So Much to Learn:
The Ozark National Scenic Riverways and Its Karst Landscape

BY QUINTA SCOTT

Paddle the spring-fed rivers of Ozark National Scenic Riverways, the Current and its tributary, the Jacks Fork. Montauk Spring, Welch Spring, Cave Spring, Pulltite Spring, Round Spring, Blue Spring, and Big Spring are also Current tributaries. A second Blue Spring and Alley Spring feed the Jacks Fork. Put in below at Akers, below Welch Spring, where it is the sixth largest spring in the state and turns the Current from a lazy Ozark stream into a first-class float. Don't forget the Eleven Point, the Wild and Scenic River that flows through Mark Twain National Forest south of Winona. It has two major tributaries: Greer Spring and Hurricane Creek, a classic Ozark losing stream.

Use your imagination to understand the subterranean drainage of the three rivers. Consider Hurricane Creek, the losing stream with a topographic watershed of 116 square miles. Yes, it's a tributary to the Eleven Point River, but only its last mile carries surface water to the river. The rest seeps into a subterranean system that carries water under the drainage divide between the Eleven Point and the Current to deliver water to Big Spring. The same holds true for Logan Creek, a losing stream that is a tributary to the Black River. Rain falls on Logan Creek, spills into the subterranean system, crosses under the surface divide between the Black and the Current, and delivers water to Blue Spring. Alley Spring draws from an amazing system of sinkholes and losing streams, including Spring Valley Creek, which becomes a tributary of the Current, once it passes through Round Spring.

When Missouri established its conservation department in 1937, agency scientists began learning how to manage the Ozark landscape for wildlife, beginning with Irwin Bode, its original director, and his team of young biologists. In 1937 Missouri's geologists had only begun to learn about the Ozark's karst landscape.

Not until 1912 did Thomas Jacob Rodhouse measure the flow of the Current River above and below Big Spring to come up with the discharge figure for the spring. From that beginning, geologists began to learn from which rock formations springs appear and to understand and trace the subterranean systems that feed the springs. That work culminated in the early 1970s with the Hurricane Creek Barometer study, in which Thomas Aley tied land management at the surface to the quality of springs and created a model for understanding subterranean systems that could be applied to any Ozark spring.

Left–Current River, Round Spring Access, Shannon County

Current River: Log Yard Landing

On August 27, 1964, President Lyndon Johnson signed the bill that created the nation's first scenic riverway, the Ozark National Scenic Riverways. The bill created a long, thin, 80,000-acre national park that features the limestone bluffs and floodplain of the Current River and the Jacks Fork.

The National Park Service (NPS) began studying the possibility of a Wild and Scenic river park in the 1950s. First, the NPS proposed including two-thirds of the Current River, Jack Fork, and Eleven Point watersheds in a national recreation area with the purpose of preserving the streams and springs that fed them. After the U.S. Forest Service nixed the inclusion of 350,000 acres of Forest Service land in an NPS project, the NPS proposed a national monument that would preserve the wild character of the rivers over 113,000 acres. Two bills went before Congress in 1960, one for the Forest Service project, preserving the rivers, and the other for the Park Service Project.

Multiple-Use Sustained Yield Act

In a third bill, passed in 1960, Congress created the Multiple-Use Sustained Yield Act, stipulating that America's National Forests "shall be administered for outdoor recreation, range, timber, watershed, and wildlife and fish purposes" for the benefit of the American people. In light of this guarantee, Leo A. Drey, a major landowner along the Current and Jacks Fork, favored the Forest Service proposal. Ozarkers had come to know and trust the Forest Service over the twenty-five years since it had purchased cut-over lands in the Ozarks. He trusted the Forest Service proposal would promote multiple use of the watershed and protect the rivers with scenic easements, without impinging on private lands. On the other side, journalist Leonard Hall, from Caledonia, Missouri, shifted back and forth on the issue, first siding with Drey and then to the NPS proposal as recreation on the rivers increased year by year. He concluded that because recreational growth was inevitable, the NPS, which had a long history of managing landscapes for recreation and tourism, should manage its growth on the rivers.

Interior Secretary Stewart Udall settled the issue after floating the Current with Hartzog and Hall. Hartzog became its first superintendent.

Eleven Point River: Turner Mill Access

Although Congress left the Eleven Point, which runs through the Mark Twain National Forest, out of the bill, the river did not go unnoticed. Congress included it in the 1968 National Wild and Scenic Rivers Act and put it under Forest Service management. It also dropped the lower Current south of Big Spring, where the agricultural floodplain was more productive and the residents more resistant to government interference. Congress appropriated $7 million to the National Park Service for the purchase of 65,000 acres, which it acquired through eminent domain or scenic easements, measuring 300 feet from the rivers' edges. The process embittered 200 landowners who objected to the low government appraisals on their property and went to court.[1]

Alley Spring Mill, Shannon County

In 1970 Missouri agreed to include Alley Spring, Round Spring, and Big Spring State Parks in the project, adding 15,000 acres and bringing the total to 80,000 acres. The Riverways encompassed 134 river miles with gaps where the Jacks Fork runs through Eminence and the Current through Van Buren.

