National Park Service
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Natural Resources Stewardship and Science
Geologic Resources Division
Cave and Karst Program

Summary of previous dye tracing reports in the area of the Buffalo National River, Arkansas

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National Park Service - Natural Resources Stewardship and Science

Location & Area

The Buffalo National River, located in northern Arkansas, was the first National River designated in the United States. The Park was established "for the purpose of conserving and interpreting an area containing unique scenic and scientific features, and preserving as a free-flowing stream an important segment of the Buffalo River in Arkansas for the benefit and enjoyment of future generations". The Buffalo National River manages a 135 mi (217 km) stretch of the river with bluffs and numerous springs (Hunt et al. 2008).

Geologic Background

The Buffalo National River drains a large portion of the southern Springfield Plateau and the northern Boston Mountains, with the Salem Plateau on its lower end, cutting its way down through Paleozoic rocks ranging in age from the Pennsylvanian Atoka Formation to the early Ordovician Cotter Dolomite (300 to 480 Ma) that comprise this portion of north central Arkansas (Hunt et al. 2008).

In the Buffalo River area, the Boone Formation unconformably overlies sandstone of the Everton Formation, which acts as a regional aquitard. The Boone Formation consists of various amounts of chert and limestone both horizontally and vertically. In some occurrences, the chert may comprise as much as 60 to 70% of the rock. At the base of the formation is the St. Joe Member (aka St. Joe Limestone), a massively bedded limestone that is contains very little chert. In the Buffalo River area, the thickness of the Boone formation is generally in excess of 76 to 91 m. (250 to 300 ft.) (Aley et al. 2006).

The Silurian St. Clair Formation, located (where it has not been removed by erosion) beneath the Boone Formation. Is a dark red to pinkish-grey finely crystalline limestone. Beneath the St. Clair Limestone are the St Peter Formation (where present) and the Everton Formation, both of the Ordovician. The Everton Formation consists of an intertounging complex of sandstone, limestone, and dolomite from 350 to 650 feet in thickness (Suhm 1974). The Newton Sandstone Member is a thick bluff former on the Buffalo River. It forms an aquitard between the formations above (usually Boone) and the calcareous portions of the Everton.

The contact between the Boone and the Everton Formations is marked by the largest number of springs within the western Buffalo River watershed. In addition, erosion of the Buffalo River valley has left most karst aquifers perched above the current river level, and consequently, their local base level elevations are controlled by relief across structures (Murray and Hudson 2002).

There are approximately 350 caves within the Buffalo River ranging in size from less than 100 feet to caves with over 12 mi (19 km) in length of known passages (Santucci et al. 2001; National Park Service 2007). At the Park erosion and dissolution form large sandstone overhangs which create bluff shelters, which may contain archeological resources (National Park Service 2007).

Hydrology

In most geologic settings, the area of recharge for a groundwater system is contained within the topographic divides that form the watershed boundaries. However, in karstic areas groundwater flow in the subsurface often crosses the surface watershed boundaries. In the Buffalo River karstic region, the groundwater watershed does not correspond with the surficial drainage basin divides. Characterization of groundwater flow in these areas is essential for the water quality and for evaluating, the potential contaminants transport pathways through karst systems (Murray and Hudson 2002).

The Buffalo River basin can be divided in two geologic settings. The upper river basin, which is composed primarily of clastic rocks overlying a thick carbonate sequence, and the lower river basin, which is composed almost entirely of, carbonate rocks. The greatest variability in flow occurs in the upper river basin due to its size, high relief, and impermeable surface strata. Furthermore, there are two types of aquifers in the Buffalo River area; shallow and deep, depending on their occurrence within the basin. The shallow aquifers are recharged by precipitation falling directly within the basin whereas the deep aquifers are recharged outside the basin where they are exposed in southern Missouri. The shallow aquifers are strata of the Atoka through Cotter Formations, composed primarily of limestone, sandstone, and shale. The deep aquifers are strata below the Cotter Formation and are primarily dolomite (Dillard 1978).

