value and integrity of the national park system." Furthermore, no activities should be undertaken "in derogation of the values and purposes for which these various areas have been established", except where specifically authorized by law or as may have been or shall be directly and specifically provided for by Congress.

The *National Parks Omnibus Management Act* of 1998 attempts to improve the ability of the NPS to provide state-of-the-art management, protection, and interpretation of and research on the resources of the national park system by:

- Assuring that management of units of the national park system is enhanced by the availability and utilization of a broad program of the highest quality science and information;
- Authorizing the establishment of cooperative agreements with colleges and universities, including but not limited to land grant schools, in partnership with other Federal and State agencies, to establish cooperative study units to conduct multi-disciplinary research and develop integrated information products on the resources of the national park system, or of the larger region of which parks are a part;
- Undertaking a program of inventory and monitoring of national park system resources to establish baseline information and to provide information on the long-term trends in the condition of national park system resources, and;
- Taking such measures as are necessary to assure the full and proper utilization of the results of scientific study for park management decisions. In each case in which an action undertaken by the NPS may cause a significant adverse effect on a park resource, the administrative record shall reflect the manner in which unit resource studies have been considered. The trend in the condition of resources of the national park system shall be a significant factor in the annual performance.

Executive Order 13112: *Invasive Species* complements and builds upon existing federal authority to aid in the prevention and control of invasive species.

Executive Order 11988: *Floodplain Management.* The objective of the Executive Order is, "…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-repetitive actions, the Executive Order states that all proposed facilities must be located outside the limits of the 100-year floodplain. If there were no practicable alternative to construction within the floodplain, adverse impacts would be minimized during the design of the project.

Director's Order #2: Park Planning provides the policies and guidance related to park planning. The Park Service has a mandate in its Organic Act and other legislation to preserve resources unimpaired for the enjoyment of future generations. NPS park planning will help define what types of resource conditions, visitor uses, and management actions will best achieve that mandate. The NPS is to maintain an up-to-date General Management Plan (GMP) for each unit of the national park system. The purpose of the plan is to ensure that each park has a clearly defined direction for natural and cultural resource preservation and visitor use. The National Park Service completed a GMP for HOSP in 1986 (National Park Service, 1986). A park's Resources Management Plan (RMP) describes the specific management actions needed to protect and manage the park's natural and cultural resources. HOSP's 1997 RMP (National Park Service, 1997) identifies existing resources and conditions, present actions, and identifies future needs consistent with legislative and administrative guidance, resource significance, and other park planning documents. Discipline-specific planning documents that complement the RMP (e.g., Fire Management Plan, Water Resources Scoping Report, etc.) are prepared for NPS units when warranted.

Description of Water Resources

The hot springs (fig. 2) are the primary natural resource of HOSP. The hot springs at HOSP are a designated "significant thermal feature" in the Geothermal Steam Act Amendments of 1988 (P.L. 100-443). Most of the hot and cold spring outlets have been developed through installation of lateral collection lines that feed into capped, concrete collection boxes. Water is directed from collection boxes into a primary central holding reservoir through a series of connecting trunk lines. Water is distributed to users from the central reservoir. A number of bathhouses and associated cultural features exist because of the presence of these springs and the primary cultural resource of HOSP is the Historic Landmark District of Bathhouse Row (National Park Service, 1986).

Two cold (relative to the temperature of the hot springs) springs, a few intermittent and perennial streams, and a few small lakes also occur within the boundaries of HOSP (fig. 2). The cold springs (Whittington Spring and Happy Hollow Spring) are treated with ultra-violet light and ozone before being used by the public as sources of drinking water (Stephen Rudd, National Park Service, written commun., 2002). The cold springs also are capped with concrete collection boxes. Gulpha Creek (which flows through the Gulpha Gorge Campground) and Whittington Creek (which flows into an urban area of the city of Hot Springs and into Hot Springs Creek) are the streams most visible to the public. Hot Springs Creek flows through a creek arch (tunnel) underneath the street along Bathhouse Row. Unused water from many of the hot springs is discharged by the National Park Service into the creek. The lakes are in relatively undeveloped parts of HOSP.

In the cold springs (and to a lesser extent the hot springs), streams, and lakes, water discharge and volume is a function of preceding precipitation and runoff. Precipitation and runoff are greater in the Ouachita Mountains than in other parts of Arkansas (Freiwald, 1985). Average annual precipitation near Hot Springs is about 56 inches. Typically, March, April, and May are the wettest months and June, July, August, and October are the driest months. Average annual runoff near Hot Springs is about 20 inches. The higher runoff in the Ouachita Mountains is the result of higher precipitation, steep gradients, and surficial geology.

Land Use

Recent (primarily 1992) land-use data (table 1) show that land use was primarily forest (exceeding 85 percent) in the four stream basins in HOSP. Urban land use (residential plus commercial/industrial) exceeded 1 percent only in the Whittington Creek and Hot Springs Creek Basins. Agricultural land use (pasture/hay or row crops) exceeded 2 percent only in the Bull Bayou Basin. The urban land use of about 12 percent in the Hot Springs Creek Basin and about 1 percent in the Gulpha Creek Basin is substantially lower than the 26 percent and 5 percent, respectively, reported for the 1970’s by Bedinger and others (1974). Property has been bought and several houses have been razed by the National Park Service since the 1970’s in the Sleepy Valley area south of Desoto Park of the Gulpha Creek Basin and in the extreme northeastern corner of the Hot Springs Creek Basin. Much of this land (and land in existing subdivisions with low residence density) was classified as urban and is now classified as forest.

Based on the 1970’s and 1992 (primarily) land-use data, the area of land being converted from forest to other land uses appears to be insignificant and urban land use may even be decreasing. In 1997, about 80 percent of the undeveloped land in the Hot Springs and Gulpha Creek Basins was hilly and unsuitable for construction (National Park Service, 1997).

Table 1. Land use percentages for the Bull Bayou, Whittington Creek, Hot Springs Creek, and Gulpha Creek Basins.