In creating the park, Congress charged the National Park Service with protecting the rivers' sensitive floodplain habitats while inviting increasing numbers of tourists to float and fish the rivers; equestrians to ride 14 miles of designated horse trails and any unpaved roads in the park; and campers to park their trailers on the floodplain. They did. Between 1968 and 1979, the number of canoeists jumped from 40,000 to 300,000. By the beginning of the new century, 1.5 million people visited the park annually.[2]

Karst and Current River Country
Spring Valley

"Suddenly, there was a roar of water and the previously dry bed of Spring Valley, by which we had camped, was filled with a rushing torrent 4 to 10 feet deep and 30 to 100 feet wide. In about three days the water had disappeared except for occasional small pools. The explanation of this is to be found in the fact that the ground, which is largely of limestone formations, is honey-combed with caves and sinkholes, the latter sometimes a hundred feet deep. Springs appear only to disappear as suddenly a few feet below. The water is of a greenish blue color on account of the great amount of lime which it contains in solution."–Edward Seymour Woodruff, 1908[3]

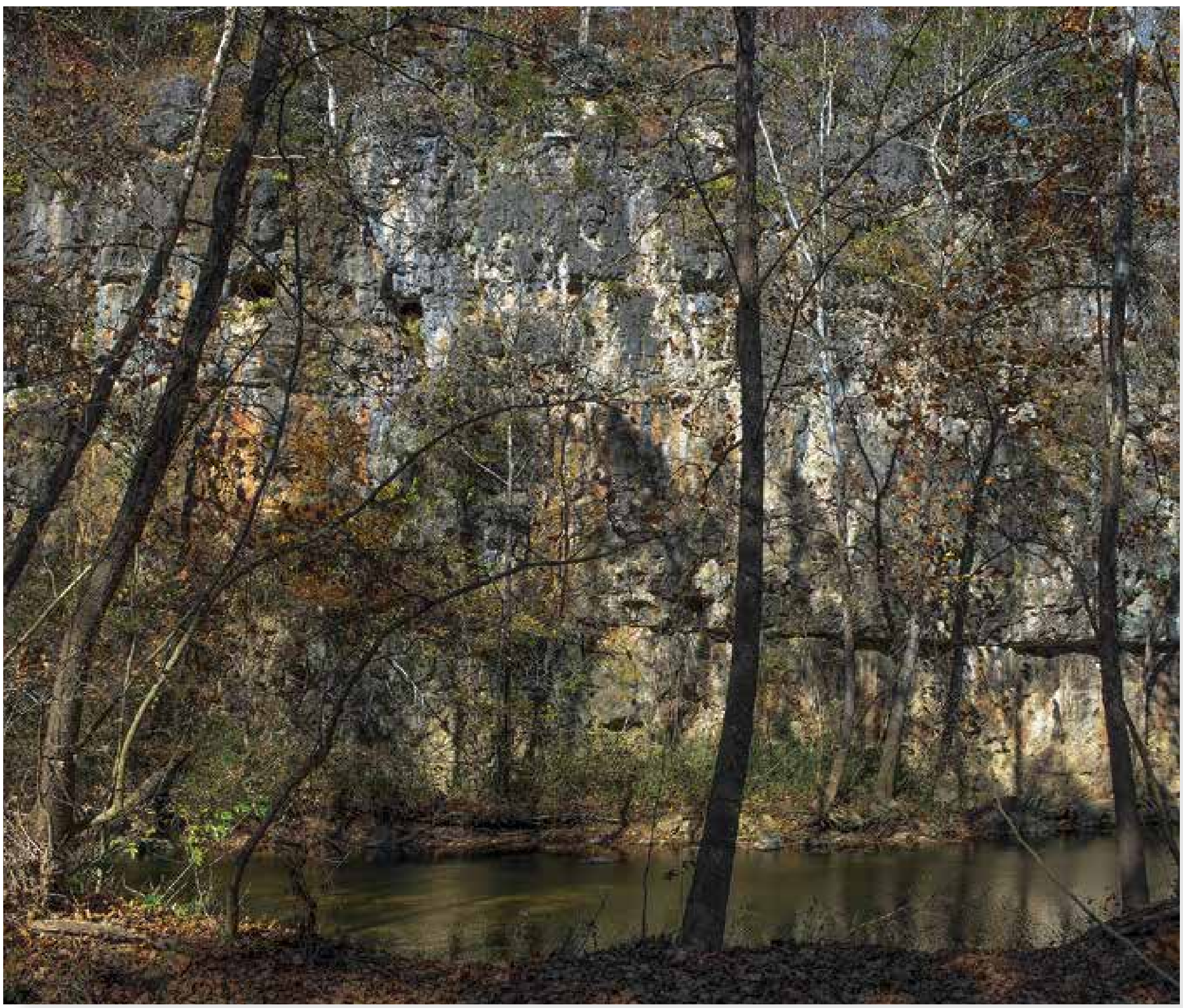
Round Spring, Shannon County

Edward Seymour Woodruff, an ornithologist from New York, learned one night just how dangerous camping next to a dry, losing stream could be. Pounding rains or even a mild thunderstorm can create torrential floods that can wash away a campsite and possibly the campers. After the storm clears, the creek may continue to flow for a few days and then disappear into the underground system. In the case of Spring Valley Creek, underground channels deliver water to both Alley Spring to the south and Round Spring to the east.

A tall bluff in Eminence Dolomite rises out of Spring Valley Creek, where it becomes a flowing stream just short of Round Spring.

