Present and Future Water Supply for Mammoth Cave National Park, Kentucky

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1475-Q

Prepared in cooperation with the National Park Service

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By R. V. CUSHMAN, R. A. KRIEGER, *and* JOHN A. McCABE

HYDROLOGY OF THE PUBLIC DOMAIN

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PRESENT AND FUTURE WATER SUPPLY FOR MAMMOTH CAVE NATIONAL PARK, KENTUCKY

By R. V. CUSHMAN, R. A. KRIEGER, and JOHN A. McCABE

ABSTRACT

The increase in the number of visitors during the past several years at Mammoth Cave National Park has rendered the present water supply inadequate. Emergency measures were necessary during August 1962 to supplement the available supply.

The Green River is the largest potential source of water supply for Mammoth Cave. The 30-year minimum daily discharge is 40 mgd (million gallons per day). The chemical quality is now good, but in the past the river has been contaminated by oil-field-brine wastes. By mixing it with water from the existing supply, Green River water could be diluted to provide water of satisfactory quality in the event of future brine pollution.

The Nolin River is the next largest potential source of water (minimum releases from Nolin Reservoir, 97–129 mgd). The quality is satisfactory, but use of this source would require a 8-mile pipeline.

The present water supply comes from springs draining a perched aquifer in the Haney Limestone Member of the Golconda Formation on Flint Ridge. Chemical quality is excellent but the minimum observed flow of all the springs on Flint Ridge plus Bransford well was only 121,700 gpd (gallons per day). This supply is adequate for present needs but not for future requirements; it could be augmented with water from the Green River.

Wet Prong Buffalo Creek is the best of several small-stream supplies in the vicinity of Mammoth Cave. Minimum flow of the creek is probably about 300,000 gpd and the quality is good. The supply is about 5 miles from Mammoth Cave. This supply also may be utilized for a future separate development in the northern part of the park.

The maximum recorded yield of wells drilled into the basal ground water in the Ste. Genevieve and St. Louis Limestone is 36 gpm (gallons per minute). Larger supplies may be developed if a large underground stream is struck. Quality can be expected to be good unless the well is drilled too far below the basal water table and intercepts poorer quality water at a lower level. This source of supply might be used to augment the present supply, but locating the trunk conduits might be difficult.

Water in alluvium adjacent to the Green River and perched water in the Big Clifty Sandstone Member of the Golconda Formation and Girkin Formation have little potential as a water supply.

INTRODUCTION

The purpose of this progress report is to summarize the available information on the quantity and quality of all sources of water in the area and to evaluate the information for use by National Park Service engineers and planners. Specifically, the report presents information to answer the questions: (1) Where can additional water supplies be obtained, (2) what is the chemical quality and dry-weather yield of the potential sources, (3) what is the type and extent of present or potential pollution of the sources, (4) how are the several potential supplies interrelated, and (5) which of the potential supplies can be developed to meet present and future needs?

Mammoth Cave National Park, in south-central Kentucky (fig. 71), is one of the best known national parks in the Eastern United States; it operates on a year-round basis for a steadily increasing number of visitors. For the past several years the water system of the park was not adequate to supply all the water needs during the period of peak visitor load (late July and August), and water-conservation measures or water hauling was resorted to during the critical period. Because of the increased water use and because the Mission 66 program includes plans for the expansion of the overall facilities at Mammoth Cave National Park, a water supply much larger than that now developed is needed.

At the request of the National Park Service, an investigation of the water resources of Mammoth Cave National Park was undertaken by the U.S. Geological Survey in 1961. In addition to an overall appraisal of the hydrology of the area, the study includes an evaluation of the dry-weather yield of the developed sources of supply and the quantity, quality, and dependability of all potential sources of supply

WATER REQUIREMENTS

The increase in the number of visitors to Mammoth Cave National Park in the past several years and the estimated range of attendance to 1980 under the Mission 66 program are shown in figure 72. Any water supply that is planned must be able to meet not only the present water needs of the park but also future needs.

The greatest demand for water is during June through September because of increased visits during the vacation months. Unfortunately, the period of greatest demand is also the period when the available supply is nearing its annual low. The maximum use recorded was 623,000 gallons during the week of July 25–31, 1962 (Perry E. Brown, Superintendent, Mammoth Cave National Park, written commun., 1963), or an average daily rate of 89,030 gallons. On a peak day, June 27, 1962, 97,000 gallons were consumed by park visitors

(Glenn C. Farrar, Engineer, Mammoth Cave National Park, written commun., 1962).

The existing supply was inadequate during the drought of August 1962, and it was necessary to supplement the supply by pumping from Blair Spring and hauling water by truck from Adwell Spring (fig. 71). Signs asking users to conserve water were posted.

Long-term flow records of the developed supply are not available to evaluate the frequency of a drought of this magnitude. The mean discharge of the Green River during August 1962 is an approximate measure of the severity of the drought as it affects the park water supply during the period of greatest demand. The disadvantage of using Green River flow as an indicator is that the flow represents an integrated resultant of that part of the hydrologic cycle occurring in several thousand square miles of central Kentucky, whereas the present supply of Mammoth Cave comes from a perched aquifer that has a recharge area of only a few square miles. An advantage of using the mean flow of the Green River during August as an indicator is that the flow during August not only reflects the precipitation during August but the carryover effect from antecedent precipitation. Records for the gaging stations on Green River at Munfordville, Brownsville, and Calhoun were correlated to give an estimated mean August discharge at Brownsville for each missing year of record during the years 1915–22, 1925–62. This list of actual or estimated mean August discharges of Green River at Brownsville for the 46-year period shows that a mean August flow of about 230 cfs (cubic feet per second) or 148 mgd (million gallons per day) has a recurrence interval of about 50 years, and that the 1962 mean August discharge of 367 cfs or 237 mgd has a recurrence interval of about 12 years. This recurrence interval in no way implies that, once an August mean discharge of 367 cfs occurs, it will not recur for another 12 years. It means that on the basis of past experience at Brownsville an August mean discharge of 367 cfs or lower can be expected to occur on an average of once every 12 years. If the flow at Brownsville is a valid indicator of the present water supply at Mammoth Cave, the deficiency experienced in 1962 can be expected to be equaled or exceeded every 12 years. However, it must be emphasized that the use of this indicator is an approximation only, owing to the large drainage area of the Green River being compared to the small recharge area of the perched aquifer and the small watersheds in the park.

On the basis of the estimated increase of visitors to the park to 1980 and the expanded facilities, the water consumption by 1980 will be at least 200,000 to 250,000 gpd (gallons per day) during the summer season. The present supply is not capable of furnishing this amount of water during the summer seasons.

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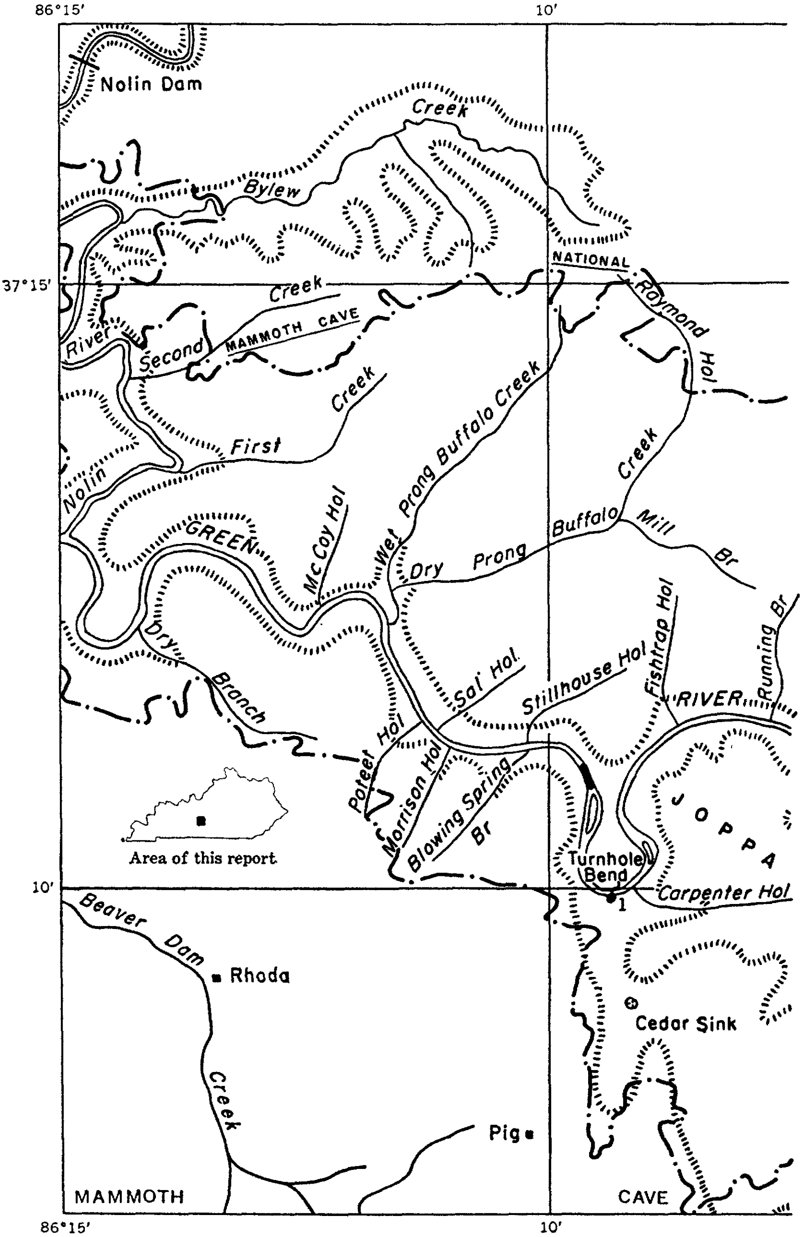
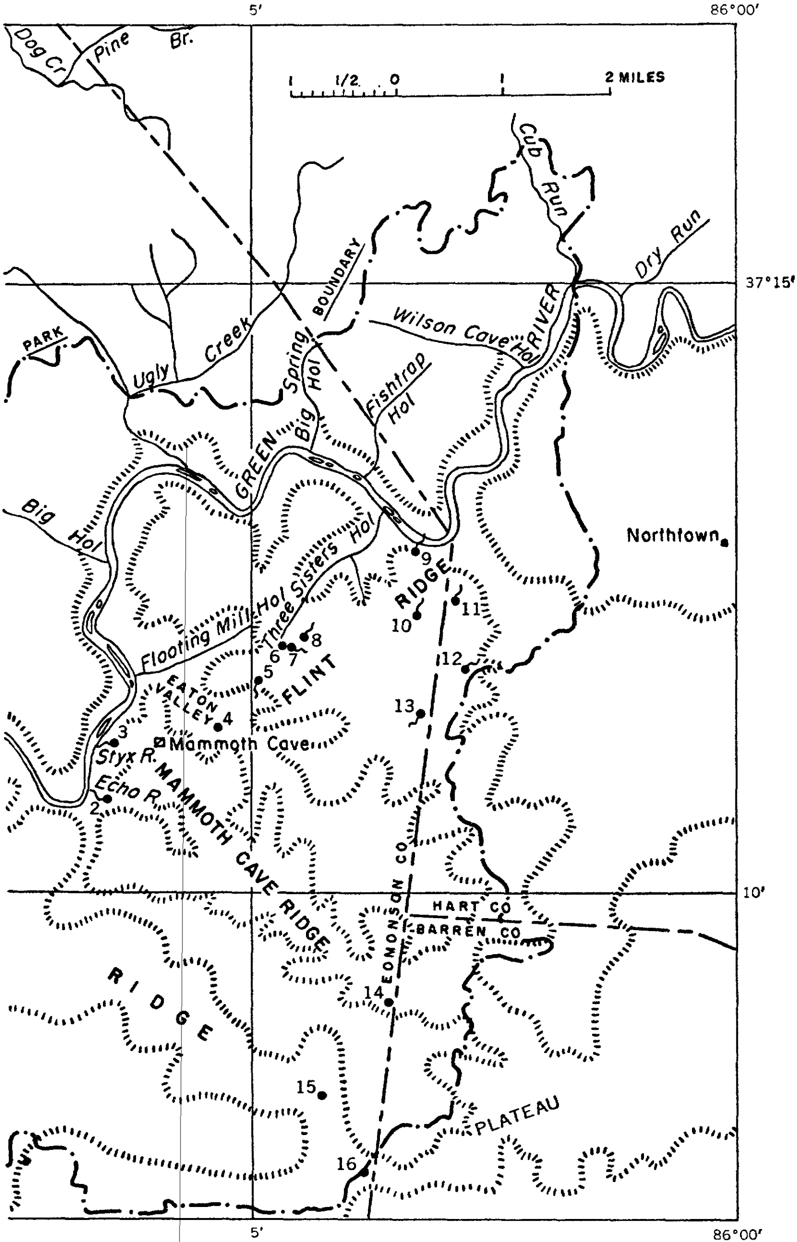


FIGURE 71.—Physiographic features, streams, wells, and springs in the Mammoth Cave area, Kentucky. 1, Sand Cave Spring; 2, Echo River; 3, Styx River; 4, Eaton Valley well; 5, Three Springs; 6, Bransford well; 7, Bransford Spring; 8, Blair



Spring; 9, Pike Spring; 10, Spring at CCC No. 1; 11, Collins Spring; 12, Cooper Spring; 13, Adwell Spring; 14, well at CCC No. 1; 15, Union City well; 16, Chaumont well.

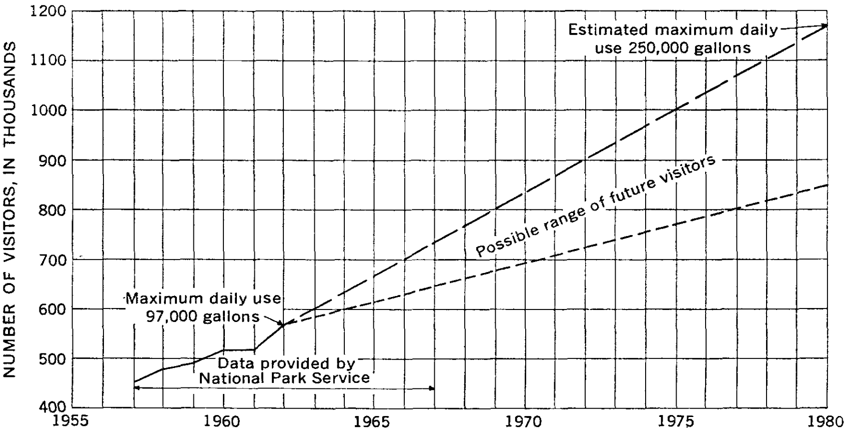


FIGURE 72.—Increasing numbers of visitors and increasing per-capita water use require additional water-supply development for Mammoth Cave National Park.

AVAILABLE WATER INFORMATION

In addition to the data obtained during the present investigation, this report is based in part on studies of the geology and hydrology of the area in 1953 by R. F. Brown.[1] Also available are intermittent gage-height and discharge measurements of outlet streams of Mammoth Cave since 1953, daily staff-gage readings of Green River at Mammoth Cave since 1938, continuous record of the water level in Mammoth Cave since 1958 and of Green River since 1960, chloride determinations of water from Green River at Munfordville since 1950 and at Mammoth Cave since 1958, periodic and intermittent chemical analyses of water from Styx, Echo, and Green Rivers since 1953, and continuous record of water level in three deep wells at Mammoth Cave since 1953. Gaging-station records are published in reports of the U.S. Geological Survey for the Green River at Munfordville (1915–22, 1927–31, 1936–37, 1937–63), at Mammoth Cave (1938–50), and at Brownsville (1924–31, 1936–37, 1938–63). The above data were obtained by the U.S. Geological Survey in cooperation with the Kentucky Geological Survey and the National Park Service.