Dye Tracing Reports

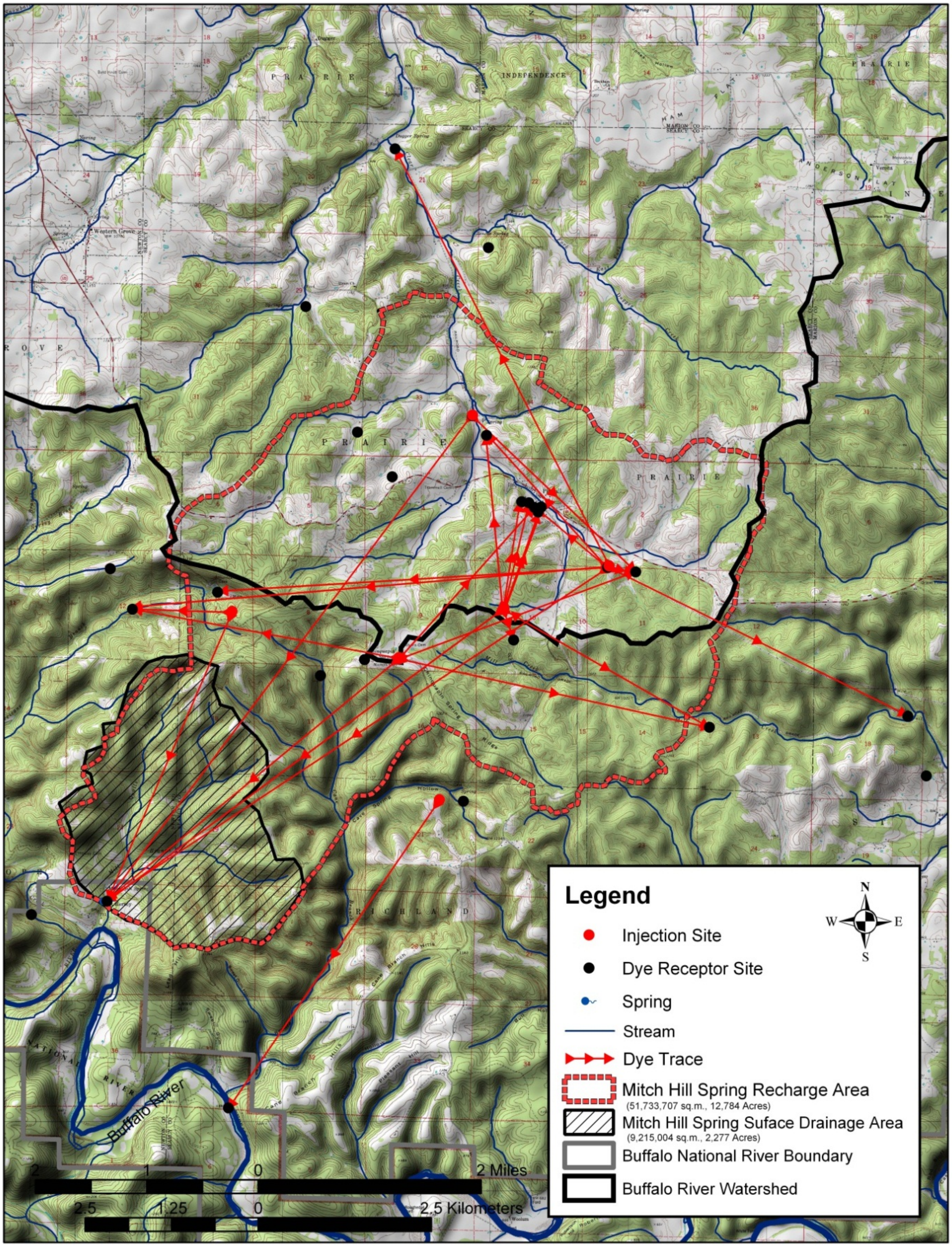
An essential need related to preserving the Buffalo River is determining the sources of water that feed the river. By conducting dye tracing studies scientist can characterize groundwater flow in the area in order to preserve its water quality. Eight groundwater traces have been documented for different watershed areas around the area of the park. The following are discussed below;

Mitch Hill Spring Recharge Area

Mitch Hill Spring, located near Mt. Hersey, is a major tributary to the Buffalo National River. The first phase of the study conducted by Aley and Aley (1989) comprised of a hydrogeologic study on the recharge area for Mitch Hill Spring. The study focused on a proposed landfill near the community of Pindall and was funded by the Citizens Against the Landfill (CALF). The dye tracing study demonstrated that the proposed landfill was within the recharge area for Mitch Hill Spring even though the site was within the topographic basin of Clear Creek. The results led to the cancellation of an initially granted permit for the proposed landfill, which was then never built. The next phase of the groundwater tracing studies focused on lands in the Clear Creek, Mill Creek, Mill Branch, and Cane

Branch topographic basins. The Clear Creek basin is topographically tributary to Crooked Creek and does not subsequently flow into the Buffalo River. Mill Creek, Mill and Cane Branch stream basins are surface tributaries to the river.

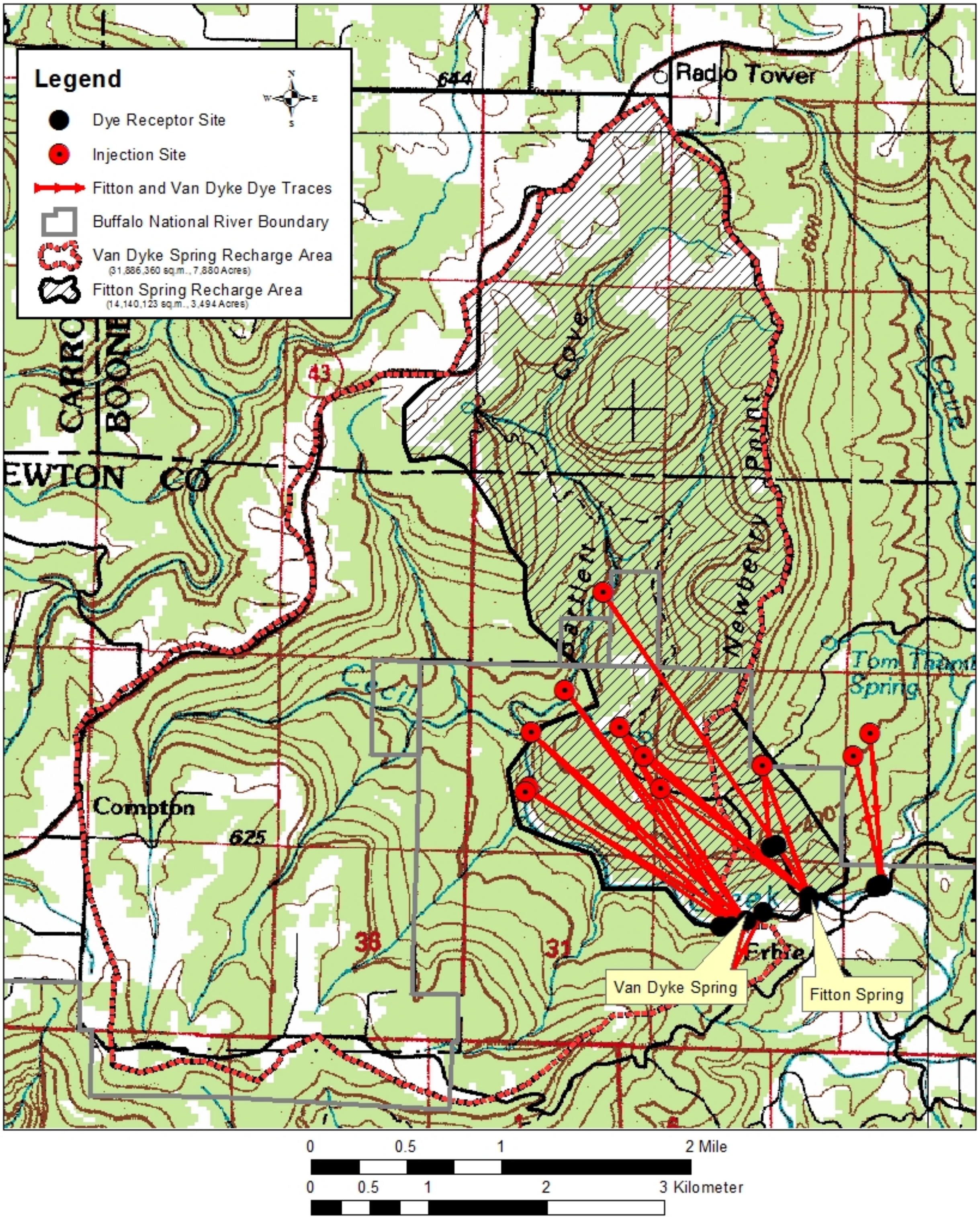
Aley and Aley (1989) conducted six dye injections which resulted in 15 dye detections at different sampling stations. In addition, five of the six introductions resulted in dye detections at Mitch Hill Spring. A recharge area of 20.8 mi^2 (53.8 km^2) was delineated for Mitch Spring. The study also demonstrated that significant amounts of land outside the topographic basin of the Buffalo River contribute groundwater to the springs inside the Buffalo River basin (Aley and Aley 1989). It should be noted, that Mott et al. (2002) demonstrated that Mitch Hill Spring also receives water from a large area west of the recharge area delineated by Aley and Aley (1989).