Those who have explored the Ozarks know the Eminence Formation even if they don't know they know it. They certainly know the famous springs—Big Spring and Blue Spring, which emerge from under bluffs of Eminence Dolomite. They see it when they float the Ozark Rivers, the Current, the Meramec, and their tributaries, where massive bluffs rise out of the streams. They experience it when they crawl through caves, where underground streams hollowed out rocks in the formation.

The Cambrian Era ended 485,000,000 years ago with the deposition of the Eminence formation, a sandy dolomite 350 feet thick and filled with chert. The sandy layers in the formation suggest that an uplift to the north and west exposed older sandstone formations to erosion. At the beginning of Ordovician times, some 48,000,000 years ago, the seas withdrew, leaving Missouri above water for a brief time. The returning seas deposited a thin layer of sandstone, Gunter Sandstone, only twenty-five feet thick, but important, for this layer of sandstone confines underground streams to the Eminence below. The Gasconade Formation, several hundred feet of limestone, followed the Gunter as the seas deepened. In the shallowings that followed, a pair of sandstones alternated with carbonate covered the region, the Roubidoux Formation. Again the seas deepened and layer on layer of carbonate sediment accumulated on the sea floor, interlayered with thin sandstones and shales, creating the Jefferson City formation. These are the rock formations that form the karst landscape and the Ozark Aquifer that feeds the springs of Current River Country and their recharge areas.



The Jacks Fork: Blue Spring Access

Uplift created the deep bluffs of Eminence Dolomite along the Current River and those of Gasconade Dolomite along the Jacks Fork. Geologists have proposed several explanations for this. Maybe before the uplift, the rivers meandered across a fairly flat plateau, a peneplain. At the beginning of late Pennsylvanian Era, 320,000,000 years ago, a slow uplift pushed up the peneplain, and the rivers downcut through the flat rock formations underneath, while maintaining their original meanders. Or maybe the Ozark Plateau never was a peneplain but a highland that stretched from Maine to Oklahoma. And maybe the landscape experienced repeated uplifts and downdrops as continents collided. Maybe they are even younger and they uplifted during the Pliocene Era, only 12,000,000 years ago.[4]

Layers of the Ozark Landscape

The Ozark landscape comes in layers: the residuum, a mix of soil and rock, the result of the weathering of the rocks, which can be deep or shallow; the water table, which can rise or fall; and groundwater, found in the layers of bedrock underneath the Ozark Aquifer. The aquifer lies under Jefferson City Dolomite, which caps the Salem Plateau. Underneath Roubidoux Sandstone, Gasconade Dolomite, Gunter Sandstone, Eminence Dolomite, and Potosi Dolomite hold the water in the rest of the aquifer and sit on top of Derby-Doerun shale, the confining unit of the St. Francois Aquifer below. The Ozark Aquifer, 1,000–2,000 feet of dolomite, capable of holding tremendous amounts of water, is the source of springs on the Salem Plateau.[5]

Early Research into Ozark Springs

Josiah Bridge, in his 1930 study of the Eminence and Cardareva Quadrangles, noted that geologists had come to Shannon County in search of copper, not rivers and springs. They focused on the Slater Copper Mine, east of Eminence. In 1840 E. O. Hodge visited and described the mine, shortly after Joseph Slater abandoned it. Others followed sporadically. Dr. C. P. Williams looked at the Slater Mine in 1875; H. Foster Bain and Edward O. Ulrich recorded its history in their 1905 Copper Deposits of Missouri. As for looking at stratigraphy, the layers of rock along the Current River, Frank L. Nason in his 1892 Report on Iron Ores discussed the Gasconade and Roubidoux formations, which form the uplands in the Eminence region. Bain and Ulrich separated the Eminence formation from the Gasconade above it and added to Missouri's geological column in their 1905 report.[6]

Greer Mill: Samuel Greer built his second mill in 1870 on the hill above the spring after bushwackers destroyed the 1859 mill during the Civil War.

Before the U.S. Geological Survey began collecting streamflow records for Missouri's rivers in 1903, little official attention had been paid to the power of rivers and springs to operate mills. even through pioneers had been building mills since the days of early settlement. Samuel W. Greer, a carpenter and a millwright, built the first mill next to Greer Spring in 1859. John Dougherty and Ira Barksdale, a blacksmith, built the dam and mill at Alley Spring in 1870. In 1912, Thomas Jacob Rodhouse, a professor of hydraulics at the University of Missouri, turned to the flow of Ozark streams to gather data to harness their power to run mills. On August 30, 1912, the Current River at low water flowed past Van Buren at 680 cubic feet per second, but at Club House south of Big Spring the river flowed at 1,135 cubic feet per second. Rodhouse concluded that Big Spring had delivered water to the Current at the rate of 345 cubic feet per second, which equaled the measured discharge at Big Spring on August 27. He proved that Big Spring is a tributary of the Current River.[7]

In 1921 the Missouri Senate passed a bill that required a survey of the state's water resources, "to show locations where power can be generated, and the amount and Character of lands that would be inundated by the erections of dams to secure water power." Working with the U.S. Geological Survey, Missouri geologists began to measure the flow of the state's major streams, including the Current River. In 1927 hydraulic engineer Henry Claus Beckman reported on the work done.[8]

Lake Taneycomo formed behind the Ozark Power and Water Company dam on the White River.