SUMMARY OF POTENTIAL SUPPLIES

The potential sources of water supply for Mammoth Cave National Park are listed in table 1. Quantity and quality of water and the advantages and disadvantages of each potential source are summarized and page references are given for more complete data on each source.

[1] Brown, R. F., 1953, Reconnaissance of the geology and ground-water hydrology in the vicinity of Mammoth Cave National Park, Kentucky: U.S. Geol. Survey adm. rept. to Nat. Park Service, unpublished data, 16 p., duplicated.

TABLE 1.—*Evaluation of potential sources of supply for Mammoth Cave National Park*

Potential sources of supply (listed in approximate order of value)	Refer to page	Yield	Chemical quality	Advantages	Disadvantages
Green River	613	30-year minimum daily discharge, 40 mgd.	Chemical quality good; has met USPHS standards every day since November 1961. Use would require chlorination and removal of suspended sediment.	Large supply; quality suitable with ordinary treatment; could be used as principal supply or to augment existing supply; located near area of consumption.	Needs ordinary surface-water treatment and a 350-450 ft pump lift. Possibility of renewed pollution by oil-field brine.
Nolin River	620	Minimum probable releases from reservoir, 97–129 mgd.	Chemical quality good; moderately hard to hard, but well within USPHS standards. Use would require chlorination and removal of suspended sediment.	Large supply and suitable quality.	Needs ordinary surface-water treatment, a 350-450 ft pump lift, and long pipeline. Located on north side of Green River.
Perched water in Haney Limestone Member (7 springs on Flint Ridge of which 2 springs are part of existing supply).	633	Minimum observed flow, 101,500 gpd (121,700 gpd including Bransford well).	Best quality of all potential sources; requires only chlorination.	Minimum change to existing system; excellent quality; recharge area located mostly in park; minimum treatment needed.	Inadequate quantity for future use.
Wet Prong Buffalo Creek.	626	Probable mini. mum discharge, 300,000 gpd.	Quality good; soft to moderately hard; requires only chlorination.	Adequate supply; suitable quality; most of watershed within park; could also be used as a supply for future development in park north of Green River.	Needs ordinary surface-water treatment and long pipeline (5 miles); located on north side of Green River.
Small streams (other than Wet Prong Buffalo Creek).	621	Similar to Wet Prong Buffalo Creek but not as valuable as a potential source because of smaller flows, greater distances from point of consumption, location outside of park, or location at or near Green River flood level.			
Basal ground water.	629	Minimum yield of major underground streams not known; maximum recorded yield to drilled wells, 35 gpm unless well taps a major underground stream.	Chemical quality good; moderately hard to hard; requires ordinary treatment. Poor quality if wells are drilled too deep.	Can be developed near area of use; could be used to augment existing supply. Quality good with treatment.	Minimum yield not known. Requires high pump lift and treatment for bacteria and sediment.
Water in alluvium adjacent to Green River.	628	Yields only small supplies to wells.	Similar to water from Green River.	Quality good; can be developed near area of use.	Low yield; requires ordinary surface-water treatment and 350–400 ft pump lift.
Perched water in Big Clifty Sandstone Member and Girkin Formation.	639	Yields only small supplies to wells.	Chemical quality good; subject to pollution.	Good quality	Low yield.

The sources are listed in their approximate order of value. It is recognized that any order of listing must take into consideration quantity, quality, and economics. In the listing the quantity is weighted heavily. In evaluating the several sources a maximum daily demand of 250,000 gallons is used as a yardstick if possible growth to 1980 is considered. It reflects a two-fold increase in the estimated number of visitors during the period 1962 to 1980.

Combinations of these supplies might be used, such as the present supply augmented by Green River during periods of peak demand. Another possibility is the use of one or more of these sources as a separate supply for a future development in another area of the park.

PRESENT WATER SUPPLY AT MAMMOTH CAVE: ADEQUACY OF PRESENT SOURCES AND STORAGE

The present water supply in Mammoth Cave National Park is obtained from a group of three springs (appropriately named Three Springs) on Flint Ridge about 6,000 feet northeast of park headquarters, from Bransford Spring about 2,500 feet northeast of Three Springs, and from a deep well at Bransford Spring (fig. 71). Blair Spring, located about 3,000 feet east of Bransford Spring, was used as an emergency supply for about 5 weeks in the summer of 1962 and during at least one other summer season. During the critical period in August 1962, additional water was hauled by truck from Adwell Spring, about 8,000 feet east of Three Springs. Three Springs and Bransford, Blair, and Adwell Springs, along with several other springs and seeps, drain the perched aquifer in the Haney Limestone Member of the Golconda Formation on Flint Ridge. The deep well at Bransford Spring obtains water from the basal aquifer at or near the level of the Green River.

Minimum flows during the critical period in August 1962 and observed minimum flows of presently used sources of water are summarized in the following table.

Source	Minimum discharge during August 1962 (gpm)	Minimum discharge observed	
		Gpm	Date
			1962
Developed supply:			
Three Springs	15	12	Sept. 20.
Bransford Spring	[1] 10	7	Oct. 21.
Blair Spring	[2] 6	6	Sept. 6, 20.
Bransford well	14		
Total	45		
Supplementary supply:			
Adwell Spring	20	18	Sept. 20; Oct. 25, 31; Nov. 8.

[1] Estimated by comparison with flow of Three Springs; may be high, inasmuch as flow was reported as "about dry" Aug. 22, 1962, and estimated as 3 gpm, Aug. 29, 1962.
[2] Estimated.

The flow from the springs is piped by gravity to storage tanks at Three Springs and Bransford Spring. Water from the deep well is pumped into the storage tank at Bransford Spring. Water from Blair Spring was pumped from a basin at the spring through a plastic pipeline on top of the ground to the storage tank at Bransford Spring.

Each of the storage tanks at Three Springs and Bransford Spring has a capacity of 50,000 gallons. Water from these tanks is pumped to the 50,000-gallon tanks on top of Flint Ridge, about 7,000 feet northeast of park headquarters. Two additional tanks, each having a capacity of 500,000 gallons, have been constructed (1963) at this site to increase storage from 200,000 gallons to 1,200,000 gallons. From the storage tanks on Flint Ridge water is supplied by gravity flow to park headquarters, Mammoth Cave Hotel, staff living quarters, service station, and other facilities.

During August 19–25, 1962, 590,570 gallons (Perry E. Brown, Supt., Mammoth Cave National Park, written commun., 1963) was used at an average daily rate of 84,370 gallons. The major supply during the critical period in August was 45 gpm (gallons per minute) or 64,800 gpd (the Bransford well was pumped 24 hours per day). This supply was supplemented by water hauled from Adwell Spring by tank truck at the rate of about 17,000 gpd; the total supply was thus 81,800 gallons. The difference between the demand, 84,370 gpd, and the supply, 81,800 gpd, is 2,570 gpd that was obtained from storage in the four 50,000-gallon tanks.

August 1962 was thus a very critical period for the present water system at Mammoth Cave National Park. Even with conservation measures, the demand exceeded the supply at the rate of nearly 3,000 gpd. However, the problem could have been considerably worse if the drought had been more serious, if the pumping equipment had failed, or if a fire had occurred.

As shown previously, hydrologic conditions were not extreme during August 1962; there have been at least three more severe August droughts in the period 1915–22, 1925–62. A failure of equipment at Bransford well would reduce the supply by 14 gpm, or 20,160 gpd. The amount of water needed for fire fighting is difficult to estimate, but the Kentucky Inspection Bureau's rating for eighth-class protection is 500 gpm for 4 hours, or a total of 120,000 gallons.

The addition of the two 500,000-gallon storage tanks has partially alleviated the deficiency of the present water supply but additional supplies are still needed. With the same supply (Bransford Spring, Three Springs, and Bransford well) and demand that existed in May–September 1962 but including the additional storage, the emergency sources (Blair and Adwell Springs) would still be needed. Average daily use was estimated to increase from 60,000 gpd at the end of May to 85,000 gpd in the last week of July and remain constant thereafter to the end of the season. It was also assumed that Bransford well would be pumped continuously at the rate of 14 gpm unless storage was full. Storage decreased from 1,200,000 gallons June 26 to 136,000 gallons August 22 and was completely depleted before August 29. This decrease means that some or all of the emergency methods would have to be initiated again so that either the supply would be increased or the demand would be decreased.

HYDROLOGIC SYSTEM

Mammoth Cave National Park is located on the Mammoth Cave plateau, which is underlain by a thick sequence of limestone formations capped by sandstone (fig. 73). The rocks dip gently northwestward toward the Western Coal Field. The Green River bisects the park in a general east-west direction and cuts deeply into the thick limestones. The limestones are soluble; and south of the Green River, in the vicinity of Mammoth Cave, extensive solution action has taken place to approximately the level of the river. Solutional features include the famed caverns of Mammoth Cave. In this area the flat-topped plateau surface is deeply and irregularly dissected by northwest-trending closed valleys. Each valley consists of many sinkholes that coalesce to form a master valley. There is no surface flow in any of the valleys except during periods of heavy precipitation when some water may overflow from one sinkhole to adjacent ones. Subsurface channels carry all the drainage during normal flow. Only two permanent streams, Echo and Styx Rivers, enter the Green River from the south in the park. Both are very short streams emerging from caverns as springs.

Dendritic surface streams that are mostly perennial characterize the extreme western part of the general area south of the Green River. Drainage is generally northward via Beaver Dam Creek and short streams flowing into the Green River.

The Dripping Springs escarpment forms the southern boundary of the Mammoth Cave plateau and faces south to the lower Pennyroyal plain. Immediately below the escarpment, shallow sinkholes are especially numerous in an east-west belt about 2 miles wide. Elsewhere, the Pennyroyal plain is gently rolling and is drained by perennial streams that flow northwestward to the area of sinkholes. All streams terminate in one or more sinkholes and in solution channels under the Mammoth Cave plateau to the Green River.

Owing to the northwesterly dip, the insoluble Big Clifty Sandstone Member of the Golconda Formation and younger formations north of

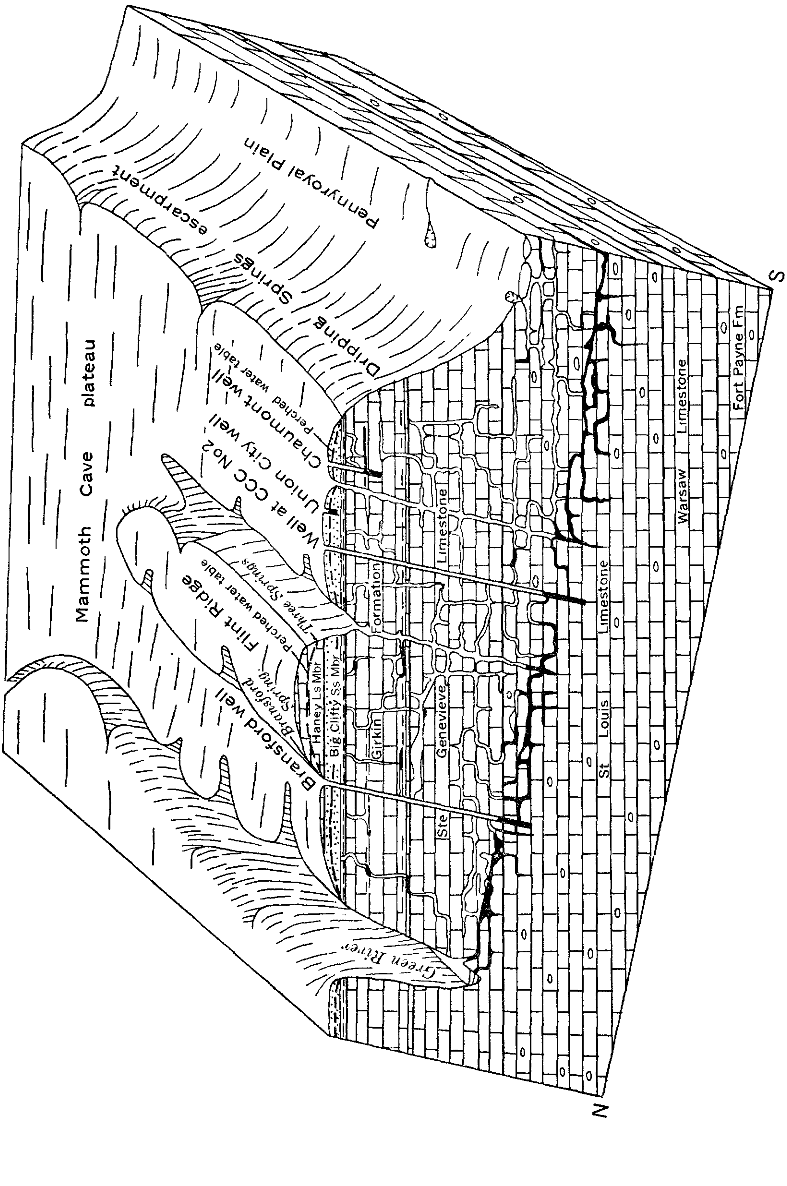


FIGURE 73.—Topography and geology control the occurrence and movement of ground water in the Mammoth Cave area.

the Green River are much closer to the level of the river, and an extensive solution drainage pattern has not been formed. Short interrupted streams having steep gradients drain the area southward to the Green River.

All water that moves through or is stored in the Mammoth Cave area comes from precipitation. All surface and subsurface drainage from the Mammoth Cave plateau and Pennyroyal plain in the vicinity of the park is eventually into the Green River.

Precipitation in the area of Mammoth Cave National Park north of the Green River and in the extreme western part of the park south of the Green River runs off partly through surface streams and partly by subsurface drainage through the rocks. The larger surface streams that drain this area are the Nolin River and Beaver Dam, Bylew, Dog, and Buffalo Creeks (fig. 71).

Almost all precipitation on Mammoth Cave plateau south of the Green River in the vicinity of Mammoth Cave that does not evaporate or transpire moves downward through the rocks as ground water. It reaches the Green River as outflow from large springs such as Echo, Styx, Pike, and Sand Cave Springs and probably from numerous smaller springs and seeps. Downward movement through the rocks underlying the plateau is almost entirely in openings along joints and bedding planes, whose number and size control the rate of movement. Openings are numerous in the Hardinsburg Sandstone and Big Clifty Sandstone Member, but are few in number or nonexistent in the thin shale beds in the Girkin Formation and at the base of the Big Clifty and Haney Limestone Members. They are numerous and greatly enlarged by solution in the several thick limestone formations. Thus the rate of movement is rapid through the limestone, slower through the sandstone, and very slow through the shale beds. These differences in rate of movement have created several bodies of ground water beneath the plateau. A body of ground water is perched above the shale at the base of the Haney Limestone Member and is contained in solution openings in the limestone (fig. 73). It is this water that maintains the flow of Three Springs, Bransford Spring, and the several other springs on Flint Ridge. A second body of ground water is perched in the Big Clifty above the shale bed at its base. Some of this water discharges horizontally to the edges of the plateau and forms the "dripping springs" from which the escarpment is named. Other small and discontinuous bodies of ground water are perched above thin shale beds in the Girkin Formation.