[Land use data (primarily from 1992) are from the National Land Cover Data produced as a cooperative project between the U.S. Geological Survey and the U.S. Environmental Protection Agency. These data were obtained from the web site http://edcwww.cr.usgs.gov/pub/edcuser/vogel/states]

Basin	Drainage area (square miles)	Forest	Residential	Commercial/ industrial	Pasture/hay	Row crops	Other
Bull Bayou[1]	18.0	94.6	<0.1	0.1	3.0	0.1	2.2
Whittington Creek[2]	1.2	94.4	3.6	1.2	0.5	0.0	0.3
Hot Springs Creek[1]	3.7	86.0	10.2	1.9	1.6	0.0	0.3
Gulpha Creek[1]	4.6	97.3	0.5	0.4	1.4	0.1	0.3

[1]At most downstream HOSP boundary
[2]At entry to creek arch

Land use in the area within 0.5 mile of the cold and hot springs within HOSP typically is between 50 and 55 percent forest, 20 and 22 percent residential, 13 and 17 percent pasture, 7 and 8 percent commercial/industrial, and 0 and 2 percent crops (Arkansas Department of Health, 2000a-c). Source water assessments (Arkansas Department of Health, 2000a-f) of Happy Hollow Spring, Whittington Spring, and the hot springs indicate that there are 37 (Happy Hollow Spring), 15 (Whittington Spring), and 41 (hot springs) potential point sources of contamination within 0.5

mile of these springs. Most of these potential sources of contamination are motels and hotels, small businesses, or schools. Four “individual sewage disposal systems” (probably septic systems) are reported to occur about 2,500 feet northwest of Whittington Spring. The HOSP maintenance area lies immediately adjacent to Whittington Spring and is a potential source of contamination not listed in the Arkansas Department of Health assessment. Susceptibility of these springs to contamination is considered to be medium (Arkansas Department of Health, 2000a-f) based on land use, soil, geology, and hydrology factors (Arkansas Department of Health, 2002).

A few old or operating landfills are known to exist within or near HOSP. A new Garland County Class IV landfill (adjacent to an existing County landfill) was recently (2001) constructed in an area north of HOSP in the Bull Bayou Basin (Stephen Rudd, National Park Service, written commun., 2002).

A facility that produces and handles lubricating oils and greases and volatile organic compounds is located about 0.5 mile southeast of Bull Bayou on Blacksnake Road (U.S. Environmental Protection Agency, 2000). No releases to land or water were reported in the 1998 reporting year.

Hydrogeology

The rocks cropping out in the vicinity of the hot springs at HOSP are sedimentary rocks, although intruded igneous rocks are exposed in the region (Purdue and Miser, 1923; Bedinger and others, 1979). The sedimentary rocks are relatively old (Paleozoic) and consist of shale, chert, novaculite, and sandstone. The most areally extensive formations with outcrops near HOSP are the Stanley Shale, Hot Springs Sandstone Member of the Stanley Shale, Arkansas Novaculite, and Bigfork Chert (fig. 3). The beds of sedimentary rocks generally are steeply inclined because of mountain building forces in late Paleozoic time.

The flow system that yields thermal water to the hot springs of HOSP is not fully understood. Bedinger and others (1979) present data and conceptual and mathematical models based on geologic and geochemical data that describe the hot-springs flow system (fig. 4). They provide evidence that almost all of the hot-springs water is of local, meteoric (i.e., atmospheric) origin from recharge of the Bigfork Chert and the Arkansas Novaculite. They suggest that the water slowly percolates to depth, resides in the heated part of the system for a relatively short time (no more than a few hundred years), and then travels rapidly to the surface. Based on carbon-14 dating, Bedinger and others (1979) estimate that the age of much of the water exceeds 4,000 years. The hot springs emerge along a line about 1,500 feet long, from the plunging crestline of a large overturned anticline (a fold of rock with the stratigraphically older rock at its core) along the southern margins of the Ouachita anticlinorium in the Zigzag Mountains (Bedinger and others, 1979). The springs emerge from the Hot Springs Sandstone Member of the Stanley Shale. Some geophysical and geological data suggest a somewhat different scenario (Bergfelder, 1976) —that the hot springs are located above the western edge of a large pluton (an igneous intrusion) with an upper surface about 4,000 feet below land surface that extends eastward from an igneous outcrop near Magnet Cove (fig. 1). Bergfelder suggests that the meteoric water percolates through a fracture zone (location unspecified) associated with the margin of the pluton and then (because the heat source is unknown) either takes in heat from the pluton, percolates below the pluton to