Beckman's work over the next fifteen years reflects our growing knowledge of the role of groundwater in feeding Missouri's streams, and the changes in our attitude toward springs. In 1927 Beckman recognized Ozark streams as a source of waterpower to generate electricity. He pointed to the hydroelectric plant at Taneycomo, where the Ozark Power and Water Company had dammed the White River and built a plant. Beckman turned to the Current River and its chief tributaries—the Jacks Fork, and Welch, Blue, and Big Springs, where the underground storage capacity of the springs maintains the river's uniform flow, except when it rains. Otherwise, ordinary rains do not produce floods. Beckman concluded that the Current's uniform flow and the presence of good dam sites made it a suitable candidate for the development of waterpower, particularly south of the mouth of the Jacks Fork. Similarly, the presence of decent dam sites at Greer Spring, with its average flow of 209,000,000 gallons a day to maintain the Eleven Point's uniform flow, made it a candidate for waterpower development.[9]

Blue Spring draws its water from Logan Creek, a losing tributary to the Black River, but delivers it to the Current River.

Josiah Bridge, with the Missouri Bureau of Geology and Mines, enlarged on Beckman's studies of springs when he mapped the geology of the Eminence and Cardareva Quadrangles in Shannon County. He began his work the summer of 1922. He concluded that other than the Jacks Fork, most of the Current River tributaries are springs, giving it the largest low-water flow of any river its size in the state.[10]

In discussing its physical characteristics, Bridge observed that the Eminence Formation is highly soluble along bedding planes, which creates the caves that litter the 450- square-mile Current watershed. Such solubility also produces systems of subterranean drainage capable of storing huge quantities of water. These systems come to the surface as springs, particularly Big Spring and Blue Spring, two of the largest.[11]

Logan Creek, Reynolds County: A Classic Ozark Losing Stream

Bridge detailed the elements that contribute water to subterranean systems. Rainfall disappears into streams paved in highly porous rock and cobbles, which is sometimes hundreds of feet deep and absorbs all but the most extreme storms. He speculated, correctly, that Blue Spring in Shannon County reaches under the divide that separates the Current and Black River watersheds, and draws from Logan Creek, a dry stream except when it rains. In examining other large springs along the Current and Jacks Fork, he concluded that these dry streams tended to be adjacent to large springs. For example, Round Spring rose inevitably after heavy rains in the Spring Valley drainage basin adjacent to it.[12]

Round Spring: Shannon County

Bridge observed that sinkholes contribute to the underground systems. He described Round Spring: "This spring occupies a large, circular sinkhole of Eminence dolomite." The rest are circular depressions underpinned by porous soil and rubble. They dot the upland of the Eminence Quadrangle. Where the soil is impervious to water, ponds form. Otherwise, surface runoff drains to them and into the underground system quickly. He gave the example of Alley Spring, where its flow ceased one day. When flow resumed 12 hours later, the spring spewed muddy water. At the time observers guessed that a sinkhole had formed in the uplands about 15 miles northwest of the spring, dropped rock and soil into the underground system, and blocked flow to Alley Spring.[13]

Alley Spring: Shannon County

In 1917, Missouri established its state park system and allocated five percent of the funds collected from the sale of hunting and fishing licenses to the purchase and maintenance of well-watered land. Governor Arthur M. Hyde and his fish and game commissioner, Frank Wielandy, looked at the Ozarks and saw land was cheap, the natural landscape intriguing, and the interest great. Big Spring, Missouri's first park, opened in 1924. Negotiations began on the purchase of Round Spring, Montauk Spring, and Deer Run on the Current River and Alley Spring on the Jacks Fork.[14]

In 1944, Henry Claus Beckman turned from waterpower to tourism and collaborated with Norman Shreve Hinchey, a geologist, on Large Springs of Missouri. Beckman drew on the 20 years he had spent measuring the flow of springs; Hinchey supplied the data on their geology. They directed their book to tourists who visited the state parks centered around springs, local residents who used them for their water supply, teachers in public schools across the state to educate children about the state's waterways, and scientists who advance knowledge of Missouri's springs.

Big Spring, a high storage spring, rises in a distinctive boil from the base of a bluff of Eminence Dolomite. It draws its water from a 426 square-mile-recharge area.

To come up with his template, of the 34 successful traces Aley conducted within the Hurricane Creek surface watershed, which drains to the Eleven Point, none arrived at Greer Spring, the major tributary to the Eleven Point. All arrived at Big Spring and confirmed Bridge's supposition that Big Spring drew its water from as far away as Pike Creek at Winona, in the Eleven Point surface watershed. Of those he conducted in the larger Eleven Point watershed, all arrived at Big Spring proving the great extent of its recharge area. Two arrived at Greer Spring.