Most of the water that falls on the plateau eventually finds its way down to the zone of basal ground water in the cavernous St. Louis and Ste. Genevieve Limestones. All rock openings below the water table or upper surface of the zone of basal ground water are filled with water. Owing to the ease with which water moves through the large solution channels, the basal water table is nearly flat. It slopes gently northwestward and is continuous with Green River. The basal ground water is recharged by water that moves directly down from the surface through sinkholes or open shafts in the limestone, by water that discharges from the edges of the perched zones, and by water moving through solution channels from the Pennyroyal plain. When the stage of the Green River rises faster than the level of the adjacent ground water, the flow of River Styx and Echo River is reversed and recharges the basal ground water in the immediate vicinity of the river.

A small part of the precipitation in the area and part of the runoff from the steep rock slopes flanking Green River move through and are temporarily stored in a narrow body of alluvium along the river. The body of water in the alluvium is connected hydraulically to the Green River. During periods of low flow, the water table in the alluvium slopes toward the Green River and water moves through the alluvium into the river. During periods of high flow, the alluvium is completely saturated.

POTENTIAL SOURCES OF WATER SUPPLY

GREEN RIVER

The Green River is the largest potential source of water supply for Mammoth Cave National Park. It drains 1,983 square miles of central Kentucky. The runoff from 444 square miles of this area does not reach the river through surface streams but drains into limestone sinks.

QUANTITY

Flow-duration curves for Green River at Mammoth Cave (fig. 74) show the percentage of time during which specified discharges are equaled or exceeded in a given period. For example, in the period 1916–22, 1928–31, 1938–61 (water years), the daily mean flow of Green River (fig. 74) was at least 205 cfs, or 132 mgd, during 90 percent of the time. The curve for this period was obtained from the curve for the actual period of gaging-station operation, 1939–50 (water years) and from records for the gaging station at Munfordville.

Figure 75 shows low-flow frequency curves for Green River at Mammoth Cave. A low-flow frequency curve is defined (Langbein, 1960, p. 13) as a graph showing the magnitude and frequency of minimum flows for a period of given length. For example, the minimum 7-day flow is expected to be less than 150 cfs (97 mgd) at average intervals of 2 years (fig. 75).

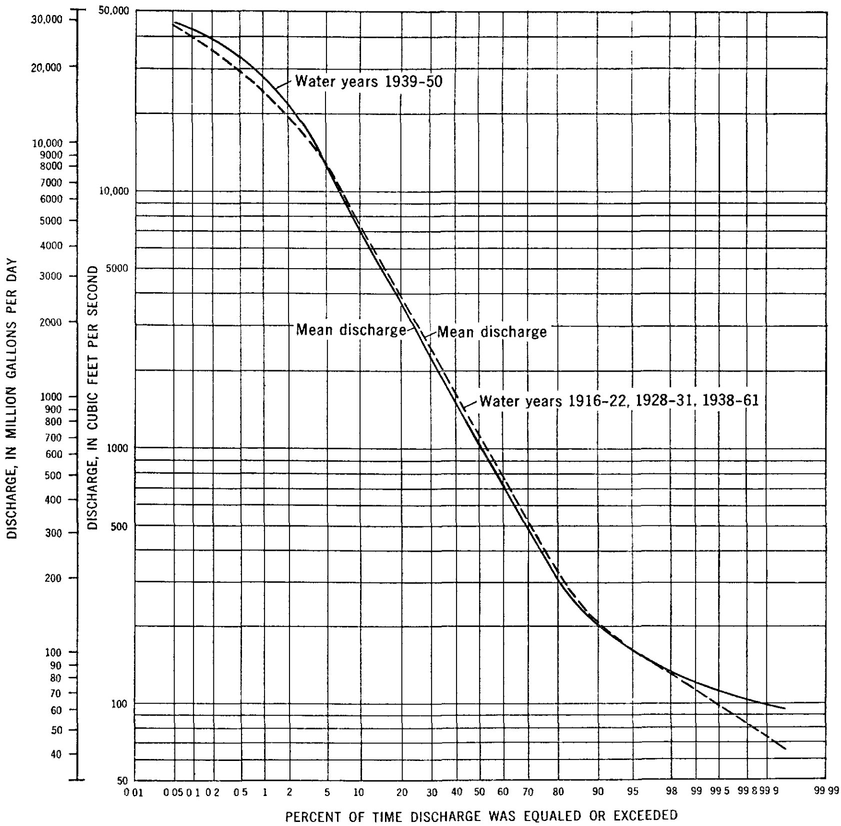


Figure 74.—Duration curves of daily flow, Green River at Mammoth Cave, Ky.

The curves in figure 75 were obtained from the records at Mammoth Cave for the period 1939–49 (climatic years) and were extended to the longer period 1915–21, 1928–30, 1938–60 (climatic years) on basis of records at Munfordville.

Flow-duration and low-flow frequency analysis thus shows that there is an ample quantity of water in the Green River at all times without storage for any present or future needs of Mammoth Cave National Park.

A frequency curve of annual floods is shown in figure 76. The curve was obtained from a regional flood-frequency analysis by McCabe (1962). The right ordinate scale is expressed in feet above the zero of the gage at Mammoth Cave Ferry and the left ordinate scale is expressed as discharge in cubic feet per second. For example, a flood having a recurrence interval of 20 years can be expected to reach a gage height of at least 51.0 feet and a discharge of at least 70,400 cfs. This in no way implies that once a flood having a stage of

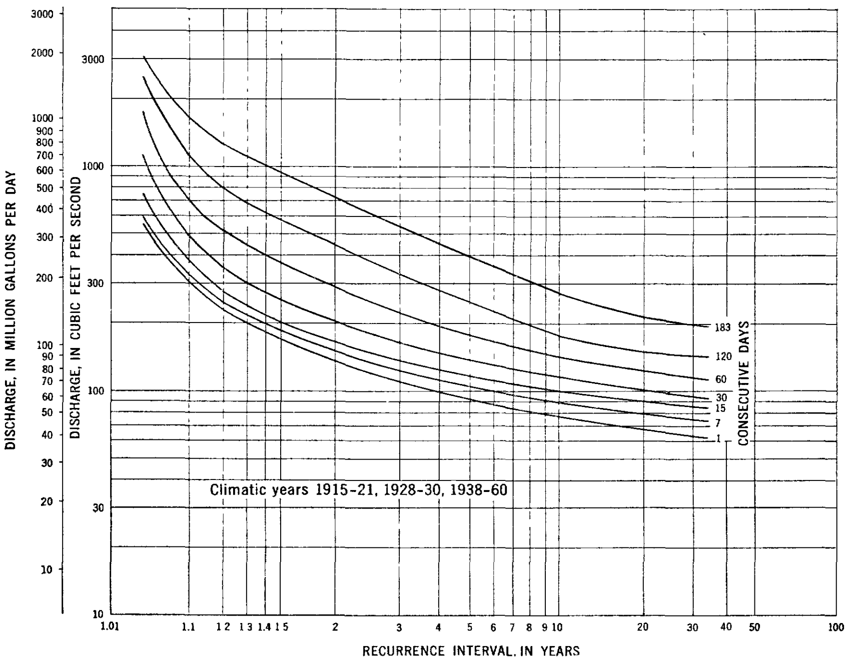


FIGURE 75.—Magnitude and frequency of low flows, Green River at Mammoth Cave, Ky.

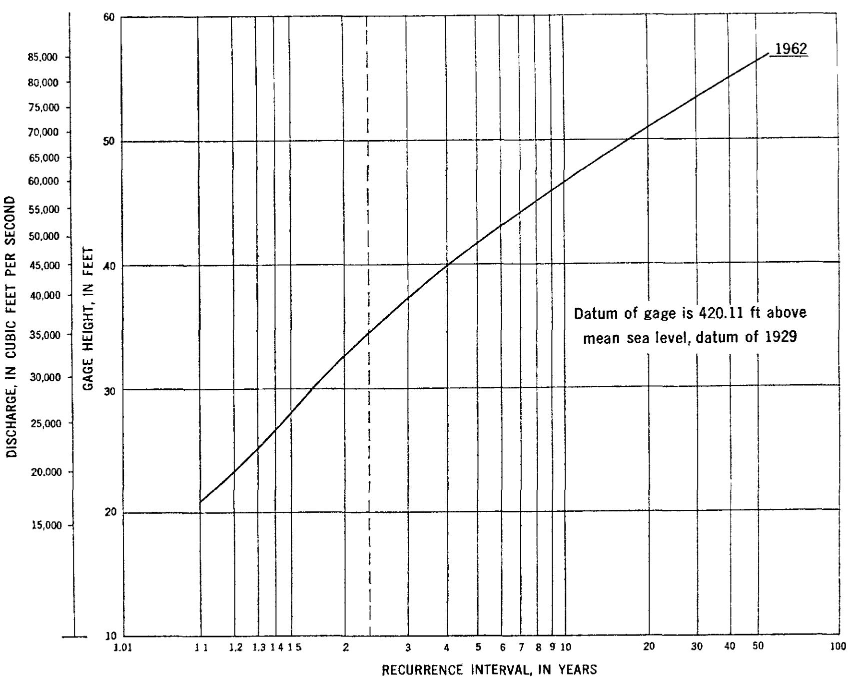


FIGURE 76.—Frequency of annual floods, Green River at Mammoth Cave, Ky.

51.0 feet and a discharge of 70,400 cfs occurs that it will not recur for another 20 years. The curve merely shows that on the basis of past flood experiences at gaging stations in this flood region and hydrologic area of Kentucky, a flood of 70,400 cfs, or higher, can be expected to occur on a long-term average of once every 20 years. This curve can be used for location and planning of water-supply structures above floods of selected frequencies.

Two reservoirs on the Green River are being considered by the U.S. Army Corps of Engineers. Green River Reservoir, 108 miles upstream from Mammoth Cave, is presently (1962) in the design stage. The reservoir is to be a flood control and water-quality control project. When built, the reservoir will augment low flows and reduce flood peaks in the Green River at Mammoth Cave. The other project, Mining City Reservoir, 93 miles downstream from Mammoth Cave, has been deferred for further study. Details of the design of the Mining City Reservoir are not known to the authors, but magnitude of flood flows or low flows at Mammoth Cave would not be affected.

QUALITY

Water in the Green River in the vicinity of Mammoth Cave prior to 1958 was suitable for nearly all uses with little or no treatment. From 1958 to 1961, however, the water was polluted by oil-field brine. Enforcement of pollution-control regulations and a decline in oil production has resulted in a marked improvement in water quality since that time. Since November 1961, the water in the Green River has met U.S. Public Health Service drinking-water standards every day in the year.

Since October 1, 1950, the U.S. Geological Survey, in cooperation with the Commonwealth of Kentucky, has maintained a daily sampling station on Green River at Munfordville, Ky., about 29 miles upstream from the ferry at Mammoth Cave National Park. The sampling station is operated to provide chemical-quality, water-temperature, and sediment data for the upper Green River basin. The basic assessment of water-quality conditions of the Green River in the park is made primarily on the data collected at the Munfordville station. Data collected from the Green River in the park shows local conditions and dilution effects in the 29-mile reach. The reliability of the data collected from the Green River in the park is increased greatly by the long daily record collected at Munfordville.

The quality of water in the Green River is normally good. However, waste brine from oil production in the Greensburg field in Green and Taylor Counties was discharged into the Green River in large quantities and drastically changed the quality of the river. Later, these practices were corrected. Some oil production also occurred in Metcalfe County, but it never reached the boom conditions characteristic of the Greensburg field. A summary of the chemical quality of Green River water is given in table 2. The 13 years of record summarized in the table are divided into four periods to show the drastic change in the quality of Green River water due to the increase and decrease in brine pollution. The effects of brine pollution were revealed principally in the analyses for dissolved solids, hardness, and chloride. Brine had little or no effect on the amount of bicarbonate (alkalinity), pH, color, or suspended sediment in the Green River.

The key to the potability of the Green River is the number of days each year the chloride concentration is within or exceeds U.S. Public Health Service drinking-water standards of 250 ppm (parts per million) chloride. Table 3 gives these days for both the long-term water-quality station at Munfordville and the short-term station at Mammoth Cave.

TABLE 2.—*Chemical quality of Green River at Munfordville, Ky., October 1, 1950–January 31, 1963*

[Chemical analyses in parts per million]

Concentration	Dissolved solid	Hardness as CO_3 (Ca, Mg)	Bicarbonate (HCO_3)	Chloride (Cl)	pH	Color units
Before brine pollution, Oct. 1, 1950–Sept. 30, 1957						
Maximum	254	166	186	45	8.6	32
Minimum	73	44	36	.5	6.9	1
Average	140	110	120	6.0	----------	5
Number of analyses	258	258	258	257	258	253
Rising brine pollution, Oct. 1, 1957–Sept. 30, 1960						
Maximum	5,830	1,220	186	3,250	8.1	38
Minimum	86	60	60	2.0	6.5	2
Average	655	209	117	351	----------	6
Number of analyses	130	133	133	756	133	130
Decreasing brine pollution, Oct. 1, 1960–Dec. 31, 1961						
Maximum	2,760	648	169	1,450	9.6	35
Minimum	124	75	74	8.0	6.9	1
Average	470	180	120	178	----------	9
Number of analyses	52	52	52	452	52	51
Present quality, Jan. 1, 1962–Jan. 31, 1963						
Maximum	376	181	150	[1] 194	8.3	55
Minimum	82	48	49	[1] 2.5	7.1	0
Average	181	109	102	[1] 44	11	12
Number of analyses	37	35	36	[1] 421	36	35

[1] Jan. 1, 1962–Feb. 28, 1963.

TABLE 3.—*Oil production in the upper Green River and its effect on the potability of Green River water*

Calendar year	Oil production Green, Taylor, and Metcalfe Counties (barrels)	Number of days chloride concentration exceeded USPHS drinking-water standards	
		Green River at Munfordville	Green River at Mammoth Cave
1957	33,088	0	0
1958	1,856,390	50	[1] 19
1959	10,839,954	220	[1] 170
1960	4,506,096	153	87
1961	1,393,568	26	[1] 5
1962	567,819	0	[1] 0
1963		[2] 0	[1] 0

[1] Estimated.
[2] Jan.-May only.

Chloride measurements at Mammoth Cave Ferry and at Munfordville show considerable dilution caused by ground-water flow into Green River within the 29-mile reach. Consequently, the quality of water at Green River at Mammoth Cave was always better than at Munfordville. The dilution not only reduced the concentration of chloride but also reduced the number of days in which the water exceeded drinking-water standards for chloride at Mammoth Cave. The chloride content at Munfordville (fig. 77) has not exceeded 250 ppm any day since December 1961 and at Mammoth Cave, since November 1961. Even the unusually low flows of the Green River in July–September 1962 did not produce chloride concentrations at Munfordville or at Mammoth Cave in excess of 250 ppm. Much of the brine currently appearing in Green River probably is due to drainage of residues of brine that polluted fresh-water aquifers previously. The data show that some oil production with proper disposal of waste oil brine does not seriously affect the quality of Green River water. There is every reason to believe that Green River water could be used to augment the water supply of Mammoth Cave National Park. Use of the river water would require chlorination and the removal of suspended sediment, which could be done with commercially available water-treatment systems.