Dye introduction locations, conceptual flow routes, and recharge area delineation for Mitch Hill Spring (from Aley and Aley, 1989; Mott et al. 2002)

Fitton Cave and Van Dyke Spring Recharge Area

Aley and Aley (1999) conducted a dye tracing and recharge area delineation project for Fitton Cave as well as an inventory of karst hydrology features. Eleven injections were reported and the delineated recharge area for the cave and associated Fitton Spring was reported to encompass 5.40 mi^2 (13.9 km^2). Results showed that water from Fitton Cave discharges from Fitton Spring (aka Hutchingson Spring), a tributary to Cecil Creek. In addition, the dye tracing demonstrated that Van Dyke Spring is not a discharge point for water from Fitton Cave. The recharge area for Van Dyke Spring consists of 12.59 mi^2 (32.6 km^2). Finally, the recharge areas for Fitton Cave, Fitton Spring, and Van Dyke Spring lie within the Cecil Creek topographic watershed, a surface tributary to the Buffalo River.



Recharge area delineation map for Fitton Cave and Van Dyke areas.

Springs in the Mill Creek Topographic Basin

Aley and Aley (2000) introduced 12 dye tracers during the Mill Creek studies, which were detected from all of the introductions. These traces provided data useful for understanding the location of recharge areas for Upper and Lower Dogpatch Springs and Boiling Springs, and for Morris, Jenkins, and Milum Springs.

Results showed that the total area that contributes recharge water to Upper Dogpatch Spring is approximately 4.82 mi^2 (12.4 km^2). While the spring is within Mill Creek topographic basin, 3.43 mi^2 (8.8 km^2) (71%) of the recharge area for this spring is located in the Crooked Creek topographic basin.

The total area that contributes recharge water to Lower Dogpatch Spring is 10.90 mi^2 (28.2 km^2). While the spring is within the Mill Creek topographic basin, 8.76 mi^2 (22.6 km^2) (80%) of the recharge area for this spring is located in the Crooked Creek topographic basin.

The recharge area for Boiling Spring is 8.58 mi^2 (22.2 km^2) and consists of all the topographic basin of Flatrock Creek. In addition, about 2.5 mi (4.02 km) of the northeastern boundary of this recharge area joins the Lower Dogpatch Spring recharge area.

Morris Spring discharges to the West Fork of Crooked Creek. In addition, most of the West Fork of Crooked Creek provides recharge water for this spring. Results showed that Milum and Jenkins Springs were individual discharge points for a single spring system, but that some localized areas yielded water to only one of the springs. These springs receive water derived from lands in the topographic basins of the East Fork of Crooked Creek and from the main stem of Crooked Creek upstream of the springs (Aley and Aley 2000).