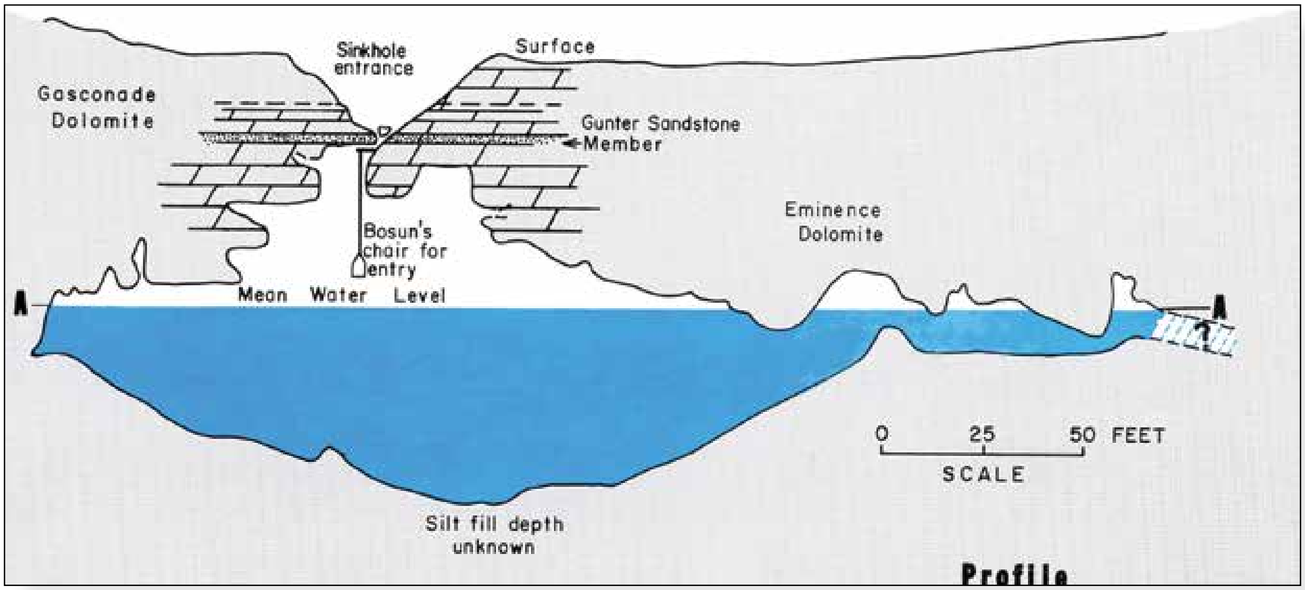
Dye Tracing Groundwater

"Dropping dye in a sinkhole or a losing stream is like a cold call. You ring the number and see who answers."[16] To understand how groundwater moves through a karst terrain, hydrogeologists use dye tracing, an art that had been developing since the nineteenth century, when most of the work was done in Europe. Researchers dropped large quantities of dye in a sinkhole or losing stream and then searched every well and every spring where the red or green water might spill out. Unfortunately, domestic wells also turned red or green, upsetting local citizens who used them for drinking and cooking. In 1906, American geologist R. B. Dole described the use of sodium fluorescein tracer tests in the U.S, but geologists did few tests before the 1950s. Until then, amateur cavers contributed most to our knowledge of the movement of underground streams.

In 1957, J. R. Dunn flipped the process with the Dunn Bug, a small packet of activated coconut charcoal placed in a spring. Then dye was injected into a losing stream or sinkhole. If hydrogeologists selected the correct injection site, they returned to the spring several days or weeks later, retrieved the packet which had absorbed the dye in spite of repeated washings in the spring, and took the bug to the lab to test it for sodium fluoroscein. The process still involved a lot of legwork. Select the wrong losing stream or sinkhole and the package could languish for weeks until found.

Davis Creek

The first known trace in Missouri happened inadvertently in 1920. The Mid-Continent Iron Company didn't inject dye in Davis Creek, a losing stream filled with sinkholes. The Company disposed of its waste isopropyl alcohol in the creek, located ten miles west of Big Spring. It sunk into the underground system and delivered it to Big Spring, which carried it to the Current River. Residents of Doniphan on the Current River, 30 miles south of the spring, noticed their drinking water, drawn from the Current, had acquired a foul taste. To learn its source, Newt Cockran poled his john-boat up river and found Big Spring gushing the foul tasting water into its spring branch. Cockran inadvertently discovered that Big Spring drew water from Davis Creek. Based on this information Josiah Bridge, who was doing his research into Current River country at the time of the dump, speculated, correctly, that Big Spring also draws water from Pike and Sycamore Creeks, all losing streams in the Eleven Point watershed.[18]



Graphic of Devils Well, *From Springs of Missouri* (Image: Jerry Vineyard)[18]

In 1961, Jerry Vineyard conducted the first dye trace in Missouri, using a Dunn Bug to test his theory that Devils Well, an open sinkhole, is connected to Cave Spring, a tributary of the Current River.

Devils Well opens onto a vast underground lake. In 1954, Bill Wallace, its owner, and his brother lowered a small boat into the lake at the bottom of the well and rode 100 feet down into the well on a bosin's chair—dangling on the end of a steel cable operated by a crank. They went exploring. They found the lake to be 400 feet long and 100 feet wide. Four springs splashed into the otherwise still lake. Two years later Jerry Vineyard, working on his master's thesis in geology, made the same trip down into Devils Well.