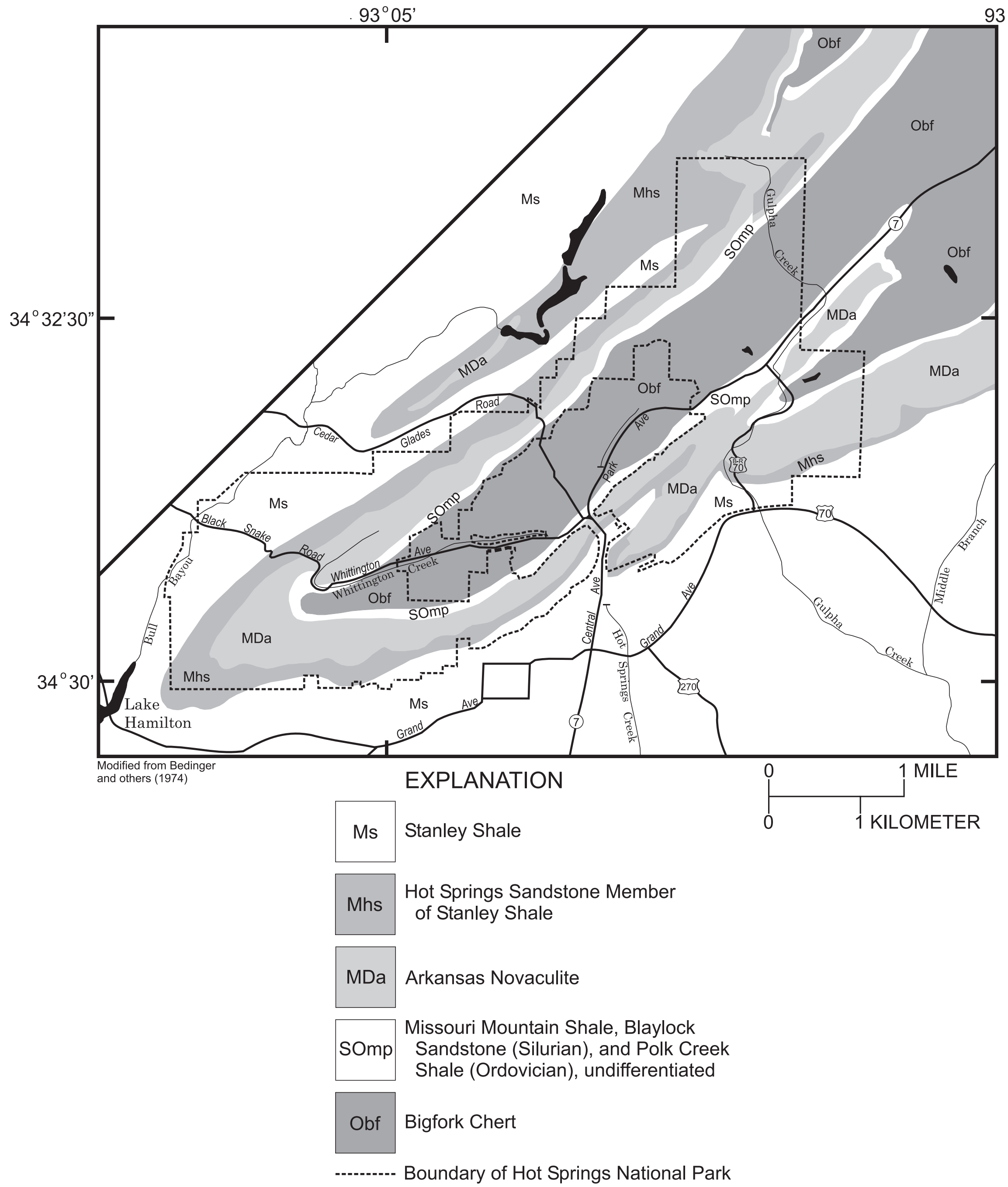

Figure 3. Surficial geology of Hot Springs National Park.

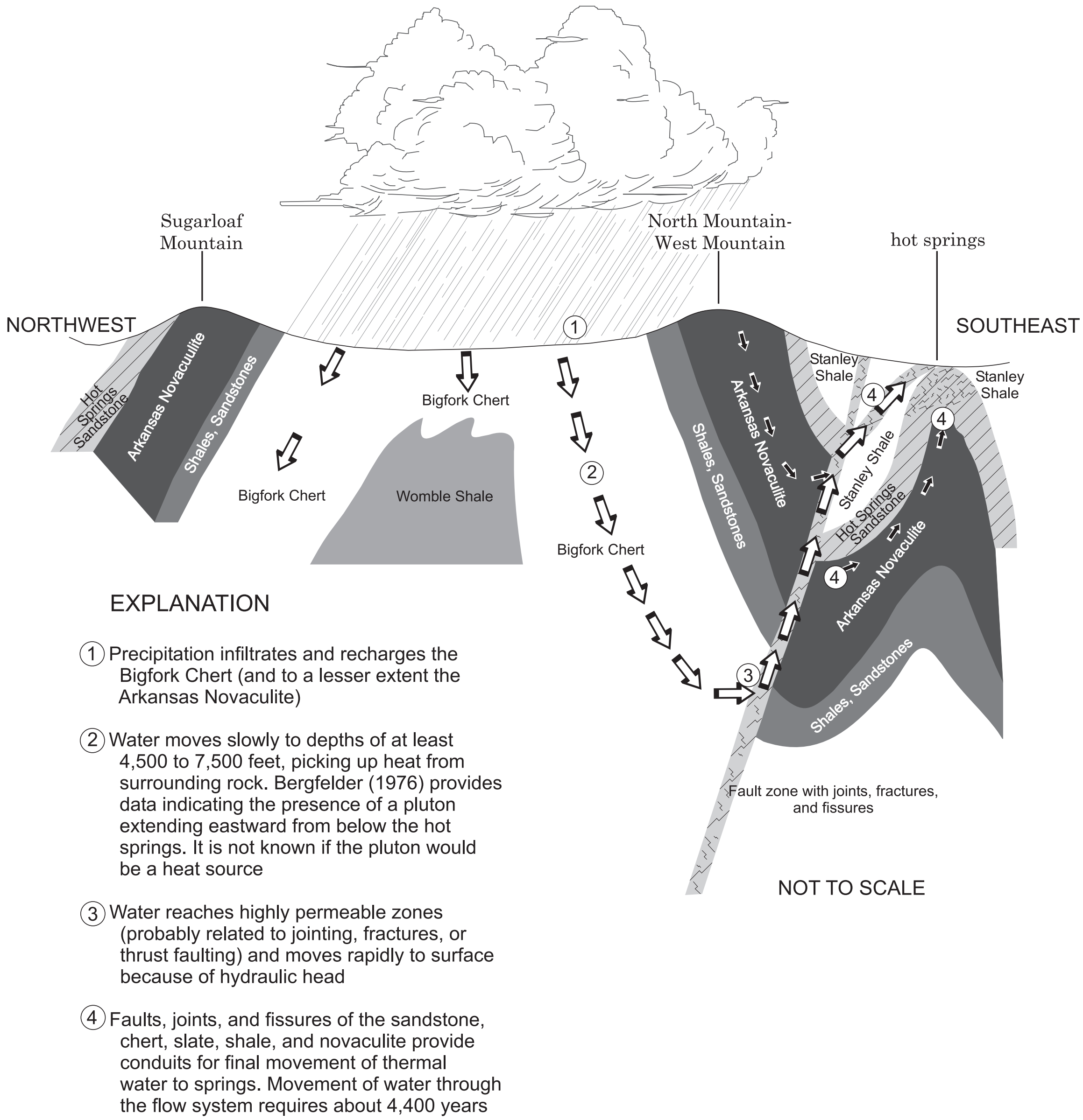

Figure 4. Conceptual model of the hot-springs flow system.

depths of about 8,000 to 12,500 feet and takes in heat, or percolates below the pluton to a lesser depth and takes in heat from underlying magma.

The Bigfork Chert and the Arkansas Novaculite outcrop areas, which may serve as recharge areas, primarily lie north and northeast of the hot springs (Bedinger and others, 1979). Outcrop area of the Bigfork Chert is about 36 square miles; outcrop area of the Arkansas Novaculite is about 13 square miles.

Many of the cold springs in the area issue from the Bigfork Chert at contacts of the Bigfork Chert with less permeable formations (Bedinger and others, 1979). This association was noted by Purdue and Miser (1923).

More detailed descriptions of the geology are found in Purdue and Miser (1923), Arndt and Stroud (1953), Bedinger and others (1974), Bedinger and others (1979), and Bedinger (1994).