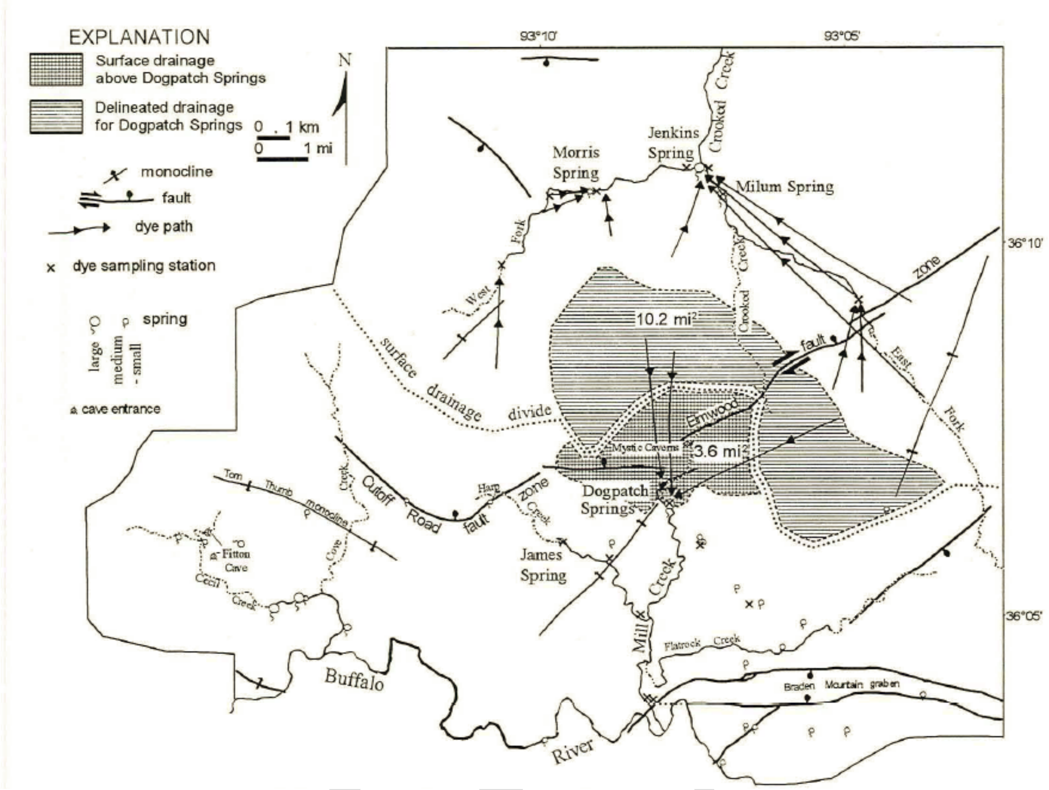
Dogpatch Springs Topographic Basin

Mott et al. (1999; 2000) conducted twelve dye traces to delineate groundwater recharge areas and to test the interbasin flow hypothesis. Results showed that 10.2 mi^2 (26.4 mi^2) of the Crooked Creek topographic basin provides groundwater to Dogpatch Spring. The total area of the Dogpatch Spring groundwater basin is thus 13.8 mi^2 (35.7 mi^2) almost four times larger than their topographic watershed 3.6 mi^2 (9.3 km^2).

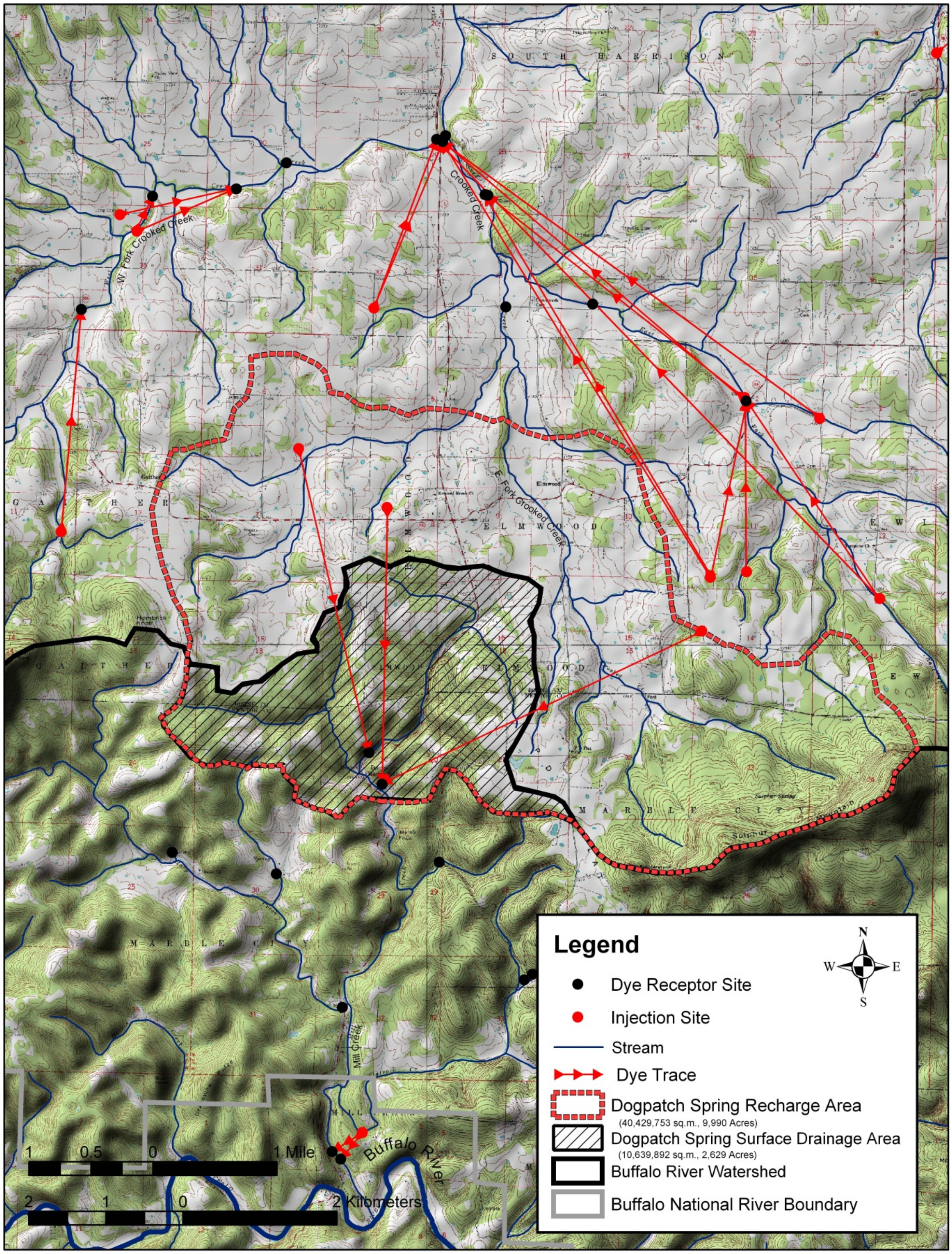
Results showed that Mill Creek contributes as much as 96% of the nitrate load in the Buffalo River below the confluence. These elevated nutrient concentrations have an impact in the aquatic communities in both Mill Creek and the Buffalo River. The percentage is highest during periods or low base flow. According to the results, these nutrients originate from two springs (Upper and Lower Dogpatch) at the head of this tributary (Maner and Mott 1991; Mott et al. 1999).