The Green River basin upstream from Mammoth Cave National Park contains only eight towns having a combined population in 1960 of 18,137. Not all of these towns have adequate sewage collection and treatment systems; however, this condition is being corrected rapidly. Columbia, Campbellsville, and Greensburg have modern sewage-treatment plants. Munfordville began construction of a collection system and treatment plant in the summer of 1963. Horse Cave, Cave City, Edmonton, and Liberty have plans and construction grants approved or pending. It appears that collection and treatment of sewage in the upper Green River basin will be adequate in the near future. How-

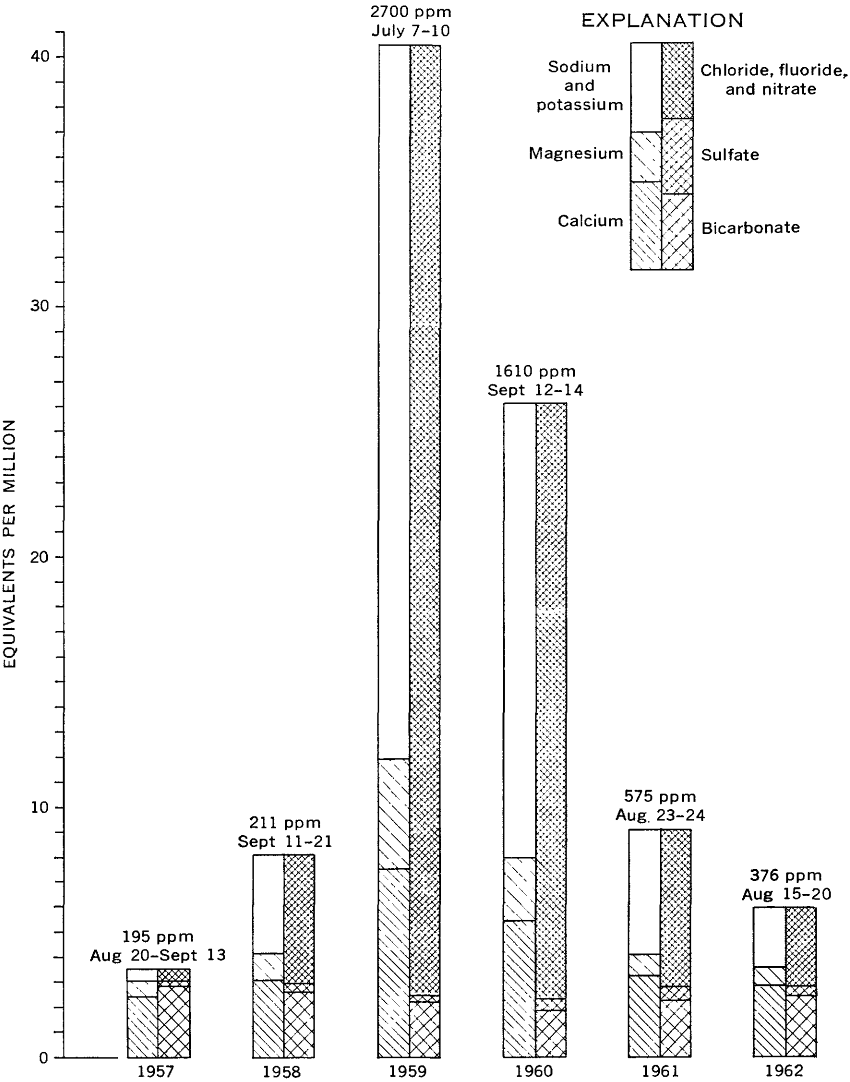


FIGURE 77.—Chemical composition of water of highest salinity during July–September, Green River at Munfordville, Ky. Number at top of bar is concentration of dissolved solids, in parts per million, of composite sample. Date at top of bar shows days in composite sample.

ever, any surface water source would need chlorination to be acceptable for public use.

SUSPENDED SEDIMENT

In contrast to ground-water sources, the Green River contains appreciable amounts of suspended sediment. Sediment characteristics of the river have been studied by the Geological Survey at the Munfordville sampling station for more than 12 years. The sediment in the Green River is almost entirely suspended because there is very little bed load. The sediment is fine, as shown by the following table. Consequently, the Green River carries a smaller volume of sediment than its muddy appearance would indicate.

Suspended-sediment characteristics of the Green River since April 1950

Particle		*Approximate percentage of total amount*
Class	*Size (mm)*	
Clay	<0.0039	50–65
Very fine silt	.0039–0.0078	15
Fine silt	.0078– .0156	15
Medium silt	.0156– .0313	9
Coarse silt	.0313– .0625	2–6
Sand	>.0625	<2

Suspended-sediment concentration varies widely during the year. On the basis of the measurements at Munfordville, concentrations of suspended sediment in the Green River are distributed as follows:

	Occurrence (percent of time)	
Concentration of suspended sediment	*July–Sept.*	*Entire year*
⋜ 10 ppm	10	25
⋜ 25 ppm	50	51
⋜ 50 ppm	63	68
⋜ 100 ppm	78	80

Surprisingly, the period of July–September contains about the same proportion of days of low concentration as the entire year.

NOLIN RIVER

The Nolin River drains 727 square miles of central Kentucky. Water from about 223 square miles of this area does not drain into the Nolin River through surface streams but into limestone sinks. The Nolin River flows into the Green River near the western edge of Mammoth Cave National Park and 8 miles west of Mammoth Cave. Above Nolin River Dam, 8 miles upstream from the mouth of the river and 10 miles northwest of Mammoth Cave, the river drains 707 square miles (of which about 223 square miles does not contribute directly to surface runoff). Storage of water in the reservoir behind the dam started in March 1963. Minimum releases from the reservoir will probably be about 150 to 200 cfs (97 to 129 mgd).

The Nolin River water is moderately hard to very hard but is generally well within the limits of drinking-water standards. A summary of chemical quality is given in table 4. Nolin River water would require chlorination and probably removal of sediment or turbidity.

TABLE 4.—*Chemical quality of water in Nolin River, Wet Prong Buffalo, Dog, Bylew, and Beaver Dam Creeks*

[Chemical analyses in parts per million]

Concentration	Analyses	Iron (Fe)	Chloride (Cl)	Dissolved solids	Hardness as $CaCO_3$	pH	Color	Turbidity
Nolin River								
Maximum	13	1.1	42	267	205	8.1	16	[1] 60
Minimum		.00	1.9	116	91	6.7	2	[1] 8
Average		.19	10	180	149	[2] 7.6	6	
Wet Prong Buffalo, Dog, Bylew, and Beaver Dam Creeks								
Maximum	[3] 19	0.53	6.4		110	8.3		
Minimum		.05	1.0		29	6.8		
Average		.21	2.7		68	[2] 7.8		

[1] Based on four analyses only.
[2] Median value.
[3] Total of from two to five analyses at each of five sampling points.

WATER FROM SMALL STREAMS

A reconnaissance of small streams was made in the Mammoth Cave National Park area during the period August-November 1961. Measurements or estimates of flow and observations of no flow were made at many points. Additional measurements of flow were made at selected locations during the period June-December 1962. The results are summarized in table 5.

TABLE 5.—*Discharge measurements made in Mammoth Cave National Park area excluding Green and Nolin Rivers, Flint Ridge springs, and Pike Spring*

Stream	Tributary to—	Location	Drainage area (sq mi)	Measurements	
				Date	Discharge (cfs)
Dry Run	Green River	Lat 37°14′52″, long 86°01′15″, at mouth, 2.6 mi northwest of Northtown, Ky., and 6.2 mi northeast of Mammoth Cave, Ky.		10- 5-61	0
Cub Run	do	Lat 37°16′09″, long 86°02′16″, at ford, 0.1 mi north of Mammoth Cave National Park boundary, 2.8 mi southeast of Cub Run, Ky., and 6.8 mi northeast of Mammoth Cave Ky.		8-24-61	0
Do	do	Lat 37°15′01″, long 86°01′40″, at mouth, 4.2 mi south of Cub Run, Ky.		10- 5-61	0
Wilson Cave Hollow.	do	Lat 37°14′14″, long 86°02′18″, at mouth, 2.6 mi northwest of Northtown, Ky., and 5 mi northeast of Mammoth Cave, Ky.		10- 5-61	0
Green River tributary.	do	Lat 37°13′28″, long 86°02′39″, at mouth, 2.5 mi west of Northtown, Ky., and 4.1 mi northeast of Mammoth Cave, Ky.		10- 5-61	0
Three Sisters Hollow.	do	Lat 37°13′03″, long 86°03′38″, at mouth, at head of Three Sisters Island and 3.2 mi northeast of Mammoth Cave, Ky.		9- 7-61	0
Fishtrap Hollow	do	Lat 37°13′26″, long 86°03′56″, at mouth, 3.3 mi northeast of Mammoth Cave, Ky.		10- 5-61	0

See footnotes at end of table.

TABLE 5.—*Discharge measurements made in Mammoth Cave National Park area excluding Green and Nolin Rivers, Flint Ridge springs, and Pike Spring*—Con.

Stream	Tributary to—	Location	Drainage area (sq mi)	Measurements	
				Date	Discharge (cfs)
Big Spring Hollow.	Green River	Lat 37°13′39″, long 86°04′27″, just below right bank spring, 200 ft above mouth and 3.3 mi northeast of Mammoth Cave, Ky.		9- 8-61	1.49
Ugly Creek tributary spring.	Ugly Creek tributary.	Lat 37°14′20″, long 86°06′41″, on north side of road, 0.15 mi south of Wilkens Cemetery and 3.8 mi north of Mammoth Cave, Ky.		8-22-61	.004
Ugly Creek	Green River	Lat 37°14′01″, long 86°06′19″, at ford, 1.3 mi above mouth and 3.4 mi north of Mammoth Cave, Ky.		8-22-61	0
Do	do	Lat 37°13′26″, long 86°05′42″, at mouth, 2¾ mi north of Mammoth Cave, Ky.		9- 6-61	[1] .5
Big Hollow	do	Lat 37°13′12″, long 86°07′41″, at telephone line, 0.35 mi south of lookout tower and 2.8 mi northwest of Mammoth Cave, Ky.		11- 2-61	.025
Do	do	Lat 37°12′38″, long 86°06′27″, at mouth, 1.7 mi north of Mammoth Cave, Ky.		9- 6-61	0
Green River tributary.	do	Lat 37°12′01″, long 86°06′30″, at mouth, at head of Floating Mill Island and 1.1 mi north of Mammoth Cave, Ky.		9- 6-61	0
Floating Mill Hollow.	do	Lat 37°11′44″, long 86°06′13″, at mouth, ¾ mi north of Mammoth Cave, Ky.		9- 6-61	[1] .1
Styx River	do	Lat 37°11′15″, long 86°06′30″, at Mammoth Cave, Ky., 50 ft below cave outlet and 0.1 mi above mouth.		4-30-53	8.05
				12-15-58	.14
				6-23-59	.254
				9-10-59	.13
				5- 8-60	0
				6- 3-60	.69
				6- 8-60	.214
				6-10-60	.33
				6-17-60	2.90
				7- 7-60	10.9
				7-20-60	0
				7-22-60	0
				7-29-60	0
				8- 5-60	0
				8-12-60	0
				8-19-60	0
				8-25-60	0
				8-26-60	0
				9- 2-60	0
				9-21-60	0
				10- 6-60	0
				10- 7-60	0
				11- 1-60	0
				11-15-60	0
				12- 7-60	.75
				2- 2-61	1.18
				8-23-61	.43
				10-30-61	.10
				11-29-61	.215
				6-12-62	[1 2] 1
				7-24-62	.13
				8-24-62	.052
				8-28-62	.095
				9-27-62	.12
				11-29-62	.45
				5- 2-63	.44

See footnotes at end of table.

TABLE 5.—*Discharge measurements made in Mammoth Cave National Park area excluding Green and Nolin Rivers, Flint Ridge springs, and Pike Spring*—Con.

Stream	Tributary to—	Location	Drainage area (sq mi)	Measurements	
				Date	Discharge (cfs)
Echo River	Green River	Lat 37°10′45″, long 86°06′30″, at Mammoth Cave, Ky., 50 ft below cave outlet and 0.2 mi above mouth.		4-30-53	72.4
				8-29-55	1.40
				11-11-55	1.10
				6-12-56	2.12
				9-25-56	1.02
				5- 7-57	4.28
				8-13-57	1.61
				2-25-58	5.19
				5-27-58	4.30
				8-20-58	2.57
				11- 3-58	1.29
				12-15-58	1.68
				6-23-59	2.06
				9-10-59	.89
				6- 8-60	[1]2.5
				7-20-60	[1]3
				8-25-60	[1]1
				10- 6-60	[2].22
				10- 7-60	.99
				8-21-61	2.28
				11- 2-61	1.11
				11-29-61	[1]2
				6-12-62	15.5
				7-24-62	1.37
				8-24-62	1.02
				8-28-62	.48
				9-27-62	.25
				11-27-62	[1]2
				5- 2-63	.55
Green River tributary.	do	Lat 37°11′03″, long 86°07′22″, at mouth, on left bank of Green River and 1.1 mi west of Mammoth Cave, Ky.		11- 2-61	0
Running Branch.	do	Lat 37°11′20″, long 86°07′36″, at mouth, on right bank of Green River and 1.4 mi west of Mammoth Cave, Ky.		11- 2-61	0
Cotton Gin Hollow.	do	Lat 37°11′21″, long 86°08′33″, at mouth, on left bank of Green River and 2.2 mi west of Mammoth Cave, Ky.		11- 2-60	0
Fishtrap Hollow	do	Lat 37°11′19″, long 86°08′43″, at mouth, on right bank of Green River and 2.4 mi west of Mammoth Cave, Ky.		11- 2-61	0
Carpenter Hollow.	do	Lat 37°09′58″, long 86°09′21″, at mouth, at Turnhole Bend of Green River, 3.2 mi west of Mammoth Cave, Ky.		11- 2-61	0
Green River tributary.[3]	do	Lat 37°08′44, long 86′11′04″, at culvert, 0.3 mi north of Kentucky 259 and 1.2 mi northwest of Pig, Ky.		10-30-61	[1].2
Tributary 1	Green River tributary.[3]	Lat 37°08′38″, long 86°11′04″, at culvert, 0.2 mi north of Kentucky 259 and 1.1 mi northwest of Pig, Ky.		10-30-61	[1].2
Tributary 2	do	Lat 37°08′46″, long 86°10′49″, at mouth, 1,100 ft east of north-south road and 1.1 mi northwest of Pig, Ky.		10-30-61	[1]1
Green River tributary.[3]	Green River[3]	Lat 37°08′46″, long 86°10′48″, 100 ft downstream from right bank tributary, 1,309 ft east of north-south road and 1.1 mi northwest of Pig, Ky.		10-30-61	0
Do	do	Lat 37°09′29″, long 86°09′46″, 1.8 mi north of Pig and 3.9 mi southwest of Mammoth Cave, Ky.		9- 7-61	0
Stillhouse Hollow.	Green River	Lat 37°11′09″, long 86°10′11″, at mouth, at Stice Island and 3.7 mi west of Mammoth Cave, Ky.		11- 2-61	9
Blowing Spring Branch.	do	Lat 37°11′12″, long 86°10′13″, at mouth, at Stice Island and 3.8 mi west of Mammoth Cave, Ky		11- 2-61	0
Morrison Hollow.	do	Lat 37°11′13″, long 86°11′03″, at mouth, 1.2 mi upstream from Buffalo Creek and 4.5 mi west of Mammoth Cave, Ky.		11- 2-61	0
Sal Hollow	do	Lat 37°11′23″, long 86°11′13″, at mouth, 1.0 mi upstream from Buffalo Creek and 4.7 mi west of Mammoth Cave, Ky.		11- 2-61	[1].02

See footnotes at end of table.