Ground Water

Approximately 47 hot springs emerge from the Hot Springs Sandstone in HOSP. Water temperatures reported between 1804 and 1972 frequently exceeded 140 degrees Fahrenheit (Bedinger and others, 1979); temperatures from selected springs sampled in 2000 and 2001 typically ranged from about 130 to 145 degrees Fahrenheit (R.W. Bell, U.S. Geological Survey, written commun., 2001) According to Bedinger and others (1979), the mean monthly combined flow of the hot springs (measured in the central collecting reservoir) ranged from 750,000 to 950,000 gallons per day between September 1970 and May 1973. The flow was highest in the winter and spring and lowest in the summer and fall. More recent measurements by the U.S. Geological Survey indicated that the mean monthly flow (measured continuously in a weir box in the basement of the Park Headquarters building) between October 1998 and September 1999 was substantially lower and ranged from 617,000 to 695,000 gallons per day (C. S. Barks, U.S. Geological Survey, written commun., 2000). The discharge from the weir box flows into the central collecting reservoir. A large spring that bypasses the weir box and emerges at the bottom of the collecting reservoir is not included in the flow reported by Barks. Therefore, at least some of the difference is because of differences in measurement procedures. Historical and current monitoring data are not sufficient to determine whether substantial short-term fluctuations or long-term declines in discharge also have occurred.

Water-quality data from a number of sources are compiled in National Park Service (1998). Water in single samples collected in 1972 from eight springs (Bedinger and others, 1979) was well buffered (bicarbonate alkalinity of 155 to 165 milligrams per liter), contained low concentrations of nutrients (less than 0.005 to 0.2 milligrams per liter nitrate as NO_3,less than 0.005 to 0.09 milligrams per liter orthophosphorus as PO_4), and did not have concentrations of dissolved solids (184 to 189 milligrams per liter residue on evaporation) that would be detrimental to most uses. Bedinger and others (1979) reported little change in the chemical quality of water from the hot springs between 1890 and 1972. Pearson (1994) stated that the water quality of samples collected from two hot springs in 1993 was not significantly different from that of 1972.

Although most of the water from the hot springs is several thousand years old, a relative small (but unknown) percentage of the water is of recent age. Carbon and tritium isotope data for samples collected in 1972 indicated that most of the water from the hot springs was about 4,400 years old and a very small amount was less than 20 years old (Bedinger and others, 1979). For example, Bedinger and others (1979) mention fluctuations (amount not specified) in temperature in some springs that were effects of mixing hot-springs water with seepage from nearby rainfall. More recent (2000) samples collected by the U.S. Geological Survey for radioactive isotope analyses confirm that the hot springs include a component of water of recent age (P.D. Hays, U.S. Geological Survey, oral commun., 2000). Also, increases in discharge and decreases in temperature of the water of the hot springs have been observed within several hours of rainstorms in the Hot Springs vicinity (C. S. Barks, U.S. Geological Survey, written commun., 2000). For example, following a rainstorm on December 3, 1993, discharge from the hot springs into the collection reservoir under the park headquarters increased from about 431 gallons per minute to a maximum of 561 gallons per minute and water temperature decreased from about 142 degrees Fahrenheit to a minimum of 119 degrees Fahrenheit.

Most of the cold water springs within or adjacent to HOSP issue from the Bigfork Chert (Bedinger and others, 1979). Water temperatures measured one time at each of 12 cold springs issuing from the Bigfork Chert and other formations during January through September of 1972 generally ranged from about 64 to 70 degrees Fahrenheit in 1972; this indicates that some of the water supplying cold springs in the area is heated by geothermal processes (Bedinger and others, 1979). Temperature of water from 30 wells in the area (single measurements, mostly from June through September 1972) generally was about 59 to 64 degrees Fahrenheit (Bedinger and others, 1979). Warmer temperatures (about 69 to 127 degrees Fahrenheit) were measured at wells closer to the hot springs; Bedinger and others (1979) state that the high temperatures of the water from wells close to the hot springs "are associated with the abnormally high geothermal gradient caused by heat conveyed to the surface by the waters of the hot springs." However, Bedinger (1994) and Pearson (1994) stated that water-quality data for samples collected in 1993 from three wells near the hot springs indicate that there is some seepage from the thermal conduit supplying the hot springs into the aquifer supplying the wells. Thus, just as the hot spring water can include a component of water of shallow origin and recent age, the water supplying wells closest to the hot springs probably includes a component of thermal water.

Water from the cold springs in the vicinity of HOSP also appears to be of good quality (with treatment) for drinking water and other uses; however relatively little is known about the presence or absence of some potential contaminants. Water in samples from seven springs (Bedinger and others, 1979) ranged from poorly to well buffered (bicarbonate alkalinity of 0 milligrams per liter with a pH of 4.58 to 211 milligrams per liter with a pH of 7.25), contained concentrations of nutrients that were relatively low (less than 0.005 to 0.7 milligram per liter nitrate as NO_3, 0.0 to 0.39 milligram per liter orthophosphorus as PO_4) but sometimes higher than concentrations in water from the hot springs, and did not have detrimental concentrations of dissolved solids (14 to 204 milligrams per liter residue on evaporation). Carbon isotope data for samples collected in 1972 indicated that the water from the Happy Hollow Spring was recent recharge water (less than 20 years old), whereas most of the water from Whittington Spring was approximately 6,100 years old. Water from Whittington Spring is substantially more mineralized than water from Happy Hollow Spring. In samples collected in 1972 the calcium concentration was 50 milligrams per liter and the bicarbonate concentration was 157 milligrams per liter at Whittington Spring, whereas the calcium concentration was 0.2 milligram per liter and the bicarbonate concentration was 1 milligram per liter at Happy Hollow Spring (Bedinger and others, 1979). Arkansas Department of Health data for samples collected in 1998 (Glen Avaritt, National Park Service, written commun., 2000) are similar to those of the 1972 samples. Bedinger and others (1979) states that the U.S. Environmental Protection Agency reported radon concentrations of about 1.0 picocurie per liter from Happy Hollow Spring and 0.60 picocurie per liter from Whittington Spring. The currently (2002) proposed federal drinking water standard for radon is 300 picocuries per liter (4,000 picocuries per liter if programs addressing radon in indoor situations are implemented) (U.S. Environmental Protection Agency, 2002).

Treated water from Happy Hollow Spring and Whittington Spring (both of which are treated with ultra-violet light and ozone before being released for consumption) and untreated thermal water and cooled thermal water are monitored as required by the Arkansas Department of Health (Stephen Rudd, National Park Service, written commun., 2002). Samples from Happy Hollow Spring and Whittington Spring are analyzed approximately every 2 years for trace elements, odor, turbidity, nitrate plus nitrite, color, and other inorganic analytes (Glen Avaritt, National Park Service, written commun., 2000). Bacteria analyses are performed weekly (heterotrophic plate count) or twice monthly (total coliforms and *Escherichia coli*) for samples collected from the two cold water springs—Happy Hollow Spring and Whittington Spring (Glen Avaritt, National Park Service, oral commun., 2000). Samples of untreated thermal water and cooled thermal water are collected and analyzed for total coliforms and *E. coli* monthly or approximately annually at several other locations in HOSP. No primary or secondary drinking-water standards have been exceeded in any of these samples (Glen Avaritt, National Park Service, oral commun., 2000).