The shape of the topographic and delineated basins relative to the Elmwood fault zone provided an indication of its influence on surface and groundwater recharge. The results suggested interbasin transfer is mostly independent of interbasin structures, and it is principally a function of hydraulic gradient. The location of the springs and the size of their recharge areas appear to be controlled by combined elements of groundwater gradient, stratigraphy, and structure (Mott et al. 2000).

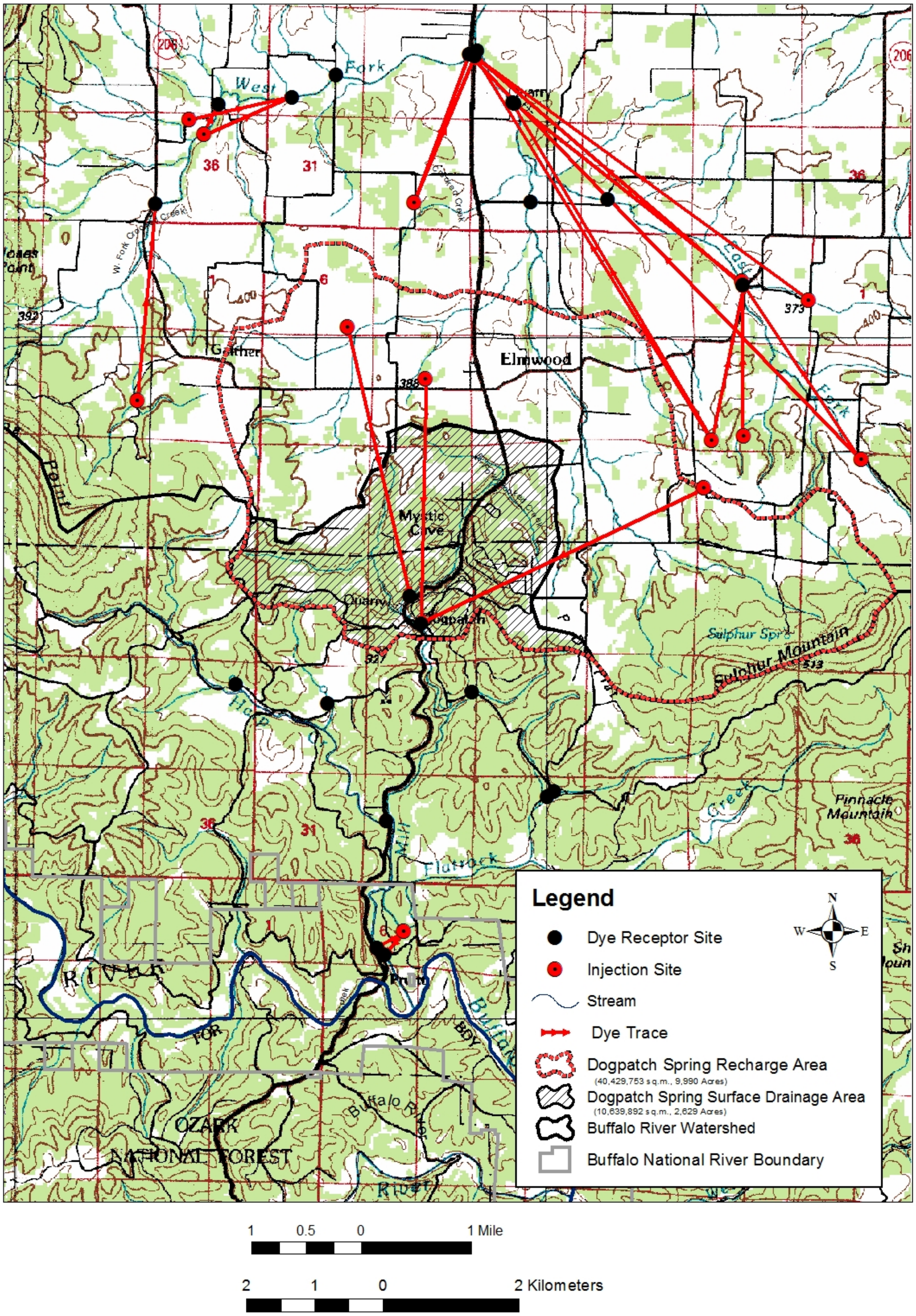
A dye introduced into a sinkhole filled with cattle carcasses moved two miles from the Crooked Creek basin to the Dogpatch Springs at the head of Mill Creek in less than five days. In addition, samples were collected from major springs within the Crooked Creek and Mill Creek basin, and at a reference spring (Luallen Spring). Results showed that James Spring was not a recovery point for any of the dye traces from the Crooked Creek topographic basin. Upper Dogpatch Spring received dye from one trace and Lower Dogpatch Spring received dye from two traces (Mott et al. 2000).



Dye trace paths and topographic and delineated watersheds (from Mott et al. 1999)



Dye introduction locations, conceptual flow routes, and recharge area delineation for the Dogpatch Springs at the head of Mill Creek (from Aley and Aley, 2000; Mott et al. 2002.)