TABLE 5.—*Discharge measurements made in Mammoth Cave National Park area excluding Green and Nolin Rivers, Flint Ridge springs, and Pike Spring*—Con.

Stream	Tributary to—	Location	Drainage area (sq mi)	Measurements	
				Date	Discharge (cfs)
Poteet Hollow	Green River	Lat 37°11′29″, long 86°11′20″, at mouth, 0.8 mi upstream from Buffalo Creek and 4.8 mi west of Mammoth Cave, Ky.		11- 2-61	0
Wet Prong Buffalo Creek.	Buffalo Creek	Lat 37°13′47″, long 86°10′24″, 10 ft upstream from Chicken Hollow and 5 mi northwest of Mammoth Cave, Ky.	2.26	1-12-62 7-26-62 9-26-62 12- 7-62	2.04 1.53 1.42 1.43
Do	do	Lat 37°13′21″, long 86°11′10″, 500 ft downstream from Pigeon Hollow and 5.3 mi northwest of Mammoth Cave, Ky.		11- 1-61	[1]1.5
Raymond Hollow tributary.	Raymond Hollow.	Lat 37°15′05″, long 86°09′12″, at Collie Ridge Road, about 0.4 mi south of Lincoln School and 5.4 mi northwest of Mammoth Cave, Ky.		9- 8-61	0
Raymond Hollow.	Dry Prong Buffalo Creek.	Lat 37°14′56″, long 87°09′06″, at Collie Ridge Road, 2.3 mi east of Ollie and 5.2 mi northwest of Mammoth Cave, Ky.		9- 8-61	0
Raymond Hollow tributary.	Raymond Hollow.	Lat 37°14′48″, loug 86°09′11″, at Collie Ridge Road, about 800 ft above mouth, 2.2 miles east of Ollie and 5.1 mi northwest of Mammoth Cave, Ky.		9- 8-61	[1].005
Good Spring	Mill Branch	Lat 37°12′35″, long 86°08′52″, about 300 ft northeast of Cemetery at Good Spring Church, 3.1 mi northwest of Mammoth Cave, Ky.		8-21-61	[1].02
Mill Branch	Dry Prong Buffalo Creek.	Lat 37°12′58″, long 86°09′30″, at mouth, 3.8 mi northwest of Mammoth Cave, Ky.		8-21-61	0
Dry Prong Buffalo Creek.	Buffalo Creek	Lat 37°12′58″, long 86°09′30″, at (including) Mill Branch, 3.8 mi northwest of Mammoth Cave, Ky.		8-21-61	0
Buffalo Creek	Green River	Lat 37°12′29″, long 86°11′26″, at confluence of Wet Prong and Dry Prong, ¾ mi above mouth and 5.2 mi west of Mammoth Cave, Ky.	12.4	8-23-61	0
Buffalo Creek tributary spring 1.	Buffalo Creek	Lat 37°12′25″, long 86°11′25″, on left bank, several hundred feet below confluence of Wet Prong and Dry Prong and 5.2 mi west of Mammoth Cave, Ky.		8-23-61	[1].2
Buffalo Creek tributary spring 2.	do	Lat 37°12′10″, long 86°11′34″, on right bank of and about 500 ft above mouth of Buffalo Creek, and 5.2 mi west of Mammoth Cave, Ky.		8-23-61 11- 2-61	[1]2.5 2.31
McCoy Hollow	Green River	Lat 37°12′13″, long 86°12′25″, at mouth, 3.0 mi east of Brownsville and 6.0 mi west of Mammoth Cave, Ky.		8-23-61	[1].1
Dry Branch	do	Lat 37°12′08″, long 86°14′11″, 300 ft above mouth, 1.5 mi east of Brownsville and 7.5 mi west of Mammoth Cave, Ky.		9- 5-61	[1].001
Dry Branch tributary.	Dry Branch	Lat 37°12′08″, long 86°14′11″, at mouth, about 300 ft above mouth of Dry Branch and 7.5 mi west of Mammoth Cave, Ky.		9- 5-61	[1].2
Dog Creek	Nolin River	Lat 37°16′47″, long 86°07′05″, at culvert, 0.1 mi below Pine Branch and 6.6 mi north of Mammoth Cave, Ky.	8.12	8-22-61 11- 1-61 6-13-62 7-26-62 8-28-62 12- 7-62	4.51 4.83 4.20 3.10 2.65 3.35
Do	do	Lat 37°18′39″, long 86°08′03″, 400 ft above Little Dog Creek and 8.8 mi north of Mammoth Cave, Ky.	14.0	8-22-61	5.04
Little Dog Creek.	Dog Creek	Lat 37°18′43″, long 86°08′03″, 50 ft above mouth and 8.9 mi north of Mammoth Cave, Ky.		8-22-61	1.29
Dog Creek	Nolin River	Lat 37°19′12″, long 86°08′02″, at bridge, 0.6 mi below Little Dog Creek and 9.4 mi north of Mammoth Cave, Ky.	19.8	8-22-61 6-13-62 7-26-62 9-28-62 12- 7-62	6.76 8.34 7.42 4.34 6.19

See footnotes at end of table.

TABLE 5.—*Discharge measurements made in Mammoth Cave National Park area excluding Green and Nolin Rivers, Flint Ridge springs, and Pike Spring*—Con.

Stream	Tributary to—	Location	Drainage area (sq mi)	Measurements	
				Date	Discharge (cfs)
Bylew Creek	Nolin River	Lat 37°15′40″, long 86°13′07″, 600 ft below Jones Branch and 8.3 mi northwest of Mammoth Cave, Ky.	5.16	9-8-61 10-31-61 6-12-62 7-25-62 9-27-62 12-7-62	1.14 1.68 3.62 1.77 1.10 1.45
Do	do	Lat 37°15′30″, long 86°14′18″, 800 ft above mouth and 9 mi northwest of Mammoth Cave, Ky.	6.10	8-24-61	1.56
Second Creek	do	Lat 37°14′13″, long 86°14′17″, at mouth, 8¼ mi west of Mammoth Cave, Ky.	2.25	8-24-61	[1].5
First Creek	do	Lat 37°13′30″, long 86°13′32″, at point of inflow to First Creek Lake, 7.4 mi west of Mammoth Cave, Ky.		8-24-61	[1].2
First Creek Lake tributary.	First Creek Lake.	Lat 37°13′36″, long 86°13′36″, 100 ft above right bank tributary, 300 ft above mouth and 7.5 mi west of Mammoth Cave, Ky.		8-24-61	0
Do	do	Lat 37°13′35″, long 86°13′37″, 100 ft above mouth and 7.5 mi west of Mammoth Cave, Ky.		8-24-61	[1].1
First Creek	Nolin River	Lat 37°13′28″, long 86°13′41″, at First Creek Lake outlet, 7.5 mi west of Mammoth Cave, Ky.		8-24-61	[1].35
Beaver Dam Creek tributary 1.	Beaver Dam Creek.	Lat 37°07′14″, long 86°10′18″, upstream from springs on right bank, 0.4 mi upstream from mouth, 1.0 mi west of Cedar Spring and 5.2 mi north of Smiths Grove, Ky.		10-31-61	0
Beaver Dam Creek tributary 1 tributary springs.	Beaver Dam Creek tributary 1.	Lat 37°07′15″, long 86°10′18″, 500 ft upstream from mouth of springs' run, 1.0 mi west of Cedar Spring and 5.2 mi north of Smiths Grove, Ky.		10-31-61	.11 .1
Beaver Dam Creek.	Green River	Lat 37°07′01″, long 86°11′10″, at bridge on county road, 1.4 mi southwest of Pig and 4.6 mi north of Smiths Grove, Ky.		10-31-61	[1].2
Beaver Dam Creek tributary 2.	Beaver Dam Creek.	Lat 37°07′38″, long 86°10′48″, at culvert, 0.7 mi southwest of Pig, Ky.		10-31-61	[1].005
Do	do	Lat 37°07′24″, long 86°11′38″, at culvert, 0.5 mi east of Cole School, 1.5 mi southwest of Pig and 5 mi north of Smiths Grove, Ky.		10-31-61	0
Beaver Dam Creek.	Green River	Lat 37°07′19″, long 86°11′48″, at bridge, 0.4 mi southeast of Cole School, 1.7 mi southwest of Pig and 4.8 mi northwest of Smiths Grove, Ky.		10-31-61	.24
Do	do	Lat 37°07′22″, long 86°12′18″, 0.2 mi southwest of Cole School, 2.1 mi southwest of Pig, and 4.9 mi north of Smiths Grove, Ky.		10-31-61	[1].25
Do	do	Lat 37°09′18″, long 86°13′35″, at bridge on StateHighway 101, at Rhoda and 7.2 mi west of Mammoth Cave, Ky.	10.9	9-5-61 10-30-61 6-13-62 7-25-62 8-23-62 9-27-62 12-6-62 4-23-63	1.27 1.06 3.04 .76 .505 .80 1.33 2.06
Beaver Dam Creek tributary.	Beaver Dam Creek.	Lat 37°09′34″, long 86°13′33″, at bridge on State Highway 259 (formerly 65), at Rhoda, 0.3 mi above mouth, and 7.1 mi west of Mammoth Cave, Ky.		9-9-61	[1].01
Beaver Dam Creek.	Green River	Lat 37°09′22″, long 86°13′41″, at Rhoda, 0.15 mi below right bank tributary, and 7.3 mi west of Mammoth Cave, Ky.		9-5-61	.67

[1] Estimated.
[2] Reverse flow.
[3] No surface connection to Green River.

Many streams in the area are wet-weather streams; that is, they carry storm runoff only and are dry most of the time. However, an observation of no flow at one point on a stream does not necessarily mean that the stream does not have flow in it somewhere upstream or downstream. (See below.) Therefore, the results of the reconnaissance made in 1961 are not complete. A complete reconnaissance would necessitate observing each stream channel from the divide to the mouth; however, it is believed that the most important perennial surface flows have been observed. All references to streamflow are under dry-weather conditions.

Wet Prong Buffalo Creek is probably the best potential supply from a small stream. A discussion of the perennial streams and information not included in table 6 follows. Because of its importance Buffalo Creek is discussed first, followed by the remaining small streams.

DESCRIPTION AND DISCHARGE

Buffalo Creek.—Wet and Dry Prongs of Buffalo Creek are aptly named. The flow of several small springs in the Dry Prong Buffalo Creek basin is suitable for small local supplies, but the flow disappears into the streambed at some point downstream. Wet Prong Buffalo Creek is fed by springs in the headwater tributaries. The Wet Prong is a perennial stream to some point between Pigeon Hollow and the confluence with Dry Prong. At the confluence both prongs are dry. Flow from two springs (see table 5) enters Buffalo Creek between the confluence of the two prongs and the mouth of the creek. Presumably the flow that disappeared into the streambed of Wet Prong downstream from Pigeon Hollow reappears in the larger of the two springs tributary to Buffalo Creek. However, the Buffalo Creek tributary springs are near Green River level. Data collected to date indicates that the minimum flow to be expected in Wet Prong is probably about 300,000 gpd. This supply is ample for present or future needs of Mammoth Cave. Most of the drainage area of Wet Prong lies within the park, which will assist pollution control of the watershed. The principal disadvantage of this source is that it is 5 miles from Mammoth Cave and on the north side of the Green River.

Three Sisters Hollow.—The interruption of streamflow is evident in Three Sisters Hollow. On September 7, 1961, no flow was observed in the westernmost tributary and in the main stem throughout its length, but Blair Spring, a tributary of Three Sisters Hollow, was undoubtedly discharging some water that never reached the main stem.

Big Spring Hollow.—The flow of Big Spring Hollow was 1.49 cfs (963,000 gpd) September 8, 1961. However, this flow was from a spring on the right bank of the hollow about 200 feet upstream from the mouth of the hollow. Because the spring is at Green River level and the hollow is on the north side of the Green River, its potential as a source of water supply for Mammoth Cave National Park is negligible.

Ugly Creek.—A small tributary spring of Ugly Creek is near the north boundary of the park. Flow on August 22, 1961, was less than 3,000 gpd. The spring could be used as a small local supply but is too small to be considered for any other purpose. The discharge from the spring disappeared into the streambed at some point upstream from a ford over Ugly Creek, 1.3 miles upstream from its mouth. On September 6, 1961, a discharge of 0.5 cfs (323,000 gpd) was estimated at the mouth of Ugly Creek, but most of this flow was from a spring on the right bank 800 feet upstream from the mouth of Ugly Creek and near Green River level.

Big Hollow.—The flow was 0.025 cfs (16,200 gpd) November 2, 1961, in the headwaters of Big Hollow. This water disappeared into the streambed a short distance downstream, and the streambed was dry from this point to the mouth. This water could be a local source, but the supply is too small and the distance too far to be a source for Mammoth Cave.

Floating Mill Hollow.—Several local people reported the existence of a "large" spring in the upper part of the drainage basin of Floating Mill Hollow. No spring was found except at a point 150 feet upstream from the mouth of the hollow and below Green River flood level; thus its potential as a source of water supply is negligible.

Styx and Echo Rivers.—Discharge measurements made since 1953 are listed in table 5. These streams are discussed on page 631.

Closed basin near Pig.—A closed basin of about 4 square miles northwest of Pig has a well-defined drainage pattern. The runoff from this basin probably enters the Green River through underground passages at or near Turnhole Bend. A total of about 0.5 cfs (323,000 gpd) was estimated in several branches of this tributary about 1 mile northwest of Pig on October 30, 1961. However, this combined flow disappeared into the streambed a short distance downstream, and the tributary was dry from this point to its end at a sinkhole. Its distance from Mammoth Cave (about 5 miles) and its location outside the boundary of the park precludes considering the tributary as a potential source of water supply.

Sal, McCoy, and Dry Hollows.—Small flows were observed at or near the mouths of Sal, McCoy, and Dry Hollows. However, these supplies are below Green River flood level.

Dog Creek.—The drainage area of Dog Creek, a tributary of the Nolin River, lies outside the park to the north. Quantity and quality of the water are satisfactory, but the distance of the tributary from Mammonth Cave and its location outside the park and north of the Green River probably precludes its use for a source of water supply for Mammoth Cave. Results of measurements of flow of Dog and Little Dog Creeks are shown in table 5.

Bylew, First, and Second Creeks.—Three streams—Bylew, First, and Second Creeks—tributary to the Nolin River are perennial, but their distance from Mammoth Cave and proximity to the Nolin River with its larger flow would dictate that the Nolin River be used as a possible source. However, these smaller streams might be used to supply local areas within the undeveloped part of the park. Discharge measurements or estimates are listed in table 5.

Beaver Dam Creek.—Beaver Dam Creek, a tributary of the Green River, is 6–8 miles southwest of Mammoth Cave. It is a perennial stream, but its distance from Mammoth Cave and location outside the park probably preclude its use as a potential source of water supply for Mammoth Cave. See table 5 for results of discharge measurements.