In December 1961, Jerry Vineyard secured his Dunn Bug in Cave Spring, dropped his fluorecein dye in Devils Well, and tested his theory that underground streams connected the two. A week later water, he retrieved his bug from Cave Spring and confirmed his theory.[19]

"Most caves in limestone or dolomite are, or have been, subterranean water courses." Those are the opening words of the second paragraph of J. Harlen Bretz's 1956 book, *Caves of Missouri*. He summed up Bridge, Beckman, and Hinchey about the role of the erosion of river valleys in the development of springs and their evolution into caves. He drew on Bridge to speculate that Big Spring's water comes from surface streams that lose water to underground conduits and added Bridge believed that Big Spring drew its water from Davis, Pike, and Sycamore creeks. Thomas J. Aley would work on that theory a decade later.[20]

In 1962, Congress added the McIntire-Stennis Act to the 1960 Multiple-Use Sustained Yield Act. The first stipulated that surface activities such as outdoor recreation, timber, watershed, and fish and wildlife should be managed for the benefit of the American people. The McIntire-Stennis Act funded the Cooperative Forestry Research Program, focusing on forestry research by state-supported colleges and universities offering studies in it by the federal government. Forestry research included the "management of forest and related watershed lands to improve conditions of waterflow and protect resources against floods and erosion." Within the U.S. Forest Service this act funded the Watershed Barometer Study.[21]

Byron Beattie, who directed the Division of Watershed Management within the Forest Service, and Edward Dortignac, Branch Chief of Water Resources of the Forest Service national office in Washington, D.C., proposed a study of watersheds within the national forest system to improve water yield, the amount of water delivered to a stream after precipitation. To measure water yield, the U.S. Forest Service would send out hydrologists, soil scientists, geologists, and natural resource managers, most of whom were recent graduates in their fields, to inventory and appraise 24 experimental watersheds within different national forests. They hoped the scientists would assemble enough information about the soil, vegetation, climate, and hydrological behavior of individual watersheds to predict how individual watersheds would respond to rainfall or drought.

Pine River, one of the Barometer Watersheds, flows between tall sand dunes in the Manistee National Forest, Manistee County, Michigan.

Their choice of watersheds varied from "semiarid to humid landscapes; from alluvial valleys to rocky hillsides, geological formations from soft sandstone and shale to hard granite; soils from coarse sand and gravel to fine-textured clays; and vegetation from semi-desert shrub to alpine tundra. Each watershed is a separate entity." They called their experimental watersheds "barometer watersheds."[22]

In 1966, the U.S. Forest Service hired Thomas J. Aley, stationed him at Winona, Missouri, and assigned him to a Barometer Watershed—Hurricane Creek, a tributary of the Eleven Point River. Aley received his bachelor of science and master's degrees in forestry, both from the University of California-Berkeley. For his master's degree, he studied wildland hydrology in forests. He continued at Berkeley in the Department of Geography, where he studied hydrology and geology. He went on to the University of Arizona at Tucson in the Department of Watershed Management, again with a focus on wildland hydrology. However, much of what he learned about karst landscapes came through his work with the Cave Research Associates, a Berkeley-based nonprofit focused on cave research.[23]

Mark Twain National Forest: Turner Mill Access Road, Eleven Point River

Aley published a series of articles in *Cave and Karst*, the organization's publication. He laid out a method to measure water balance, defined as the amount of water that finally flows to a spring after rainfall or snow melt. First, delineate the extent of a watershed, both the surface and subsurface areas. Locate precipitation stations in the watershed. Calculate the loss of rainfall to interception, evapo-transpiration, and soil moisture storage. Rain falls on the trees and soaks into their leaves and bark—interception. How much is lost to interception depends on the density and species of the trees and other vegetation. Soil absorbs rainfall, some of which is lost when trees and other vegetation draw water from the soil through their roots and evaporate it through their leaves—evapo-transpiration. Such loss is dependent on regional temperatures; generally, the higher the temperature, the greater the loss. What is left is water available for surface or subsurface runoff. But surface runoff only happens on saturated soil, which depends on the character, texture, depth, and rock content of the soil. Measure surface runoff with gauges in streams, subtract that from what is left after interception, evapo-transpiration, and soil-absorption and you have the amount of water that slips into the underground stream.[24] He rounded out his water balance study with a study of Greer Spring.

In 1965, Aley purchased Tumbling Creek Cave in Protem, Missouri, with the intention of setting up an Underground Laboratory. But first, he went to work for the U.S. Forest Service and the Hurricane Creek Barometer study. Between 1966 and 1973, Aley directed the study of the watershed and its larger region. That done, he returned to Protem, opened his underground lab, and completed his project report in 1974, while under contract with the Forest Service. The report provided a template for understanding and managing a karst watershed.

He laid out a method. First, collect basic data on the geology of a watershed, its geomorphology, its climate, and its land use.[25]