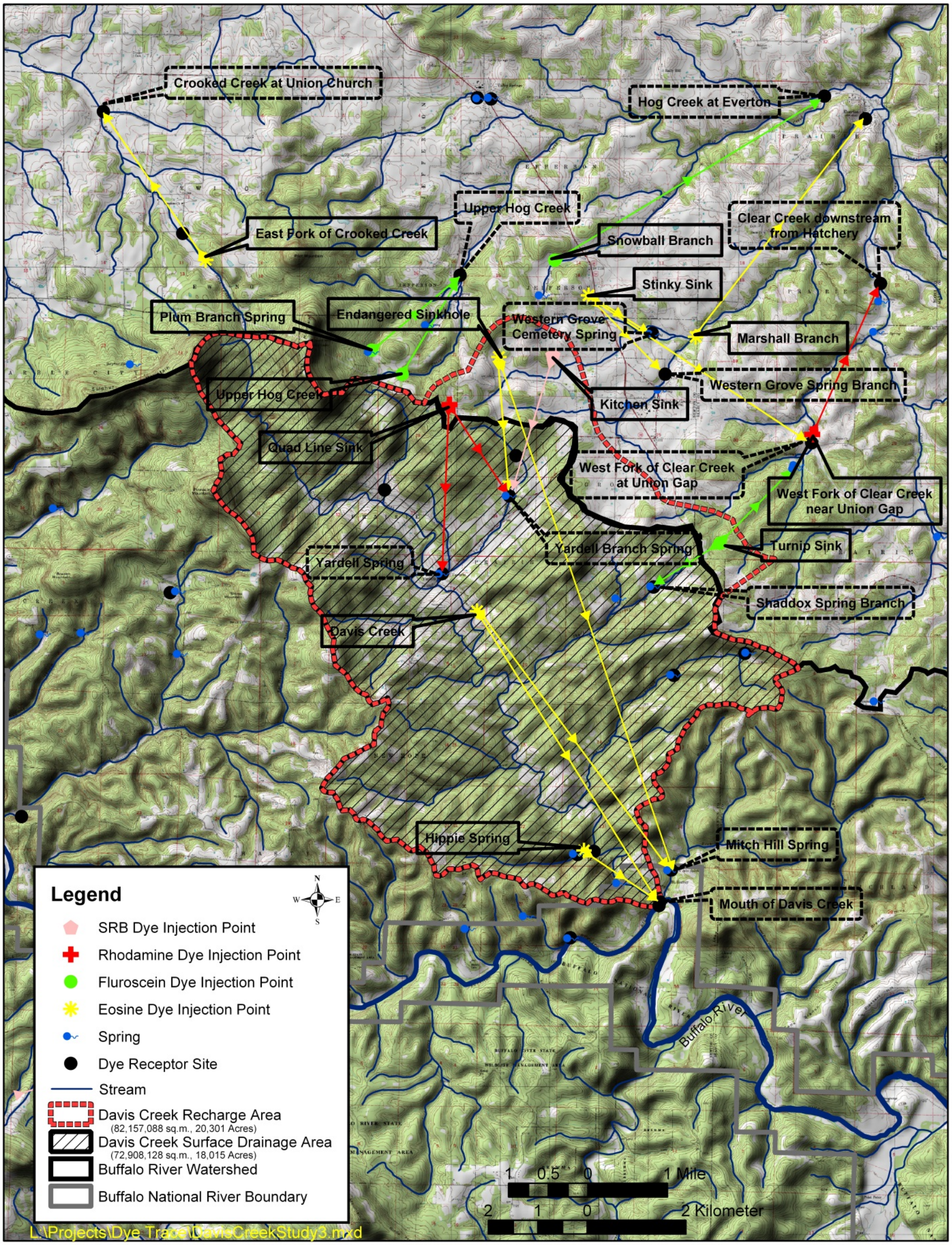


Recharge area delineation map for the Dogpatch Springs area.