QUALITY

A summary of the chemical quality of water from four of the small streams is given in table 4. Water from the four small creeks is of better quality and very similar to that from Three Springs. Water from Wet Prong Buffalo Creek is soft, and that from the other three small creeks is moderately hard. The small creeks usually are clear except after a storm. These small streams would probably require only chlorination most of the time.

WATER IN ALLUVIUM ADJACENT TO GREEN RIVER

Ground water in the alluvium adjacent to the Green River is a potential source of water supply for Mammoth Cave National Park. However, the permeability and water-yielding capacity of the alluvial material is low, and the potential is probably small. The development of a municipal supply of adequate yield from sand and gravel in the Green River alluvium at Brownsville, about 18 miles downstream from Mammoth Cave, prompted the exploration of this source at Mammoth Cave. Eight exploratory test holes were augered into the alluvial terrace on the bank of the Green River between the Styx and Echo Rivers in October 1961. All test holes were bottomed on resistant material, probably limestone, at depths ranging from 25 to 35 feet below land surface. All penetrated compact yellowish-brown silt and clay but no sand or gravel.

The alluvium in the bed of the river in this area, as at Cave Island upstream from the mouth of Styx River, may be coarser and more permeable, but it was not tested. If found to consist of coarse sand and gravel, this alluvium, which undoubtedly would have hydraulic continuity with the river, could yield substantial supplies of water to properly constructed wells. Development of this source by vertical wells or a horizontal collector well would necessitate that the well be constructed to a level above the highest flood stage of the river.

Water obtained from wells in the alluvium would consist, in part, of water infiltrated from the Green River, and thus would be similar in quality to the river water. Water pumped from the aforementioned well at Brownsville, for example, contains an undesirable concentration of iron and, during the period when the Green River was contaminated by oil-field brines, contained a high concentration of chloride.

GROUND WATER IN BEDROCK

BASAL GROUND WATER

GENERAL CONSIDERATIONS

The basal ground water in the Mammoth Cave area is contained in, and moves through, a thick sequence of limestones, the Ste. Genevieve and St. Louis Limestones. The occurrence of water in these limestones is described in detail by Brown. (See footnote 1, p. 606.)

The storage and movement of ground water in limestone in the Mammoth Cave area is confined to numerous openings along interconnected joints and bedding planes. Most openings have been enlarged by solution, and large quantities of ground water move through them at relatively high velocities. The body of basal ground water, although confined to random openings, is continuous and is controlled by the Green River. The upper surface is continuous with the level of the Green River, and all openings below this level are completely saturated.

Recharge to the basal ground-water body comes from several sources: (1) The sinking streams that drain the surface of the Pennyroyal plain and disappear into sinkholes before they reach the Dripping Springs escarpment, (2) local precipitation on the Mammoth Cave plateau, which moves rapidly downward through sinkholes or vertical shafts or percolates slowly downward along innumerable conduits of different diameters and shapes, and (3) recharge from the Green River in time of flood. No information on the total amount of recharge or the amounts from the several sources is available. Except for the part that is lost by evapotranspiration (about 50 percent), most of the precipitation ultimately reaches the basal water body. Thus, 24 inches of the annual precipitation, or an equivalent of about 420 million gallons per year for each square mile, recharges this body.

Recharge from the Pennyroyal plain is continuous throughout the year and is greatest in the winter. Recharge from the Mammoth Cave plateau is intermittent; it is large in winter but is negligible during the late summer and fall.

The general movement of basal ground water in the area is northwestward from the Pennyroyal plain to the Green River. The water table slopes in this general direction from an altitude of about 570 feet on the Pennyroyal to 420 feet at Green River level. The water probably moves in several large conduits or drains trending generally northwestward. Large conduits probably underlie the Mill Hole-Cedar Sink area and the Mammoth Cave plateau. Their specific location and the location of other large conduits will have to await the results of further exploration and tests. The large conduits are adjoined by numerous smaller cross conduits of many diameters and shapes.

The large and small conduits discharge to the Green River through such springs and underground streams as Pike and Sand Cave Springs and the Echo and Styx Rivers. The magnitude of the low flow from these points of discharge is indicated by flow data of the Echo and Styx Rivers listed in table 5.

DEVELOPMENT

Basal ground water in the Mammoth Cave area can be developed by deep drilled wells or by direct pumping from known large conduits, such as the underground parts of Echo River in Mammoth Cave. The basal ground water in the vicinity of the developed area of the park is contained in the Ste. Genevieve and St. Louis Limestones.

The success of a drilled well depends on its intersecting a trunk conduit or one of the numerous cross conduits at an altitude equivalent to that of the basal water table. The conduits are controlled by the systems of joints and by bedding planes, and their locations are difficult to predict in advance of drilling. In fact, drilling into the larger water-filled conduits requires considerable luck. The few wells in the area of Mammoth Cave plateau that have been drilled to the basal ground water all yielded water, but none yielded significantly large supplies. The test well in Eaton Valley, pumped for 8 hours at an average rate of 36 gpm, is probably the largest-yielding well penetrating the basal water in the plateau area. The well at Bransford Spring was pumped throughout the summer of 1962 at an average rate of 14 gpm. The depth to water is usually great; wells on the Mammoth Cave plateau generally reach water at about 400 feet below land surface.

Basal ground water also can be developed by pumping it directly from known flooded underground passages, such as Echo River in Mammoth Cave and the flooded passage in the lower level of Great Onyx Cave. The dry-weather yield of these sources, if no water is taken from storage, is probably equal to the low-flow data of Echo River and Pike Spring given in table 5. Withdrawals greater than the low flows would be from storage in the submerged passages below the water level. Little is known of the configuration and volume of the submerged parts of the passages, and no estimate can be made of the amount of water in storage, but the amount is probably large. However, withdrawals greater than the low flow at known points of outflow would cause a lowering of the water surface. Such lowering may induce recharge of water from the Green River, which would maintain the yield but would probably change the quality of the water.

QUALITY

Styx River, Echo River, and Pike Springs drain the basal water table at about the same level as the Green River. They become flooded whenever the Green River is in flood, and consequently can yield water that is either basal ground water or Green River water and at times a mixture of the two waters. Sediment concentration, chloride, and pollution depend to a large extent on the stage of the Green River, but these effects are usually diluted by the normal water of the springs. The Green River seems to back up into Pike Spring and Styx River Spring more readily and frequently than into Echo River Spring. The daily analyses of Echo River and Styx River Springs show that the quality of water flowing from Echo River Spring is not influenced by the Green River nearly as much as the other two springs. A summary of the quality of water from the three springs is shown in table 6. With the improvement in quality of the Green River water, the three springs are acceptable sources of water. Echo River Spring, however, is the best of the three. In Mammoth Cave, suspended-sediment concentrations are usually less than 20 ppm at low flows of the Green River. At higher flows concentrations of 40 ppm have been measured several times, and much higher concentrations probably occur.

The chemical quality of water from wells tapping the basal ground-water body generally is similar to that from Echo, Styx, or Pike Springs when the latter are draining into the Green River (see table 7). Because the wells tap the basal water distant from the Green River, the chemical quality and turbidity are not affected by Green River flooding. However, the water from the Eaton Valley well (table 7), is of poor and contrastingly different quality from the average quality of the basal ground water. This well was drilled considerably

TABLE 6.—*Chemical quality of Styx River, Echo River, and Pike Springs*

[Chemical analyses in parts per million]

Concentration	Period of record				July-September data only			
	Iron	Chloride	Hard-ness	pH	Iron	Chloride	Hard-ness	pH
Styx River Spring, Nov. 3, 1958–Sept. 27, 1962								
Maximum	1.5	550	294	8.1	0.36	185	194	8.1
Minimum	.01	1.0	89	6.9	.01	7.0	120	7.0
Average	.21	64	144	------	.18	61	156	------
Mode	.14	38	135	7.3	.15	38	152	7.2
Median	.11	48	139	7.3	.16	50	159	7.2
Number of analyses	58	608	72	72	19	111	19	19
Echo River Spring, Aug. 29, 1955–Sept. 29, 1962								
Maximum	0.88	740	200	8.3	0.50	442	153	7.8
Minimum	.00	.5	86	6.8	.01	.5	110	6.8
Average	.13	18	125	------	.13	20	131	------
Mode	.08	5.9	134	7.5	.08	8.1	136	7.4
Median	.09	6.0	122	7.4	.10	10	133	7.4
Number of analyses	70	721	78	77	22	138	22	22
Pike Spring, May 19, 1959–Sept. 21, 1962								
Maximum	1.7	200	136	8.2	------	------	------	------
Minimum	.04	1.5	111	7.1	------	------	------	------
Average	.6	44	123	------	------	------	------	------
Mode	------	------	------	------	------	------	------	------
Median	------	6.0	------	------	------	------	------	------
Number of analyses	3	7	4	4	------	------	------	------

below the basal water table in an effort to increase its yield. It is believed that it penetrated deeper water of a poorer quality, and that this water is now moving upward in the bore and mixing with the upper basal ground water. To insure that it will yield good quality basal ground water, a well should not be drilled more than 20 to 30 feet below the basal water table in the Mammoth Cave area.

PERCHED GROUND WATER IN BEDROCK

The geology and topography of the Mammoth Cave plateau area combine to create conditions favorable to the formation of several zones of perched ground water. These zones are: (1) a generally continuous body of ground water in the Haney Limestone Member of the Golconda Formation (fig. 73) perched above shale beds in the lower part of the Haney, (2) a generally continuous body of ground water in the Big Clifty Sandstone Member of the Golconda Formation perched above a shale at the base of the Big Clifty, and (3) discontinuous bodies of ground water perched above local shale beds near the top of the Girkin Formation.

PERCHED GROUND WATER IN HANEY LIMESTONE MEMBER OF THE GOLCONDA FORMATION ON FLINT RIDGE

The following discussion is concerned only with the occurrence of perched ground water in the Haney Limestone Member of the Golconda Formation on Flint Ridge. Similar conditions may occur elsewhere, as east of Rhoda and north of the Green River, but all are distant from the area of present use.

GENERAL CONSIDERATIONS

The Haney Limestone Member and the overlying Hardinsburg Sandstone and the underlying Big Clifty Sandstone Member are the so-called caprocks that form Flint Ridge. The thick Big Clifty forms the cliffs around the margin of Flint Ridge. The Haney, only about 40 feet thick in this area, is exposed in places above the Big Clifty along the margin of the ridge at an altitude of about 740–760 feet. The caprocks are broken by numerous joints. The openings along joints in the Hardinsburg Sandstone and Big Clifty Sandstone Member are small. The openings along joints in the Haney are enlarged by solution, and the limestone is cavernous.

Almost all the precipitation on Flint Ridge either sinks into the permeable surface rocks or runs off in short intermittent streams to the edge of the ridge and is diverted downward in underground drainage channels in the Girkin Formation to the basal water table. Probably more than 50 percent of the precipitation is disposed of in this manner; the remainder is evaporated or transpired. Water penetrating the permeable surface rocks on Flint Ridge moves downward until it reaches the relatively impermeable shale at the base of the Haney Limestone Member and then moves laterally in solution channels in the limestone to emerge as seeps or springs along the margin of the ridge. This outflow also sinks to the basal water table via the solution channels in the Girkin Formation. Some of the lateral flow probably never appears at the surface along the margin but is abruptly diverted downward in places where the impermeable shale is breached by joints.

The solution openings in the Haney may have considerable reservoir capacity, and thus may sustain the flow of the visible springs during dry periods longer than those previously experienced. Several test wells drilled in April 1961 on the surface of Flint Ridge to the base of the Haney penetrated a body of ground water, the upper surface of which was in the overlying Hardinsburg Sandstone. Thus, at these locations in April 1961 the Haney Limestone Member was completely saturated. At the lowest observed decline of this water surface in October 1962, about 20 feet of the Haney was saturated.

TABLE 7.—*Chemical analyses of water from wells and springs, Mammoth Cave National Park*

[Dissolved constituents given in parts per million]

Date	Temperature (° F)	Iron (Fe)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25° C)	pH	Remarks
Perched water in Haney Limestone Member												
Three Springs												
Oct. 4, 1957		0.04	126	4.6	3.0	0.1	0.5	99	0	201	7.5	Clear when collected.
Feb. 20, 1958		.09	55	1.4	4.0	.2	.4	37	0	93	8.2	Do.
Feb. 2, 1959	48		48	2.0	1.0	.0	.1	40	1	87	7.1	Do.
Mar. 4	55	.06	27	.0	2.0	.1	.2	23	1	52	6.7	Do.
Oct. 29	56	.07	114	2.8	2.0	.1	.6	93	0	195	7.3	Do.
Mar. 3, 1960	54	.10	30	2.4	2.0	.1	.3	25	1	58	6.8	Do.
Oct. 13	57	.08	115	1.2	2.0	.1	.8	96	2	197	7.5	Do.
Jan. 11, 1961	54	.16	48	4.8	2.0	.1	.3	41	2	93	6.9	Do.
Feb. 6		.05	44	3.2	1.5	.1	.1	34	0	77	6.8	Do.
Mar. 9	53	.04	23	4.4	.5	.1	1.3	20	1	53	6.5	Do.
Apr. 4	54	.03	24	6.2	3.5	.1	.0	21	2	50	7.3	Do.
May 4	54	.05	25	6.0	2.0	.1	.1	25	4	51	6.6	Do.
May 31	55	.17	59	2.8	2.0	.1	.4	46	0	103	6.9	Do.
June 27	55	.11	59	2.6	2.0	.0	.4	49	1	106	6.9	Do.
July 25	56	.09	73	2.4	2.0	.1	.5	59	0	124	7.0	Do.
Aug. 30	57	3.6	102	5.4	2.0	.1	2.8	85	2	183	6.9	Do.
Sept. 27	56	.10	106	3.6	2.0	.1	.8	86	0	179	7.3	Do.
Feb. 26, 1962	49	.00	40	8.6	1.0	.0	.6	32	0	71	7.3	Clear, sediment when collected.
May 8	56	.05	49	4.8	1.0	.1	.4	42	2	89	6.9	Clear when collected.
Bransford Spring												
Feb. 20, 1958		.07	64	1.8	2.0	.2	.6	48	0	104	8.3	Do.
Feb. 26, 1962	46	.02	28	6.6	2.0	.0	1.1	22	0	51	7.3	Do.
Blair Spring												
Jan. 31, 1962	47	.02	30	4.5	3.0	.0	3.3	26	2	63	7.0	Do.
Feb. 27	52	.00	22	5.8	2.0	.0	.5	18	0	41	6.9	Do.
Cooper Spring												
July 3, 1962	59	.00	86	.0	2.0	.0	.6	67	0	138	7.5	Do.