Few pesticide data are available for organic compounds in ground water in HOSP. Samples were collected from two hot springs and two cold springs and analyzed for approximately 80 chlorinated insecticides and semivolatile organic compounds in September 2000 and October 2001 (R.W. Bell, U.S. Geological Survey, written commun., 2002). No compounds were detected (reporting limit was 10 micrograms per liter for most compounds) in samples from the two hot springs and two cold springs. Very little data are available for pesticides in ground water of the Ouachita Mountains (Hays, 1999). For the purpose of comparison with ground water in eastern Arkansas, Cavalier and Lavy (1987) sampled for four pesticides (2,4,-D, dichlorprop, hexazinone, and picloram) at eight sites in primarily forested areas in the Ouachita Mountains in 1987; no pesticides were detected.

Surface Water

Three second- and third-order perennial streams and a few intermittent streams flow through HOSP (fig. 2). Hot Springs Creek (downstream from the hot springs), Gulpha Creek, and Bull Bayou are small, perennial streams. The 7-day, 10-year low flows of these streams exceed 0.0 cubic feet per second but are less than 1.0 cubic feet per second (Hunrichs, 1983). Whittington Creek (also known as West Fork Hot Springs Creek), several small tributaries of Bull Bayou that flow northward off of Sugarloaf Mountain, and a few small tributaries of Gulpha Creek that flow southward off of Sugarloaf Mountain are the only other streams in HOSP. Drainage areas of all these streams are small; Hot Springs Creek has a drainage area of 4.72 square miles at the Missouri-Pacific Railroad crossing about 1.5 mile downstream from HOSP, Gulpha Creek has a drainage area of 4.62 square miles just downstream from HOSP at Highway 70, and Bull Bayou has a drainage area of 18.0 square miles at Lake Hamilton just downstream from where it leaves HOSP (Yanchosek and Hines, 1979).

Historically, the natural channel of Hot Springs Creek occupied the bottom of the gorge between Hot Springs Mountain and West Mountain (U.S. Army Corps of Engineers, 1993). Because of concerns about flooding, in 1883 Hot Springs Creek was enclosed in a tunnel. This tunnel, which still exists, is locally known as "the creek arch".

Two small lakes (Ricks Pond and an unnamed lake) are located in the eastern part of HOSP (fig. 2). Both of these lakes are smaller than 10 acres.

Some water quality data are available for the streams and lakes of HOSP (National Park Service, 1998; Buchanan and others, 1978). Most of these data are associated with sampling conducted between 1974 and 1978. Several sites on Ricks Pond and nearby streams (including Gulpha Creek) were sampled three times during the summer of 1978 (Buchanan and others, 1978; National Park Service, 1998). Other data are available for a few sites on Bull Bayou and Hot Springs Creek. Typically, Ricks Pond and the streams within or upstream from HOSP had low nutrient concentrations (less than 0.1 milligram per liter of nitrate as nitrogen, less than 0.05 milligram per liter total phosphorus as phosphorus), low to moderate specific conductance (58 to 330 microsiemens per centimeter), circumneutral pH (usually 6.7 to 7.5), relatively low alkalinity

(25 to 45 milligrams per liter as calcium carbonate), low concentrations of chloride (3 to 5 milligrams per liter) and sulfate (5 to 10 milligrams per liter), and low turbidity (less than 10 nephelometric turbidity units). Fecal coliform bacteria concentrations commonly were less than 1 colony per 100 milliliters, but concentrations sometimes exceeded 100 colonies per 100 milliliters at several sites. The only known recent (since 1990) data are for five samples from the Bull Bayou Basin upstream from HOSP collected on July 12, 1999 (J.A. Wise, Arkansas Department of Environmental Quality, written commun., 2000). Samples were analyzed for chloride, sulfate, fluoride, nutrients, total organic carbon, biochemical oxygen demand, turbidity, total suspended solids, and dissolved solids. Conditions were typical of Ouachita Mountain streams in basins with primarily forest land use (see studies described below; chloride concentrations of 2.0 to 3.0 milligrams per liter; sulfate concentrations of 5.5 to 7.5 milligrams per liter; nitrate of 0.1 to 0.2 milligram per liter as nitrogen; total phosphorus less than 0.02 milligram per liter; turbidity of 0.8 to 5.3 nephelometric turbidity units; dissolved solids of 43 to 75 milligrams per liter).

Petersen (1988) and Bell (1999a, 1999b) described the water quality of streams in the Ouachita Mountains. Water generally is clear (turbidity of 2 to 20 nephelometric turbidity units), low in dissolved solids (40 to 60 milligrams per liter, specific conductance of 50 to 100 microsiemens per centimeter at 25 degrees Celsius) and slightly buffered (alkalinity of 15 to 20 milligrams per liter as calcium carbonate). Typical concentrations of nutrients in water from streams in forested areas (which characterizes the largest amount of the basins of the streams in HOSP) reported were 0.10 milligram per liter of nitrite plus nitrate as nitrogen, 0.73 milligram per liter of total nitrogen as nitrogen, 0.04 milligram per liter of total phosphorus as phosphorus, and 0.01 milligram per liter of orthophosphate as phosphorus. Nutrient concentrations in areas of mixed land use were higher (about 20 to 100 percent higher) than the concentrations in the forested areas. A relatively limited amount of pesticide data is available for streams in the Ouachita Mountains and about two-thirds of the data is for samples collected prior to the mid-1980's (Bell, 1999a). Sixteen of the 23 analyzed pesticides were not detected in any samples. With the exception of toxaphene (six detections of 0.1 milligram per liter or greater in 18 samples), concentrations did not exceed 0.04 milligram per liter. Additional information about water quality of streams in parts of the Ouachita Mountains is available in Cole and Morris (1986). Concentrations of most trace elements (metals) were typically less than 20 micrograms per liter and met drinking-water standards. Concentrations of five trace elements commonly exceeded 20 micrograms per liter: aluminum (commonly exceeding 50 micrograms per liter), iron (commonly exceeding 200 micrograms per liter), manganese (commonly exceeding 30 micrograms per liter), strontium (commonly exceeding 50 micrograms per liter), and zinc (commonly exceeding 20 micrograms per liter).