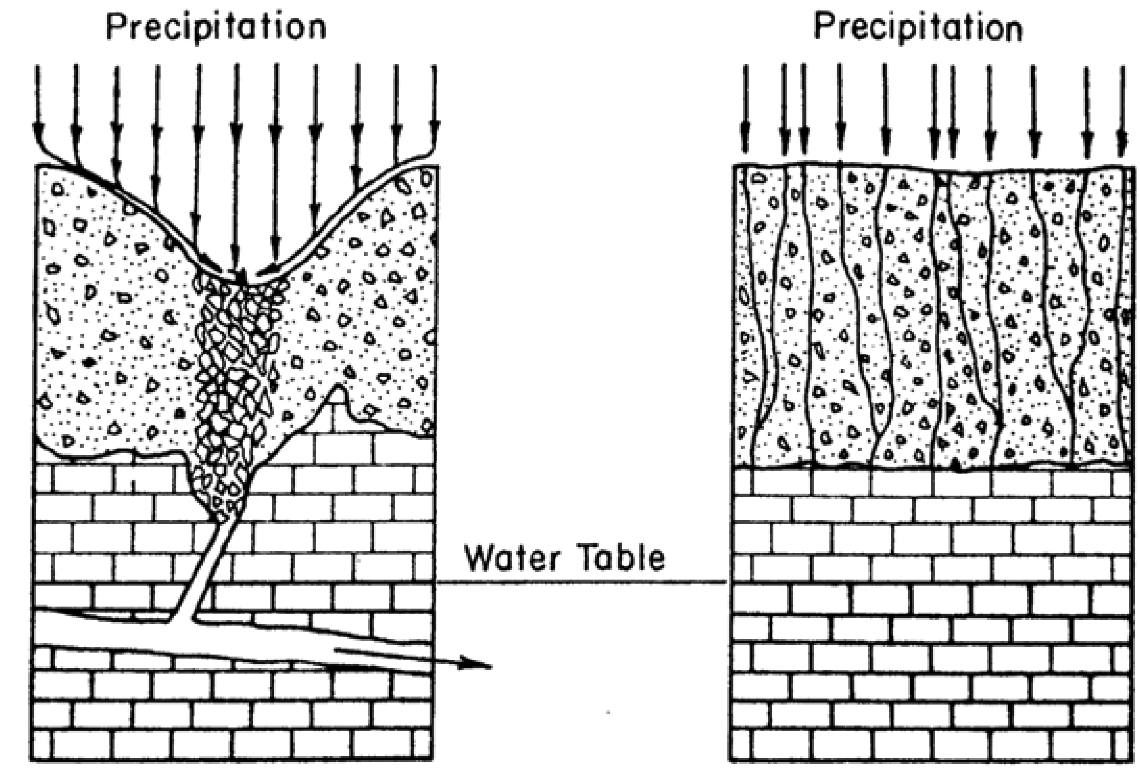
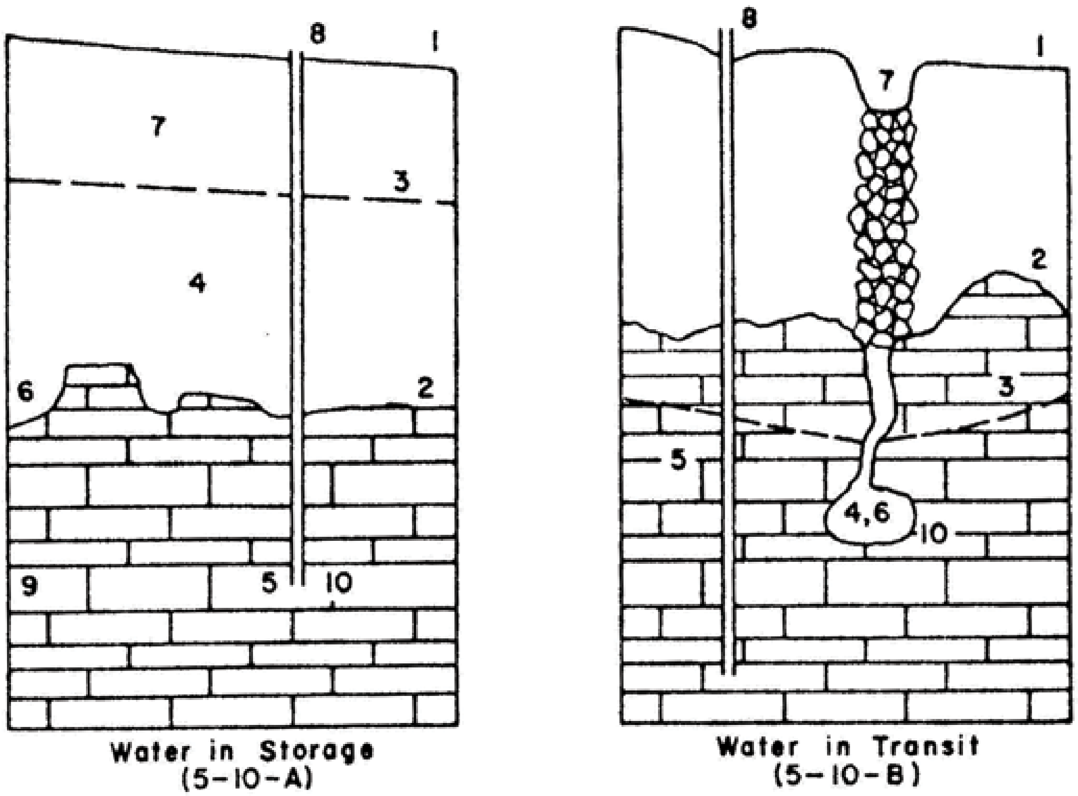


Figure 5-1. Comparison between discrete and diffuse recharge.

Thomas Aley illustrated groundwater recharge with this drawing. (Image: Thomas Aley)[26]

Then, distinguish between discrete groundwater recharge and diffuse groundwater recharge. Discrete recharge pours directly from the surface into sinkholes and losing streams, through solution-widened joints and into underground channels. Diffuse groundwater discharge seeps down through the soil in the uplands, on the hillsides, and through floodplains in river valleys to the water table and the rock formations underneath.[27]

Manage the landscape with the understanding that the surface and subsurface are intimately connected. Contaminated water can enter the underground system through both discrete and diffuse recharge.[28]



1 A/B Ground; 2A/B Contact between Residuum and Bedrock; 3 A/B Water Table; 4A Storage Water in Residuum, 4B Transit Water in Conduits; 5A Storage Water in Bedrock; 5B Some Storage Water in Bedrock; 6A Slow-moving Storage Groundwater; 6B Fast-moving Transit Groundwater; 7A Both Discrete and Diffuse Recharge; 7B Mostly Discrete Recharge; 8A/B Wells; 9A High levels of minerals; 10B Subject to High Levels of Contamination *(Image: Thomas Aley)*[29]