Adwell Spring												
Jan. 31, 1962	49	.00	50	4.1	2.0	.0	.6	36	0	85	7.3	Do.
Feb. 27	51	.00	32	3.7	3.0	.0	.8	26	0	60	7.2	Clear, sand when collected.
May 3	60	.00	54	2.0	3.0	.0	.3	42	0	95	7.3	Clear when collected.
July 3	61	.05	72	2.9	6.0	.0	1.0	60	1	137	7.4	Do.
Flint Ridge test well 2												
May 7, 1962	56	.00	96	6.4	3.0	.0	.3	73	0	169	6.7	Slightly turbid when collected.
Flint Ridge test well 4												
May 7, 1962	55	.38	112	2.5	3.0	.0	.2	90	0	188	7.0	Do.
Basal ground water												
Bransford well												
Oct. 7, 1959	----	----	----	----	9.0	----	----	176	----	351	----	
Oct. 14	----	----	----	----	9.6	----	----	----	----	637	----	
May 13, 1961	----	1.2	170	1,390	2.0	0.3	0.4	1,540	1,400	2,190	7.5	Clear when collected.
July 3, 1962	62	.02	120	202	4.0	1.2	.4	265	166	590	7.7	Do.
Crystal Cave well												
Oct. 19, 1961	58	1.1	138	45	3.0	.6	2.6	148	35	299	7.3	Clear, sediment when collected.
Apr. 16, 1962	----	.03	84	45	3.0	.8	5.8	115	46	248	7.0	Muddy, when collected.
Well at CCC No. 2												
Apr. 7, 1959	----	1.0	156	44	2.0	1.4	.1	166	38	329	7.3	Oil globules when collected.
Eaton Valley well												
July 20, 1961	----	.97	138	626	95	3.2	1.1	737	624	1,510	7.7	Turbid, dark when collected.
Pike Spring												
May 19, 1959	55	----	126	8.4	1.5	----	----	111	8	214	8.0	
Oct. 14	57	----	----	----	47	----	----	----	----	391	----	Turbid when collected.
Feb. 18, 1960	54	----	----	----	6.0	----	----	----	----	206	----	
June 29	60	1.7	108	10	50	.2	3.3	118	30	374	7.1	Turbid, muddy when collected.
Sept. 21	58	----	----	----	200	----	----	----	----	902	----	Clear when collected.
Oct. 5, 1961	55	.04	160	5.6	2.5	.2	2.0	136	5	286	7.5	Do.
Sept. 21, 1962	56	.06	134	13	4.0	.1	2.4	126	16	254	8.2	Slightly turbid when collected.
Spring in Cedar Sink												
Oct. 9, 1962	58	.11	174	10	15	.2	4.0	170	28	350	7.8	Turbid when collected.

Part of the outflow probably emerges as slow seepage, along the margin of the ridge at the outcrop of the lower part of the Haney Limestone Member and is rarely seen. However, part of the outflow emerges as visible springs having flows ranging from several hundred gallons per minute in early spring to less than 10 gpm in late fall. Seven such springs are known on Flint Ridge. In addition to the springs already mentioned in the section on present water supply (Three Springs and Bransford, Blair, and Adwell Springs), there are also Cooper and Collins Springs and a spring at CCC No. 1. Typically, these springs emerge from small caverns in the Haney at the head of deep reentrants on the sides of Flint Ridge, flow down the surface of the Big Clifty Sandstone Member for short distances, and sink into openings in the surface.

DEVELOPMENT

The perched ground water in the Haney Limestone Member can be developed by collecting the flow from the seven springs, as has been done in part, or by means of wells drilled from the top of the ridge to solution channels near the base of the limestone.

The flow of CCC No. 1 Spring is small, 4 gpm or less, and the flow of Bransford and Blair Springs decreases to 7 gpm or less near the end of the dry season. The flow of the rest of the springs is remarkably similar, the dry-weather flow being about 14–16 gpm. The graph of the flow of a typical spring is shown in figure 78. All observed flows from the seven springs are furnished the Park Service in monthly reports. Minimum flows during the critical period in August 1962 and minimum observed flows of all springs are summarized in the following table.

Spring(s)	Minimum flow during August 1962 (gpm)	Minimum flow observed	
		Gpm	Date
			1962
Three	15	12	Sept. 20.
Bransford	10	7	Oct. 21.
Blair	6	6	Sept. 6, 20.
Adwell	20	18	Sept. 20; Oct. 25, 31; Nov. 8.
Cooper	14	11	Nov. 8.
Collins	20	13.5	Nov. 8.
CCC No. 1	3	3	Numerous.
Total	88	70.5	

During the critical week of August 19–25, 1962, the developed supply of 45 gpm, or 64,800 gpd (includes Bransford well), could have been supplemented by an additional flow of 57 gpm or 82,000 gpd, had the minimum August flow of the additional springs been utilized. If it is assumed that the minimum flows observed later in 1962 represent the August flows of an extremely dry year, this supplemental supply

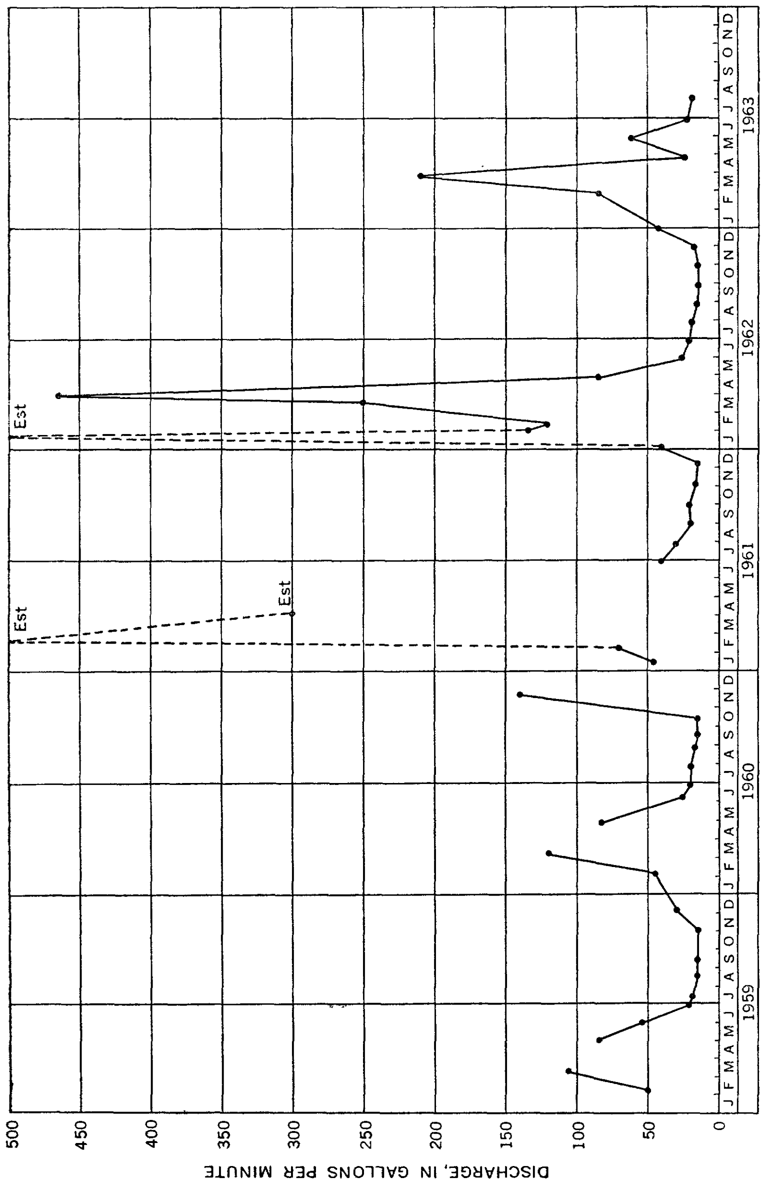


FIGURE 78.—The flow of Three Springs, Mammoth Cave National Park, is lowest in September and October.

would be reduced by 11.5 gpm to a supply of 45.5 gpm, or 65,500 gpd. Thus, during an extreme year, if the flow of the seven springs were collected and Bransford well were pumped 24 hours per day, the total available supply in August would be 84.5 gpm, or 121,700 gpd.

It is possible that the flow of one or more springs could be diverted or captured by natural means and the spring dried up. An enlargement of an underground opening by solution or a slight shifting and opening of a previously tight joint could cause this change. However, the chance of this happening is remote, and long-time residents remember that these springs have always flowed at their present locations.

Wells drilled to water-bearing solution channels in the limestone from the top of Flint Ridge are a potential means of developing the perched water. The test wells drilled in April 1961 provide information on the feasibility of this method of development. Because the solution channels are controlled by joints, one might assume that the flow of water would be concentrated along these channels and could not be found elsewhere. Of the four test wells, all penetrated solution channels in the limestone immediately below the base of the Hardinsburg Sandstone, and all but one channel contained water. The yield from these wells was small, less than 10 gpm, and all wells had difficulty with sand and silt particles washing out from the channels or caving from the bottom of the Hardinsburg Sandstone. Thus, it is probable that ground water in the Haney Limestone Member would be difficult to obtain in sufficient quantity to be useful as a supply. Wells too close to existing springs might decrease the flow of the springs if pumped heavily.

QUALITY

Perched ground water in the Haney has the best quality and is the most suitable for use of all water in the Mammoth Cave area.

The chemical quality of 37 samples of water from Three Springs obtained during the period October 1954–May 1962 is summarized in the following table. Analyses are shown in table 7.

Concentration	Iron (ppm)	Chloride (ppm)	Hardness (as $CaCO_3$) ppm	pH	Specific conductance (micromhos)
Maximum	3.6	7.0	100	8.2	203
Minimum	.00	.0	20	6.3	50
Average	.20	2.1	56	----------	124
Mode	.06	2.6	36	7.4	89
Median	.08	2.0	49	7.2	111

Water from Adwell, Bransford, Blair, Collins and Cooper Springs, and the spring at CCC No. 1 is similar in quality to water from Three Springs. Water from most of the springs seems to have a low iron content, but this may not always be true because all water shows some variation in quality.

PERCHED GROUND WATER IN BIG CLIFTY SANDSTONE MEMBER OF THE GOLCONDA FORMATION AND GIRKIN FORMATION

A potential water supply is contained in a continuous body of ground water in the Big Clifty Sandstone Member and in discontinuous bodies in the underlying Girkin Formation.

GENERAL CONSIDERATIONS

The Big Clifty Sandstone Member caps a major part of the Mammoth Cave plateau and crops out in many places on the surface of the plateau and along the sides of many of the valleys. On Flint Ridge it is overlain by beds of shale, limestone, and sandstone. Where the Big Clifty is the surface rock, it absorbs large amounts of water from precipitation through pore spaces and openings along numerous joints. Where it is overlain by other rocks on Flint Ridge, the Big Clifty is largely protected from water infiltration and probably receives water only where the overlying rocks are breached by joints, principally near the margin of the ridge.

Percolating water from precipitation moves downward to the relatively impermeable shale at the base of the sandstone. A perched body of ground water which is nearly continuous throughout the formation is supported in the sandstone by this shale. Part of the water drains laterally to points of discharge along the sides of valleys and the Dripping Springs escarpment, and part drains downward and recharges the Girkin Formation where the shale bed is locally absent or where it is broken by joints. In the Girkin Formation water flows downward through solution channels of different sizes and shapes to the basal water table. In some places this water is perched in small solution depressions or above local thin beds of shale.

DEVELOPMENT

Perched water in the Big Clifty Sandstone Member and the Girkin Formation is developed by drilled wells; some water in the Big Clifty is obtained by dug wells. Most wells on the Mammoth Cave plateau obtain water from the Big Clifty. The depth from the surface to the water table in the perched body of water in the sandstone ranges from about 2 to 20 feet. Yields of wells are not large but are reported to be adequate for domestic use. Dug wells 2 to 3 feet in diameter yield adequate quantities for domestic and stock use.

Wells drilled into the Girkin Formation obtain small supplies of water at numerous levels. Water levels in these wells change rapidly with heavy rains and dry spells, and some wells go dry. In some wells the water supply may be only a gallon or two a day; in others it may, with normal precipitation, be adequate for a domestic supply, although it will likely fail in dry summers. Commonly, none of the perched water bodies in the Girkin Formation are adequate for year-round domestic supplies with pressure systems installed.

QUALITY

The chemical quality of water from the Big Clifty Sandstone Member is suitable for most uses. It is soft and slightly acid but sometimes contains objectionable amounts of iron. Because of its widespread occurrence at the surface, water in the Big Clifty is subject to pollution from barnyard and other agricultural wastes. No samples of water were taken from wells obtaining water exclusively from the Girkin Formation. The water is probably similar in quality to that from the Haney Limestone Member, but it may be harder.

EVALUATION OF POTENTIAL SOURCES

The purpose of this report is to evaluate the hydrology of alternative sources of water supply for the National Park Service. To evaluate the several potential sources of water, it is necessary to have a figure of water demand as a yardstick. A maximum daily demand of 250,000 gallons during the period June–September is probably a reasonable yardstick to use if the projected growth to 1980 is considered. The sources are discussed in approximate order of value as potential sources of water supply for Mammoth Cave.

GREEN RIVER

The Green River is the largest source of water available. The supply is more than enough for any future needs of Mammoth Cave National Park. The chemical quality is now suitable with normal treatment of surface-water supplies. Construction of Green River Reservoir will increase the quantity and improve the chemical quality of low flows.

Use of this source will necessitate an intake structure, treatment plant, and high pump lift (350–450 ft). The principal disadvantage of the use of Green River water is the possibility of renewed pollution by oil-field brine. As an insurance against this possibility, Green River water could be used to augment the present supply. In this event, the intake structure should probably be constructed near Great Onyx Cave and a pipeline (6,000–8,000 ft) run from this point to the reservoir at Bransford Spring or to the existing storage tanks on Flint Ridge. As added insurance, a remote-recording specific-conductance meter might be installed at the gaging station at Munfordville. This would provide operating personnel with advance warning of a change of chemical quality of Green River water that might be attributed to brine pollution.

NOLIN RIVER

The Nolin River is the second largest source of water available. Its water is moderately hard to very hard but well within the limits of drinking-water standards. Use of this source would necessitate a long pipeline, an intake structure, treatment plant, and high pump lift (350–450 ft). The chief disadvantage of this source is the length of the pipeline (about 8 miles).

PERCHED WATER IN HANEY LIMESTONE MEMBER OF THE GOLCONDA FORMATION

The existing water supply for Mammoth Cave is obtained from springs draining a perched aquifer in the Haney Limestone Member on Flint Ridge and a deep well at Bransford Spring. There are several additional springs draining this aquifer that could be incorporated into the present water-supply system.

The Haney is the best source of good quality water supply for Mammoth Cave now and in the near future. The chemical quality, except for Bransford well, is excellent, and the fact that the recharge area for the perched aquifer lies mostly within park boundaries facilitates pollution control.

The main disadvantage of this source as the ultimate supply for the park is the quantity available. The minimum total flow of all the known springs and Bransford well during the critical period in July–August 1962 was 102 gpm, or 147,000 gpd, and occurred on August 22, 1962. However, the absolute minimum total flow observed was 84.5 gpm, or 122,000 gpd, on November 8, 1962, and occurred after the end of the critical period. The average weekly measurement of flow of the springs plus Bransford well for the period May 29–September 6, 1962, was 137 gpm, or 197,000 gpd.

The deficiency in quantity can be overcome by storage. Table 8 shows observed or estimated flows for known springs on Flint Ridge and Bransford well and the surplus or deficiency for several demands. The observations were made every 7 or 8 days during the 100-day period, May 29–September 6, 1962. This represents a good study period for three reasons, namely: (1) The weekly observations give a good estimate of the available flow, (2) the period includes a drought that has a recurrence interval of about 12 years, and (3) the greatest use of water at Mammoth Cave is during the period from Memorial Day to Labor Day.