Aquatic Ecology of Springs, Streams, and Lakes

Although some unique organisms live in the hot springs, no terrestrial or aquatic species in HOSP are federally-listed threatened or endangered species (U.S. Army Corps of Engineers, 1993; National Park Service, 1997). Between 13 and 17 species of blue-green algae thrive in the hot springs of HOSP (U.S. Army Corps of Engineers, 1993). One species of blue-green algae, *Phormidium treleasei*, has been recorded from only five other places in the world (Meyer, 1996). An undescribed and unnamed species of ostracod (*Darwinula* sp.) also lives and reproduces in the hot springs (U.S. Army Corps of Engineers, 1993).

Twenty-three species of fish are known to occur either within HOSP boundaries or within 0.5 mile of these boundaries. Buchanan and others (1978) lists 15 species collected in 1978 from 11 sites on Ricks Pond, Gulpha Creek, or tributaries of Gulpha Creek within the boundaries of HOSP. These species include one darter (orangebelly darter), four minnows (central stoneroller, creek chub, common carp, golden shiner), four sunfish (bluegill, green sunfish, longear sunfish, largemouth bass), two killifish or "topminnows" (blackspotted topminnow, northern studfish), two catfish (channel catfish, yellow bullhead), one sucker (northern hog sucker), and one livebearer (western mosquitofish). One additional species (black bullhead) was collected from one site less than 0.25 mile upstream from the HOSP boundary on a tributary of Gulpha Creek (Buchanan and others, 1978). Data on the CD-ROM "Arkansas Fish Database, February 22, 2000" by Henry W. Robison of Southern Arkansas University indicate that seven additional species were collected from two sites on Bull Bayou (both outside of HOSP, but within 0.5 mile of the HOSP boundary); these species include three darters (greenside darter, logperch, creole darter), three minnows (striped shiner, redfin shiner, bigeye shiner), and one sunfish (spotted bass).

The Ouachita madtom (*Noturus lachneri*) recently (1992) was collected from the Middle Branch of Gulpha Creek about 1.25 mile southeast of HOSP (from data on the CD-ROM "Arkansas Fish Database, February 22, 2000" by Henry W. Robison, Southern Arkansas University). This madtom (listed by the Arkansas Department of Heritage as a species of special concern because it appears to be rare or uncommon) is endemic to parts of the Ouachita River Basin in the vicinity of HOSP (Robison and Buchanan, 1988), but Arkansas Department of Heritage records do not show that the madtom has ever been collected in HOSP (Cindy Osborne, Arkansas Department of Heritage, oral commun., 2000).

Data on phytoplankton, periphyton, higher forms of aquatic vegetation, zooplankton, and benthic macroinvertebrates from collections made in the summer of 1978 from Ricks Pond and streams in the Gulpha Creek Basin are available in Buchanan and others (1978). Phytoplankton in Ricks Pond were numerically dominated by blue-green algae, euglenoid algae, or dinoflagellates. Periphyton from most sites on Gulpha Creek within HOSP were numerically dominated by blue-green algae. Milfoil (*Myriophyllum*), water lily (*Nymphaea*), and cattail (*Typha latifolia*) were found in Ricks Pond and were characterized as presenting "no real 'vegetation problem' in the pond" (Buchanan and others, 1978). Rooted aquatic plants were sparse along Gulpha Creek. The most common plant was water willow (*Dianthera*, now known as *Justicia*). Milfoil, water cress (*Nasturtium officinale*), horsetail (*Equisetum*), and river weed (*Podostemum ceratophyllum*) also were found. Zooplankton from Ricks Pond were numerically dominated by rotifers and copepods. Benthic macroinvertebrates in most samples from Ricks Pond were numerically dominated by a phantom midge (*Chaoborus*); samples from streams in the Gulpha Creek Basin within HOSP were dominated by the mayfly *Stenonema* or the chironomid midge *Pentaneura*.

Research conducted by scientists from the National Aeronautics and Space Administration (NASA) detected the presence of very small microbes (nanobacteria, or nannobacteria) in water from the hot springs (Stephen Rudd, National Park Service, written commun., 2000). Spherical (150-200 nanometers in diameter) and rod-shaped (50-150 nanometers in girth and less than 1 micrometer in length) nanobacteria that resemble larger known bacteria were observed, using a high resolution scanning microscope, in samples from HOSP. Some of these nanobacteria appeared to have flagella and others appeared to be dividing. The nanobacteria presence is extremely important to the scientific community. NASA scientists are interested in the nanobacteria because of their resemblance to structures hypothesized to be fossilized nanobacteria found in the Mars meteorite that NASA designates as ALH84001.

Water Resources Issues

The primary water resources issues of HOSP are related to (1) water quality of springs, (2) water quality of streams, and (3) flooding of Whittington, Hot Springs, and Gulpha Creeks. All of these issues are related to the potential effects of land use on the springs, streams, and lakes of HOSP.

Water Quality of Hot and Cold Springs

Because of concerns for public health and usability of water from the springs, water quality of the springs is a primary issue of concern for HOSP. In addition to being used for bathing, water from the hot and cold springs is collected by the public for drinking water. Treated water (which is exposed to ultra-violet light and ozone before being released for consumption) from Happy Hollow Spring and Whittington Spring and untreated thermal water and cooled thermal water are monitored as required by the Arkansas Department of Health. No primary or secondary drinking water standards have been exceeded in any of these samples (Glen Avaritt, National Park Service, oral commun., 2000). Relatively little is known about the presence or absence of some potential contaminants in the water of the hot and cold springs or about how concentrations of these potential contaminants vary with hydrologic conditions. Relatively small amounts of trace element (metals), pesticide, and other organic compounds data are available. However, little is known about how concentrations of any of these analytes vary with changes in the amount of water contributed by recent, shallow recharge following rainstorms. A U.S. Geological Survey study currently (2002) being conducted in cooperation with the National Park Service will provide some nutrient, trace element, pesticide, isotopic, and semivolatile organic compound concentration data during periods of typical flow and during periods when flow is suspected to include a larger percentage of flow contributed by recent, shallow recharge.

The quality of the thermal water that makes up the largest percentage of the water of the hot springs (and the quality of most of the cooler water of Whittington Spring) is not likely to be affected by any land-use changes for several thousand years. However, the locally derived, cold-water recharge that contributes some flow to the hot springs of HOSP is susceptible to contamination from surface input and some evidence suggests that shallow ground water in the area has been contaminated (based on elevated nitrate and chloride concentrations in water from some shallow wells in the area; Bedinger and others, 1979). It is likely that the effect of this cold-water recharge on the quality of the hot spring water varies with differing hydrologic conditions; after rainstorms, or during wet periods, a greater percentage of the water that reaches the hot springs (and Whittington Spring) is more likely to be potentially contaminated.