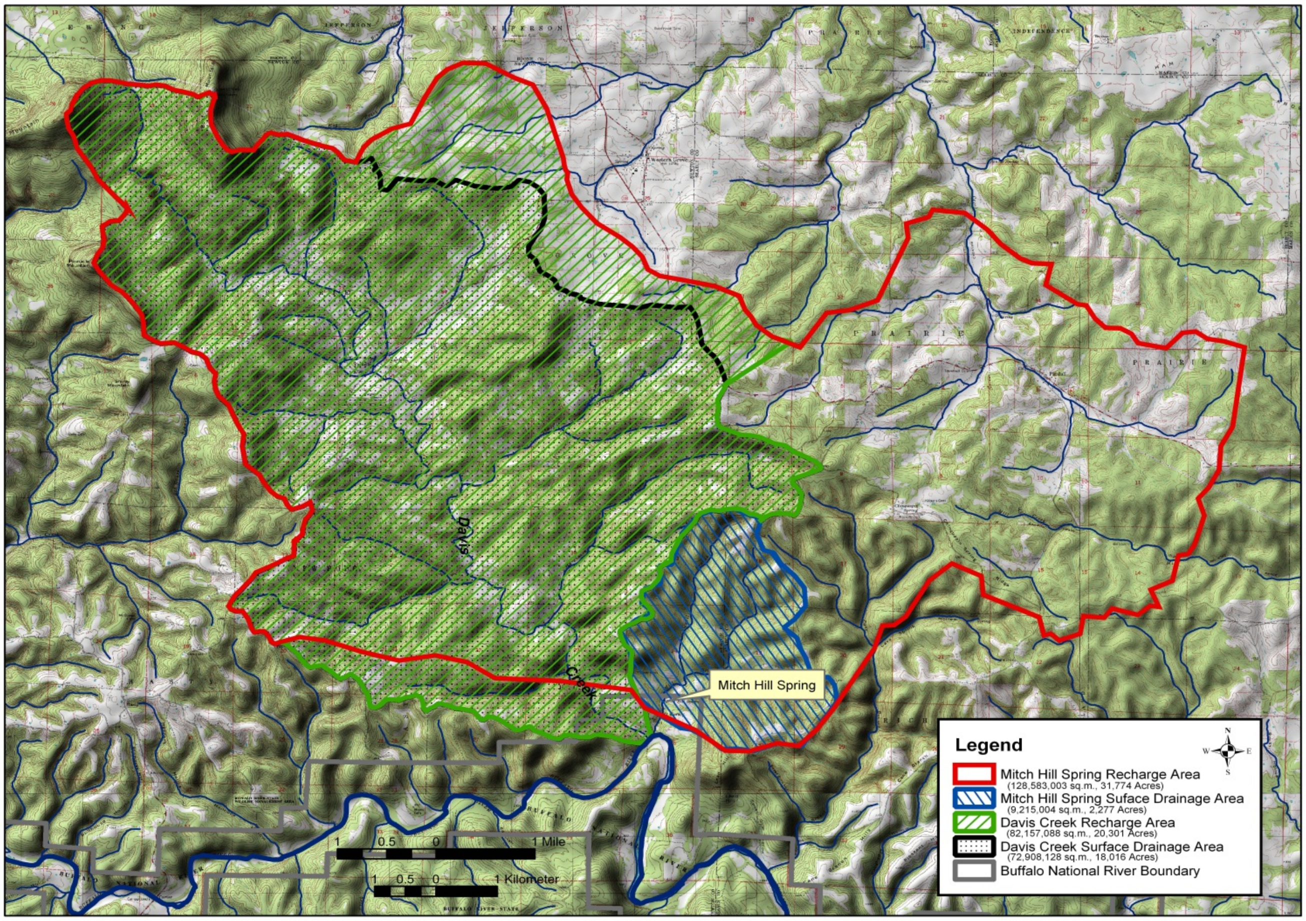
Davis Creek Topographic Basin

Mott et al. (2002) introduced 17 dye tracers in and around Davis Creek, a major surface tributary to the Buffalo River. The Davis Creek basin is located on the west side of the previously delineated area for Mitch Hill Spring. Four traces yielded dye detections in the Davis Creek basin resulting from dye introduced within the Crooked Creek basin. The study calculated that 2,285 ac (924 ha) of land in the Crooked Creek basin contribute at least some water to Davis Creek in the Buffalo River basin.

An injection was performed within the Crooked Creek watershed at the Plumb Branch Spring, which was recovered only in upper Hog Creek and did not migrate to the Buffalo River watershed. Dye was introduced into a losing segment of Davis Creek about one half mile downstream of the confluence of flow from Yardell Spring. This was the first trace to confirm interbasin recharge from Quad-line Sink in the Crooked Creek watershed to Yardell Spring and Yardell Spring Branch, which feed Davis Creek. Some of the introduced dye was recovered at the mouth of Davis Creek approximately 4.3 mi (6.9 km) downstream from injection point. The results demonstrated that much of Davis Creek basin is within the recharge area for Mitch Hill Spring. Turnip Sink was the only trace that showed radial flow with dye traveling to receptor sites in both the West Fork of Clear Creek in the Crooked Creek watershed and to Shaddox Spring Hollow within the upper Davis Creek watershed. While the increase in the Davis Creek delineated recharge area was modest relative to its surface basin, the recharge area for Mitch Hill Spring was expanded significantly to 31, 774 ac (49.65 mi^2). The study determined that the Mitch Hill Spring's recharge area almost 14 times larger than its surface watershed (Mott et al. 2002).



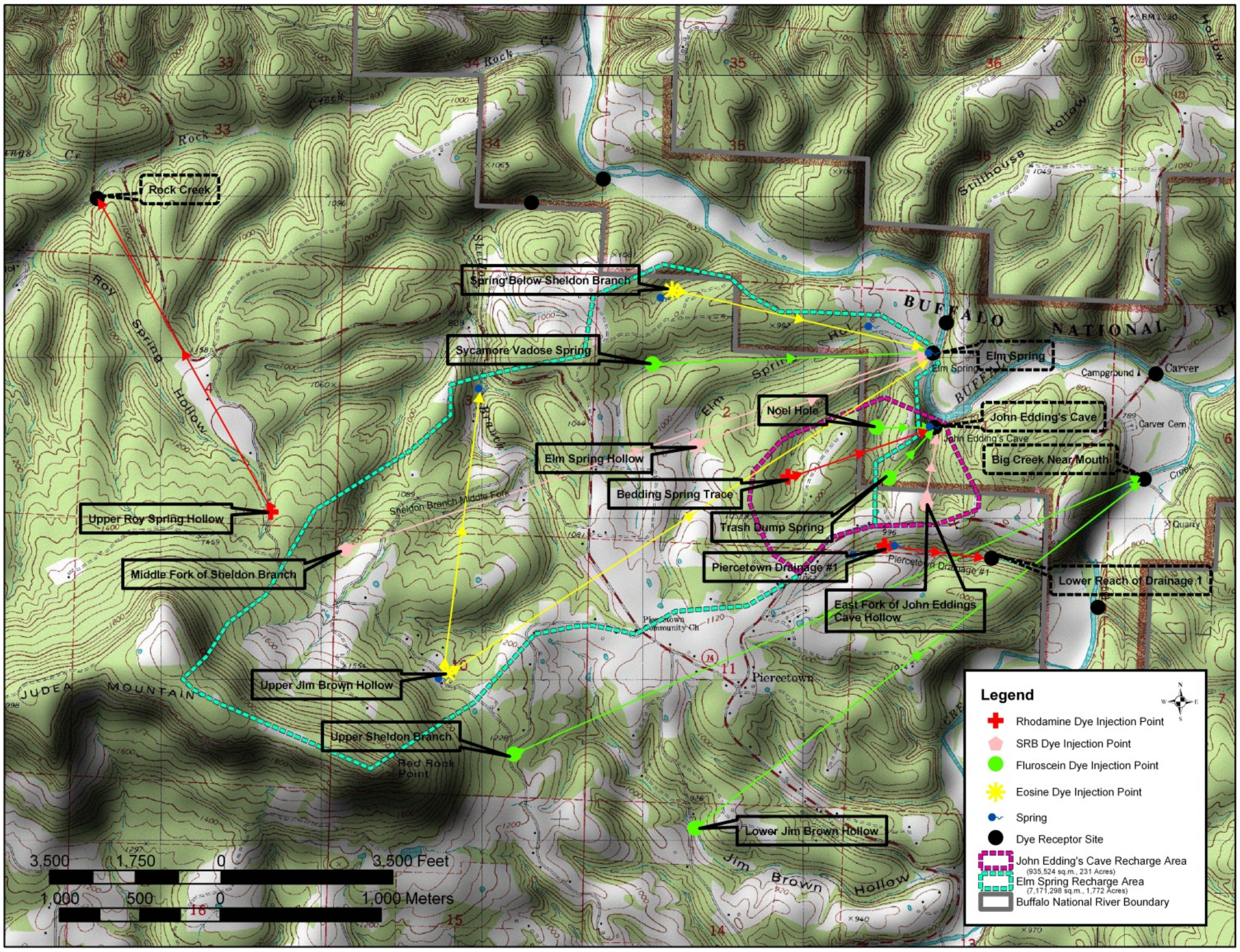
Recharge area delineation map for the Davis Creek area.