The data in table 8 were used to compile the storage requirements given in table 9 for indicated demands ranging from 50,000 gpd to 250,000 gpd. Part of these computations are illustrated graphically in figures 79, 80, and 81.

TABLE 8.—*Observed weekly flows of Flint Ridge springs and Bransford well and surplus or deficiency for several demands during June–September 1962*

[Data in gallons per minute]

Date	Three Springs	Bransford Spring	Blair Spring	Cooper Spring	Adwell Spring	Collins Spring	Spring at CCC No. 1	Total	Bransford well	Total	Surplus (+) or deficiency (−) based on a demand of— 150,000 gpd (104 gpm)	200,000 gpd (139 gpm)	250,000 gpd (174 gpm)
May 29	26	18	13	26	37	[1] 34	[2] 6	160	14	174	+70	+35	0
June 5	28	22	13	28	40	[1] 36	[2] 7	174	14	188	+84	+49	+14
12	24	21	13	26	40	[1] 36	[2] 7	167	14	181	+77	+42	+7
19	25	[3] 18	16	26	37	[1] 34	[2] 6	162	14	176	+72	+37	+2
26	21	14	13	26	34	31	[2] 6	145	14	159	+55	+20	−15
July 3	20	[3] 14	13	26	34	31	[2] 6	144	14	158	+54	+19	−16
10	21	[3] 15	9	18	26	23	4	116	14	130	+26	−9	−44
18	21	[3] 15	7	16	23	23	[2] 4	109	14	123	+19	−16	−51
25	18	[3] 12	[2] 7	16	23	23	4	103	14	117	+13	−22	−57
Aug. 1	17	[3] 12	[2] 7	16	23	23	[2] 4	102	14	116	+12	−23	−58
8	17	[3] 12	[2] 7	16	23	20	4	99	14	113	+9	−26	−61
15	15	[3] 10	[2] 6	16	20	20	3	90	14	104	0	−35	−70
22	15	[3] 10	[2] 6	14	20	20	3	88	14	102	−2	−37	−72
29	15	[3] 10	[2] 6	16	20	20	3	90	14	104	0	−35	−70
Sept. 6	15	[3] 10	6	16	20	20	3	90	14	104	0	−35	−70
Average flow — gallons per minute								123	14	137			
gallons per day								177,000	20,000	197,000			

[1] Estimated from comparison with flow of Adwell Spring.
[2] Estimated.
[3] Estimated from comparison with flow of Three Springs.

TABLE 9.—*Storage needed for selected supplies based on 100-day period, May 29–Sept. 6, 1962*

Supply	Storage required (million gals) based on demand (gpd) of—				
	50,000	100,000	150,000	200,000	250,000
Present supply: Three Springs, Bransford Spring, and Bransford well	0	3.09	8.09	13.09	18.09
Present supply plus Adwell and Blair Springs	0	.10	2.93	7.72	12.72
Present supply plus Adwell, Blair, Cooper, and Collins Springs, and a spring at CCC No. 1	0	0	.03	2.24	5.65

The computed figures do not provide a factor of safety for equipment breakdown, losses by evaporation, leakage, or a bailer-water line, or an unusual demand such as might be required for a fire.

SMALL STREAMS

Wet Prong Buffalo Creek is the best of the several small-stream supplies in the vicinity of Mammoth Cave. The advantages of this source are good chemical quality, adequate supply (minimum probably about 300,000 gpd), and location of most of the watershed in the park for control of pollution. Disadvantages of this source are distance from park headquarters (about 5 miles) and the necessity for normal treatment of surface water.

BASAL GROUND WATER

Not enough is known about the recharge, movement, and discharge of the basal ground water to evaluate it properly as a potential supply. Development of the source by means of deep drilled wells appears to have low potential because of the low yields to existing wells and the difficulty of predicting the location of trunk conduits in advance of drilling. Development by pumping from known trunk conduits, such as the underground parts of Echo River in Mammoth Cave or Pike Spring in Great Onyx Cave, has a greater potential, however. If the withdrawal is made relatively close to the Green River the greatest yields during the low-flow period, with no depletion of ground-water storage, would probably be equal to the observed low flows of Echo River (162,000 gpd) and Pike Spring (1,250,000 gpd). Larger withdrawals during the low-flow period would decrease the storage, and thus cause a decline in water levels in the underground streams and an inflow of water from the Green River. The quality of the basal ground water is suitable with the normal treatment of surface-water supplies.

The chief disadvantages of the basal ground water as a potential source, in addition to the uncertainty of its yield, are the possibility

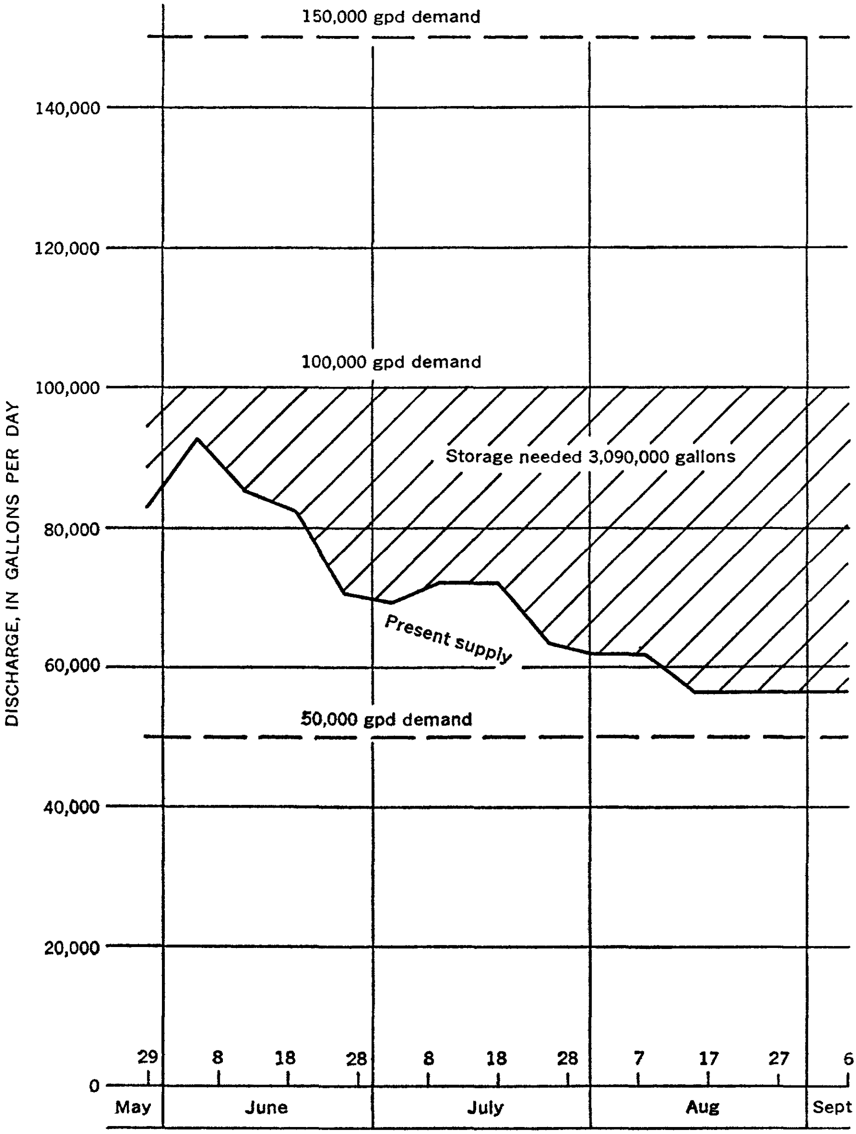


FIGURE 79.—Comparison of present water supply (Three Springs, Bransford Spring, and Bransford well) for 100-day period, May 29–Sept. 6, 1962, with indicated demands.

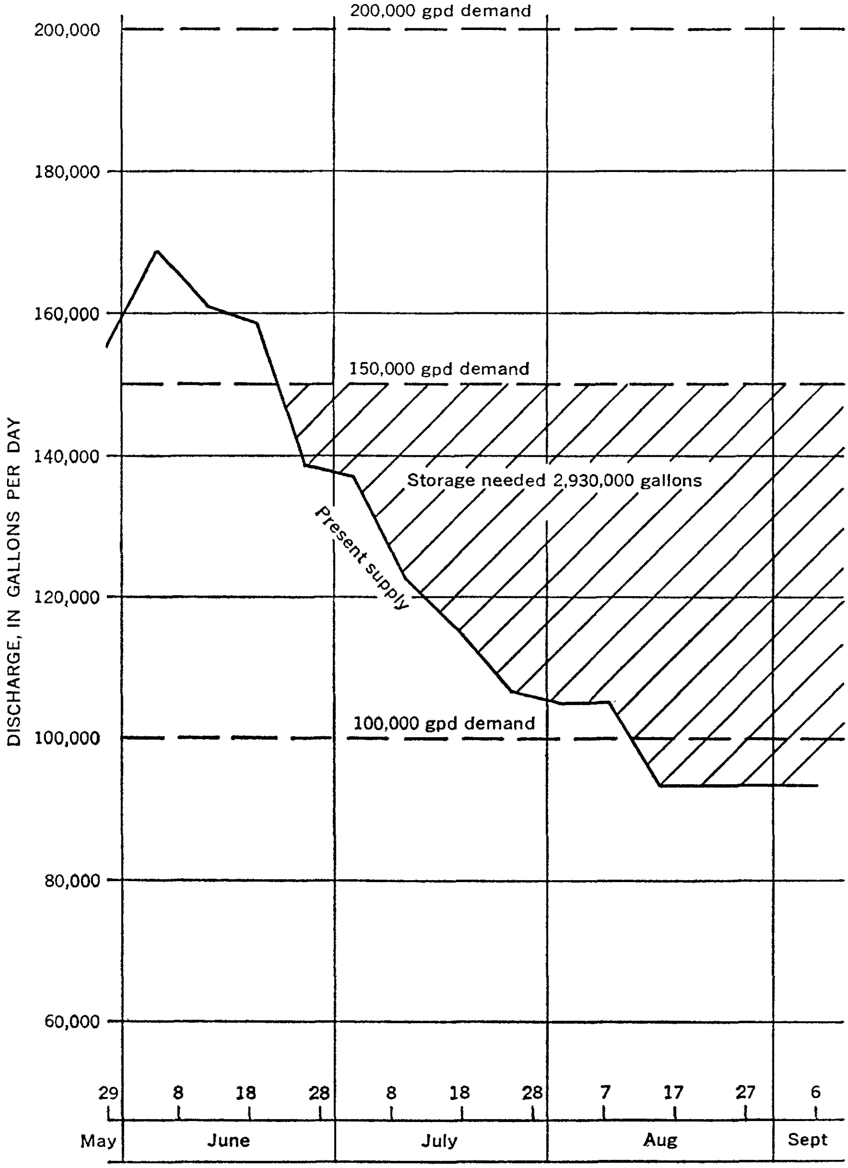


Figure 80.—Comparison of present water supply plus Blair and Adwell Springs for 100-day period, May 29–Sept. 6, 1962, with indicated demands.

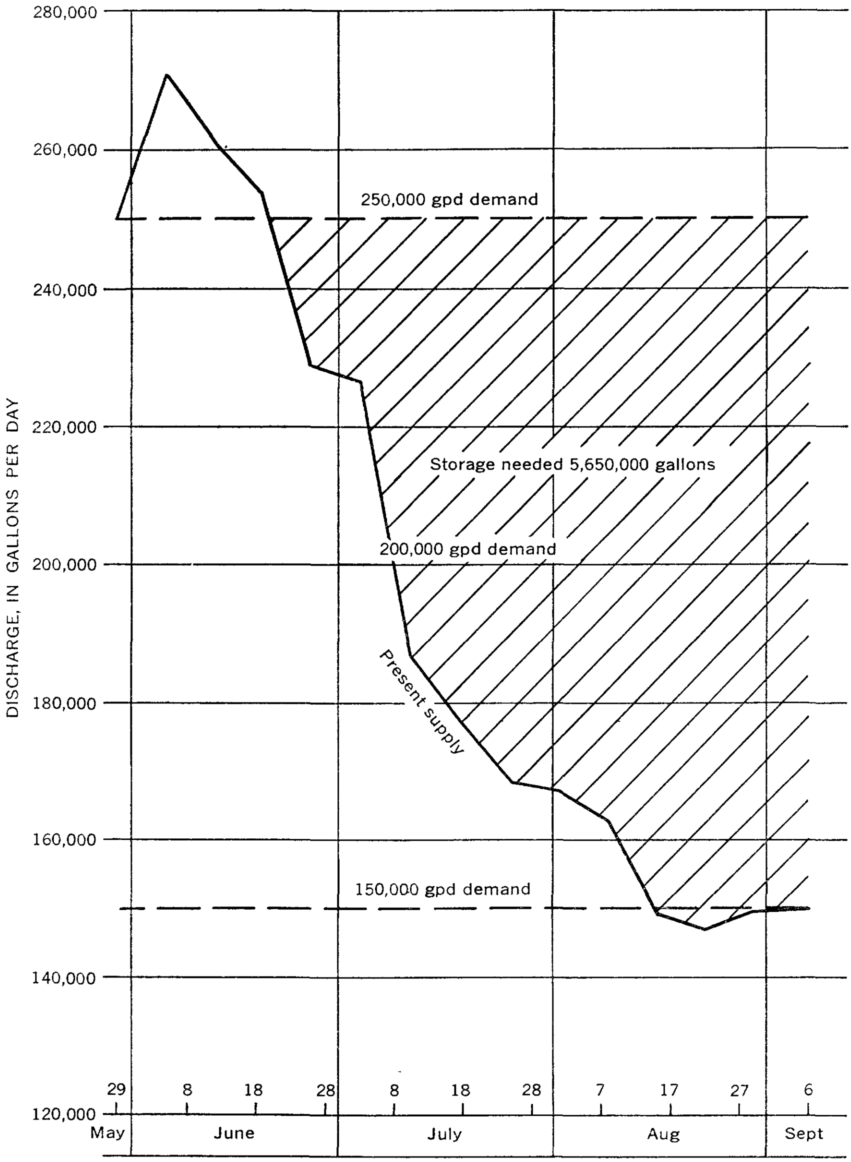


FIGURE 81.—Comparison of total known water supply on Flint Ridge for 100-day period, May 29–Sept. 6, 1962, with indicated demands.

of pollution by oil-field brine from the Green River, the high pump lift, and the difficulty of introducing the water into the present water system. Use of this source would require a treatment plant and probably a long pipeline to the reservoirs on Flint Ridge. Basal ground water might be developed as an auxiliary supply for periods of peak demand or low flow, however.

WATER IN ALLUVIUM ADJACENT TO THE GREEN RIVER

Based on available data, the alluvium adjacent to the Green River at Mammoth Cave has little potential as a water supply owing to low yield. Possibilities of better yields exist upstream from the Styx River, but the yields have not been tested. However, the water would be similar in quality to Green River water, and thus offers no advantage over the use of Green River water.

PERCHED WATER IN BIG CLIFTY SANDSTONE MEMBER OF THE GOLCONDA FORMATION AND GIRKIN FORMATION

Based on available data, perched water in the Big Clifty Sandstone Member of the Golconda Formation and the Girkin Formation has little potential as a water supply owing to its low yield.

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UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

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[The letters in parentheses preceding the titles designate separately published chapters]