Water quality of the springs is potentially affected by land use practices in the recharge area associated with the water of recent age issuing from the springs. The magnitude of effects on water quality is determined, in part, by the land use practice and the percentage of the water of recent age that is issuing from a spring. Depending on the land use, effects could include elevated concentrations of bacteria, other pathogens, nutrients, metals, and organic compounds. Source water assessments (Arkansas Department of Health, 2000a-f) of Happy Hollow Spring, Whittington Spring, and the hot springs indicate that most of the potential point sources of contamination to these springs are motels and hotels, small businesses, or schools.

Land-use influence on water quality of the cold and hot springs is an important water resources issue. It is reasonable to expect that land use within the recharge areas of Whittington Spring, Happy Hollow Spring, and the cold-water component of flow from the hot springs, may affect the quality of the cold water. However, these cold water recharge areas have not been delineated. Delineation of these recharge areas will enhance management of the spring resource. For example, land-use changes in the recharge areas can be expected to affect quantity and quality of spring discharges by affecting the quantity (because of changes in impervious area) and quality of water recharging the aquifers. Accurate predictions of these land-use driven changes are more difficult without accurate delineation of the recharge areas and their associated land use.

The size and location of the recharge areas that contributes a cold-water component to total flow of the hot springs (and to the cold water springs) in HOSP are unknown. This cold-water component is important because it follows a shorter, shallow flow path. Because of the shallower flow path, this water is vulnerable to contamination from the surface; because of the shorter flow path, any contamination reaching this water will reach the hot or cold springs in a relatively short time (possibly hours or days). As part of the delineation of recharge areas for the cold-water component of the spring flows, travel times from various locations in the recharge areas to the hot and cold springs can be estimated more accurately.

Water Quality of Streams

Although water quality of the small streams that flow through HOSP is expected to be fairly good with low concentrations of nutrients, trace elements, and organic compounds, little is known about the surface-water quality within the Park. Potential sources of contamination include landfills in the upstream parts of the Bull Bayou and Whittington Creek Basins, urban activities (including commercial activities, pest management, lawn care, fuel storage, and vehicle maintenance) in the Whittington, Hot Springs, and Gulpha Creek Basins, and portions of a golf course in the Gulpha Creek Basin. No data are available regarding hydrophobic organic compounds and trace elements (metals) in streambed sediment, these compounds often are easier to detect in streambed sediment (because of their physical properties, intermittent introduction into the stream associated with storm events, and higher concentrations in sediment).

Water quality of Gulpha and Whittington Creeks may be of greater concern than that of other creeks because of public accessibility and potential presence of a relatively rare species of fish in Gulpha Creek. Whittington Creek flows through an area of HOSP that is frequented by park visitors and is adjacent to one of the publicly-used drinking water springs (Whittington Spring). Gulpha Creek flows through the Gulpha Gorge campground and picnic area. The site where Gulpha Creek crosses the HOSP boundary is within about 2.5 river miles of the location of a 1992 collection of the Ouachita madtom.

Flooding

Since at least 1883, flooding along Hot Springs Creek and its tributaries has been a concern. The U.S. Army Corps of Engineers (1993) described the historic and recent flooding concerns and related matters. The creek arch conveys the normal flow of Hot Springs Creek but does not have sufficient capacity to convey storm flows that exceed a recurrence interval of about 3 years. As a result, flood water volumes that exceed the capacity of the arch flow down Central Avenue (Arkansas Highway 7) and adjacent areas. Bathhouse Row is located along part of the east side of Central Avenue, and several private businesses are located along the west side and other parts of the east side of Central Avenue. Flooding “has approached catastrophic proportions” in some events and three lives have been lost because of the flooding (U.S. Army Corps of Engineers, 1993). The most recent flood (May 1990) caused an estimated $5.3 million damage. Gulpha, Hot Springs, and Whittington Creeks each overtopped bridges (none were destroyed); water depths along Central Avenue were 2 to 4 ft above the sidewalks and water depths in the Gulpha Gorge campground were approximately 0.5 ft (Southard, 1992). The 1990 flood resulted from rainfall of 11.10 to 13.25 inches in the Hot Springs area with an estimated recurrence interval of 100 years (Southard, 1992). The peak discharge at a site on Gulpha Creek about 5 miles south of the HOSP boundary was estimated to have a recurrence interval of greater than 100 years (Southard, 1992). Urbanization and the related increase in impervious surfaces (roads, parking lots, roofs) has greatly reduced rainfall infiltration and increased the height and velocity of floods. The National Park Service is concerned with future flooding because of human safety and impacts on the structures along Bathhouse Row.

In the early 1990's construction of a West Mountain tunnel to divert flood waters away from the creek arch and Central Avenue was considered as part of a U.S. Army Corps of Engineers flood control study (U.S. Army Corps of Engineers, 1993). Construction of this tunnel subsequently was determined to be unfeasible (Stephen Rudd, National Park Service, oral commun., 2000).

A flood-warning system, consisting of five precipitation gages and two stage gages that monitor water levels of Hot Spring Creek and Whittington Creek linked to a siren and loud-speaker system, has been operated by the city of Hot Springs since the mid-1990's (Jeff Winter, City of Hot Springs, oral commun., 2000). Three rain gages are located on West Mountain and Sugarloaf Mountain to the north, west, and south of Whittington Creek. The other two rain gages and the two stage gages are located near the entrances of Hot Springs Creek and Whittington Creek to the creek arch. The flood-warning system does not include the Gulpha Creek Basin.

Recommendations: by David N. Mott

Water quality of geothermal springs

The enabling legislation for HOSP states that the primary mission of the National Park Service is to provide geothermal waters to the public in an unaltered condition. Since the establishment of Hot Springs as a federal reservation in 1832, drinking water is supplied to the public in raw form from the hot springs, and in treated form from two cold springs (Happy Hollow and Whittington Springs). Increasing development within the recharge area of the geothermal springs could potentially alter the natural water quality of the springs. Geothermal spring water quality should be monitored both from the stand-point of verifying no degradation of the natural quality, and that the water continues to be within drinking water standards for public consumption. Issues to be monitored include flow volumes, temperature trends, general chemical constituents, fecal coliform bacteria, and other parameters related to public water system monitoring.