Distinguish between water-in-storage and water-in-transit. Pores in residuum in aquifers hold water-in-storage. So do solution-widened joints in bedrock and bedrock itself, particularly sandstone. Water-in-storage draws from both discrete and diffuse recharge areas; water-in-transit draws only from discrete recharge areas and moves through conduits at speeds greater that one-foot an hour. Water-in-storage hardly moves at all, less than one-foot an hour. Water-in-storage leaches more calcium and magnesium from the rocks that store it than water-in-transit. Water-in-storage is less subject to contamination and therefore has lower levels of bacterial pollution than water-in-transit. Bacteria sit so long in water-in-storage they die. However, should pollution get into water-in-storage, it will stay a very long time. Water-in-transit moves so fast it does not give bacteria a chance to die and speeds it to the spring.[30]

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Falling Spring is a high transit spring, with 63.5 percent of its water coming from small intermittent valleys in the uplands above the spring. The rest comes from storage water in the residuum covering the uplands and the bedrock underneath.[31]

Differentiate between high storage springs and high transit springs. High storage springs, Big Spring and Greer Spring, draw on great reserves of water stored in bedrock aquifers, deep under the large river valleys, the Current and the Eleven Point. Smaller, high transit springs, Falling and McCormack Springs, pirate from the shallow bedrock and residuum of large storage springs.[32]

Aley understood that the dolomites and sandstones under the Hurricane Creek watershed hold water, but hydrogeologists had yet to define the Ozark Aquifer. That did not come until after 1978 when Congress mandated the Regional Aquifer-System Analysis, "a systematic effort to study a number of the Nation's most important aquifer systems." The U.S. Geological Survey published the study that defined the Ozark Aquifer in 1994.[33]

Hurricane Creek: Losing section south of Falling Spring Hurricane Creek: Losing sections south of Falling Spring

Aley measured losing sections of Hurricane Creek. Between Falling Spring and Blowing Spring downstream, Hurricane Creek loses 10 cubic feet per second (cfs) on a regular basis. A quarter of the loss comes in a 700-yard section of the creek, several yards downstream of the spring. The mill-pond at the spring can lose as much as 1.5 cfs.[33]

Jam Up Creek: Mountain View

Jam Up Creek, a losing stream, flows directly behind the Mountain View Waste Treatment Plant and past an old sewage lagoon not far from the plant.

Understand how land use and management can degrade springs. There is no such thing as natural filtration that "can erase the mistakes of water quality management on the surface."

Distinguish between point source and non-point source contamination. Never locate point sources of contamination—sewage lagoons, solid waste, or industrial waste—near discrete recharge zones—sinkholes and losing streams. Sinkholes are not dumps. Diffuse recharge is subtler than discrete recharge. Pesticides or herbicides, sprayed on pastures or in forests, diffuse slowly through residuum, but they still end up in the underground system. Be careful where you site feedlots and poultry farms. High concentrations of manure can nourish bacteria, viruses, and algae that end up in the springs. Understand that unwanted sediment can reduce both discrete and diffuse recharge rates. Bulldozing forests to convert land to pasture can send sediment into streams. Stripping hillsides of trees can send vast quantities of sediment into streams and retard recharge. Understand that engineering losing streams changes their character. Floodwater retention dams on small streams increases recharge into the underground system. However, the poor quality of floodwater can degrade springs. Straightening the channels of losing streams speeds water through a narrower channel and decreases both discrete and diffuse recharge. Understand that sewage lagoons can increase recharge within their immediate surroundings. Nutrients spewing from sewage lagoons spawn algae and other plant growth that end up in streams. Solids released from lagoons settle and retard recharge in streams.[34]

Mammouth Spring in Arkansas

When Aley dropped dye into the Middle Fork of the Eleven Point near Fanchon, 13 days later it showed up in Big Spring, 39.5 miles away. He checked out the sewage lagoon at Mountain View and found that its effluent disappeared into a losing stream within a mile of the lagoon and ended up in Big Spring, 38.1 miles away. He went off the grid, dropped dye in the Dora Sinkhole—used as a dump—and retrieved his bug in Hodgson Mill Spring on the North Fork, 5.6 miles away. He dropped dye in Renfrow Spring, near West Plains, way off the grid. It showed up in Mammoth Spring in Arkansas, just south of the Missouri border.[35]

Aley's work, particularly the Mountain View, Dora Sinkhole, and West Plains traces, "raised public awareness of the ease with which karst groundwater systems in the region could be contaminated." He intended for his template to be used to understand and manage karst landscapes similar to the Hurricane Creek Study area. It was. Aley himself went on to use it to do dye traces on springs that flow to the Jacks Fork and Current for the NPS. When hydrogeologists with U.S. Geological Survey and its Missouri counterpart began to study the impacts of lead mining on the Hurricane Creek watershed and Big and Greer Springs two decades later, they turned to Aley's (A Predictive Hydrologic Model for Evaluating the Effects of Land Use and Management on the Quantity and Quality of Water from Ozark Springs.) When they expanded the work to study all the springs that feed the Current and Jacks Fork, they turned to Aley's later work for the National Park Service.

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