Recharge area delineation map for the Davis Creek study area including Mitch Hill Spring (from Mott et al. 2002).

John Eddings Cave/Elm Spring Recharge Area

John Eddings Cave and Elm Springs are both located on the south side of the Buffalo River, approximately 1,650 ft. (503 m) of each other. Mott et al. (2002) completed 13 dye injections. The delineated size of the recharge are for John Eddings Cave was 231 ac (93.4 ha). A total of 156 ac (63 ha) in the recharge area lies outside of the topographic basin in which the cave is located. The recharge from Elm Spring was 1,772 ac (717 ha). A total of 1,017 ac (691 ha) in the Elm Spring recharge area lies outside the topographic basin in which the spring is located. No hydrologic interactions were found between the two features.



Recharge area delineation map for the John Eddings Cave study area including Elm Spring (from Mott et al. 2002).

Gilbert Spring and the Gilbert Community

Mott et al. (2002a) conducted over 30 individual groundwater traces within the community of Gilbert plus a time of travel trace from Dry Creek to Gilbert Spring. The waste-water production of Gilbert is routed to individual on-site septic systems, which are situated over karst with shallow soils. Water quality monitoring over the past fifteen years at Gilbert Spring showed this spring to be the most contaminated spring with the Buffalo River. The septic systems and the groundwater hydrology were studied to quantify the impacts of Gilbert's septic fields on the water quality of Gilbert Spring and the Buffalo River.

The study traced seven of the best septic systems identified in Gilbert simultaneously using two types of dye. Small amounts of fluorescein were recovered from these traces and the study concluded that the systems were over 98 percent efficient in removing the tracer dye from the leachate. Subsequently, 22 septic systems were traced using four types of tracer dyes over a three-month period. Two systems were found to rapidly contribute dye directly to Gilbert Spring in large quantities. Two other systems contributed measurable but minor quantities of dye to Gilbert Spring and the remaining 18 systems contributed negligible amounts of dye to Gilbert Spring. Of the two systems that contribute leachate directly to Gilbert Spring, one was found to be discharging to an old cistern, and the other was found to have a broken pipe running from the house to the septic tank, both systems were repaired. None of these traces indicated flow into the Buffalo River topographic basin from locations outside of the basin (Mott et al. 2002a).

A time of travel study was also conducted between Dry Creek and Gilbert Spring, showing a very open groundwater conduit between the losing portion of Dry Creek and Gilbert Spring. In addition, the monthly and bi-monthly flow measurements taken from Dry Creek and Gilbert Spring showed that often Gilbert Spring's flow is completely accounted for by the flow lost from Dry Creek. During rain events, surface runoff is pirated by nearby solution valleys and contributes flow to Gilbert Spring. However, during base-flow conditions, Gilbert Spring is little more than the resurgence of Dry Creek (Mott et al. 2002a).

Tomahawk Creek Area

Aley et al. (2006) conducted a total of seven dye introductions to determine groundwater movement into the Tomahawk Creek basin, a major tributary to the Buffalo River basin. Due to the dry weather conditions at the times of the study, only seven dyes were introduced. As a result, no successful traces made to any of the springs in the Tomahawk Creek basin and the study was not able to delineate the recharge areas for any of these springs.

Big Creek Area

Currently, Dr. Van Brahana, hydrogeologist and retired University of Arkansas professor, is conducting a groundwater characterization, karst inventory, and a fluorescent dye tracing in the area of C &H Farms on Big Creek, Mt. Judea. In 2013, a concentrated animal feeding operation (CAFO) was constructed in Newton County. C & H Farms, a 6,500-swine facility, is located adjacent to Big Creek, which is a major tributary to the Buffalo National River. No reports associated with the current dye tracing results were obtained during the compilation of this summary.

Conclusions

Previous dye tracing reports demonstrated that some caves and/or springs in the Buffalo area, do not appear to share recharge areas with other caves and/or springs. As seen in Fitton Cave, Upper Dogpatch Spring and Lower Dogpatch Spring, according to Aley and Aley (2006). In contrary, Mitch Hill Spring shares water with a spring, or springs, in lower Davis Hollow, Jack Keith Spring, Dugger Spring, Deaton Spring #1, Cannon Spring, Mill Creek Spring, and the SPG public water supply well (Aley and Aley 2006). Dye tracing near Pindall has shown that the recharge area for Mitch Hill Spring seasonally moves north and south (Aley 1988).

The delineation of watersheds in the Buffalo National River is an important aspect in order to understand and protect the River's resources. Previous studies have found that inter-basin transfer of water from streams outside the Buffalo River topographic watershed boundary is occurring and could pose a negative treat to Park's resources. Groundwater systems at the Park are complicated and difficult to understand; therefore, the delineation of the true watersheds is a difficult task. Additional studies will provide more information in order to understand karst systems in the area of the Park. As previously recommended in the Water Resources Management Plan for Buffalo National River (Mott and Lauraas 2004), the implementation of best management practices (BMPs) by landowners as well as the establishment of a citizen based watershed group to work with landowners, will help in protecting and preserving these significant resources for generations to come.

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