An effort is currently underway in the National Park Service to develop long-term monitoring strategies to address top priority monitoring needs in National Parks. Hot Springs National Park management has identified geothermal spring quality as their top priority. A lengthy planning process is currently underway following the guidelines of the Inventory and Monitoring Program intended to develop recommended protocols for addressing top-priority monitoring needs. The planning process utilizes collection and assessment of existing data, development of conceptual models, selection of “vital signs” that most effectively address monitoring needs, and the input of knowledgeable scientists to develop sampling designs and protocols. The Monitoring Program will also handle data management and reporting requirements, and is intended to provide useful and timely information to park managers. Because geothermal spring water quality is the top-priority monitoring need for HOSP, it is anticipated that the Inventory and Monitoring Program will adequately address this need once the planning process is completed.

Determine recharge area of cold springs and the cold water component of hot springs

As mentioned previously, land-use change in recharge areas has the potential to degrade water quality and alter recharge/runoff ratios for both hot and cold springs at Hot Springs National Park. Contaminants are a primary concern because of the use of two cold water springs, and all of the hot springs, as public water supplies for drinking and bathing. Additionally, ground water should be protected because of its roll in maintaining healthy aquatic ecosystems. Land-use changes in the spring's suspected recharge areas are primarily characterized by conversion from forest to residential or urban, or residential converting to more urban.

A phased approach is recommended to allow 1.) an initial assessment of geohydrologic factors governing ground water flow, 2.) refinement of recharge area boundaries through dye-tracing studies, and 3.) a land-use assessment focusing on areas shown to contribute recharge to the hot and cold springs within the park. The use of tracer dyes can determine both the recharge areas of springs and the relative degree of attenuation or filtration of contaminants along the flow route. Attenuation and filtration assessments can be accomplished through monitoring time of travel and concentrations of dye observed at recovery points relative to amount of dye introduced.

Hot Springs National Park is working with the Arkansas District of the USGS to secure funding for a proposal to complete the recharge area delineation as described generally above.

Effects of high-flow conditions on the water quality of springs

Spring flow volume at HOSP demonstrates a positive correlation with increased rainfall. This positive correlation means that surface recharge can, under appropriately saturated conditions, rapidly migrate into the ground water and join with existing flow paths to emerge at springs being used as public water supplies. This becomes an increasing concern as recharge zones are urbanized and contaminants ranging from yard fertilizers and pesticides to petrochemicals and other urban runoff mix with the rapidly transported storm water. The use of septic systems for on-site waste renovation represents an additional concern.

High flow water quality sampling would be most efficient if sampling was coordinated with the dye-tracing activities previously recommended. While the use of charcoal packets for adsorption of dyes alleviates the need to collect water samples at frequent intervals in order to monitor tracer movements, the combination of water quality and dye sample collection provides additional valuable information that can not be garnered from charcoal pack analysis methods alone. For example, dyes will be most mobile during times of ongoing precipitation. Water quality samples collected during these times can also be directly analyzed for their dye concentration and provide the best means of determining travel times and assessing filtration.

It is recommended that Hot Springs staff, in cooperation with NPS Water Resource Division and Regional experts, develop a proposal designed to assess changes in water quality that result from proximal recharge. The USGS has developed and submitted a proposal to accomplish this assessment, but funding has not been secured as of this time.

Surface water sampling

HOSP encompasses two significant perennial surface streams, Bull Bayou and Gulpha Creek, both of which have headwater sources outside the park boundary. The issues discussion presented previously notes the ongoing development in the surface drainages of these streams, and in the case of Bull Bayou, a newly completed Garland County landfill in its headwaters. The water quality and aquatic biota of these streams should be monitored to compile a baseline data set, assess current water quality conditions, and track changes in water quality and stream communities through time. These steps will provide park managers critical information concerning the impacts of upstream development on surface water resources.

As previously mentioned, the NPS has recently initiated an Inventory and Monitoring Program service-wide. HOSP is included within the Heartland Network of this program. A long-term monitoring plan is currently being developed that may include ongoing monitoring of water quality, aquatic biota, and land-use within Hot Springs National Park, as well as other parks in the Heartland Network. It is strongly recommended that the management at HOSP fully support this effort.

In the near term, it is also recommended that a fixed station water quality monitoring site be established on Bull Bayou to collect data during the early phases of operation of the Garland County landfill. This work could be accomplished through an existing NPS/USGS cooperative program and would involve establishment of a water quality and stream flow gauging station on Bull Bayou at the Black Snake Road bridge within HOSP. Information is needed to better understand streamflow, chemical, biological (pathogen), and sediment characteristics of Bull Bayou as a major surface water resource within HOSP.

Streambed sediment samples

Whittington Creek, Bull Bayou, and Gulpha Creek are all perennial streams within HOSP. Each of these streams drain urbanized areas, and at least in the case of Whittington Creek, a former dump site possibly containing hazardous substances. Because of the potential for urban runoff and other sources to contribute potentially hazardous substances to surface streams, and because stream sediments tend to adsorb these materials which can subsequently impact aquatic communities, it is recommended that stream sediments be assessed for the presence of semi-volatile organic compounds.

Stream sediment sampling could be completed under the auspices of the USGS/NPS water quality partnership program, and more specifically the synoptic sampling category. This recommendation represents a very cost-effective means of screening contaminant levels in sediments from all perennial streams where they enter HOSP. More detailed work could be performed based on the results if "hot spots" are detected, and the results would also provide important baseline data in view of the increasing urban development and the Garland County landfill.

Land-use database

A consistent theme running through each of the issues discussed in the report is the threat of increasing land-use development in the HOSP vicinity and the recharge areas for the park's important springs and streams. As mentioned previously, the NPS Inventory and Monitoring Program is developing a monitoring plan to address high priority park monitoring needs. In the scoping meetings and planning development conducted so far, land-use monitoring has been recognized as the second highest priority monitoring need for HOSP, and is also a high priority for many of the other units in the Heartland Network. Land use information could be assimilated with the USGS, NPS, and other water quality monitoring efforts at Hot Springs to correlate changes in water quality and aquatic communities with changes in land-use.

Land-use monitoring would be coordinated out of the Heartland Network by the Data Management Specialist already on staff. The Data Management Specialist could develop and oversee the contractual and quality control aspects of the land-use data acquisition. It is strongly recommended that the management at Hot Springs fully support continued implementation of the Heartland Monitoring effort.

Flooding

The flooding along Central Avenue and Bathhouse Row is an extremely complex issue involving numerous stakeholders. It is beyond the scope of this document to develop adequate recommendations to address this issue. However, as park management is well aware, it is extremely important to insure that recommendations, such as the previously proposed West Mountain tunnel, do not degrade the integrity of the Hot Springs or the aquifer(s) recharging the springs. Some of the proposals recommended in this document, such as the recharge area delineation, would assist with evaluating future flood-relief proposals.

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As the nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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