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EVALUATION OF A SELECTED SITE FOR A PROPOSED JOPLIN WATER SUPPLY RESERVOIR ON BAYNHAM BRANCH

ADDENDUM 1 TO DECEMBER 29, 2020 REPORT

April 2, 2021

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A contract investigation conducted by the Ozark Underground Laboratory, Inc.

for Glenn Brown, Diamond, MO.

Purpose

This addendum provides additional hydrologic information on the magnitude of subsurface leakage from the planned Baynham Branch Reservoir. Rainfall during March 2021 increased the depth of water in the channel of Baynham Branch by approximately 5 to 7 feet. As expected, this greatly increased the rate of water leakage out of the proposed reservoir area. As shown by three dye traces this leakage discharges from a group of springs that we initially called the "Hunley Springs Complex". Since our report of December 29, 2020 we have learned that the owners of the springs prefer to call them "Harris Family Property Springs". We will use this preferred name in this report. Lake Spring is the largest of these springs.

The HFP Springs

Tracer dyes were introduced at three different losing stream segments in the Baynham Branch Watershed that lie within the planned impoundment area for the Missouri American Water Company's (MAWC) Joplin Water Supply Reservoir. These dye traces proved that the HFP Springs are the principal discharge points for groundwater leaking from the planned reservoir area.

Figure 1 shows the location of the dam and reservoir planned by MAWC. The flooded area is based on an elevation of 1051 feet; this was the planned normal pool elevation identified in the document MAWC submitted to regulatory agencies in February 2019. A copy of that document was included as Appendix A in the Ozark Underground Laboratory (OUL) report of December 29, 2020. The stream channels shown in red in Figure 1 are losing streams segments identified by the OUL. The OUL introduced tracer dyes into all three losing stream segments; dye introductions were:

- Eosine dye into the upstream main channel of Baynham Branch.
- Rhodamine WT dye into the major southern tributary to Baynham Branch.
- Fluorescein dye into the downstream main channel of Baynham Branch downstream of Lime Kiln Road.

All three of the tracer dyes were detected in multiple carbon samplers and water samples from the HFP springs. Eosine was detected in 28 samples; rhodamine WT in 83 samples, and fluorescein in 53 samples from these springs.

The large blue arrow in Figure 1 is based on dye tracing results and flow rate measurements. It diagrammatically shows that massive underground water leakage from the floor and sides of the planned reservoir will bypass the dam and discharge from the HFP Springs. As demonstrated by OUL streamflow measurements, leakage through groundwater occurs at multiple points.

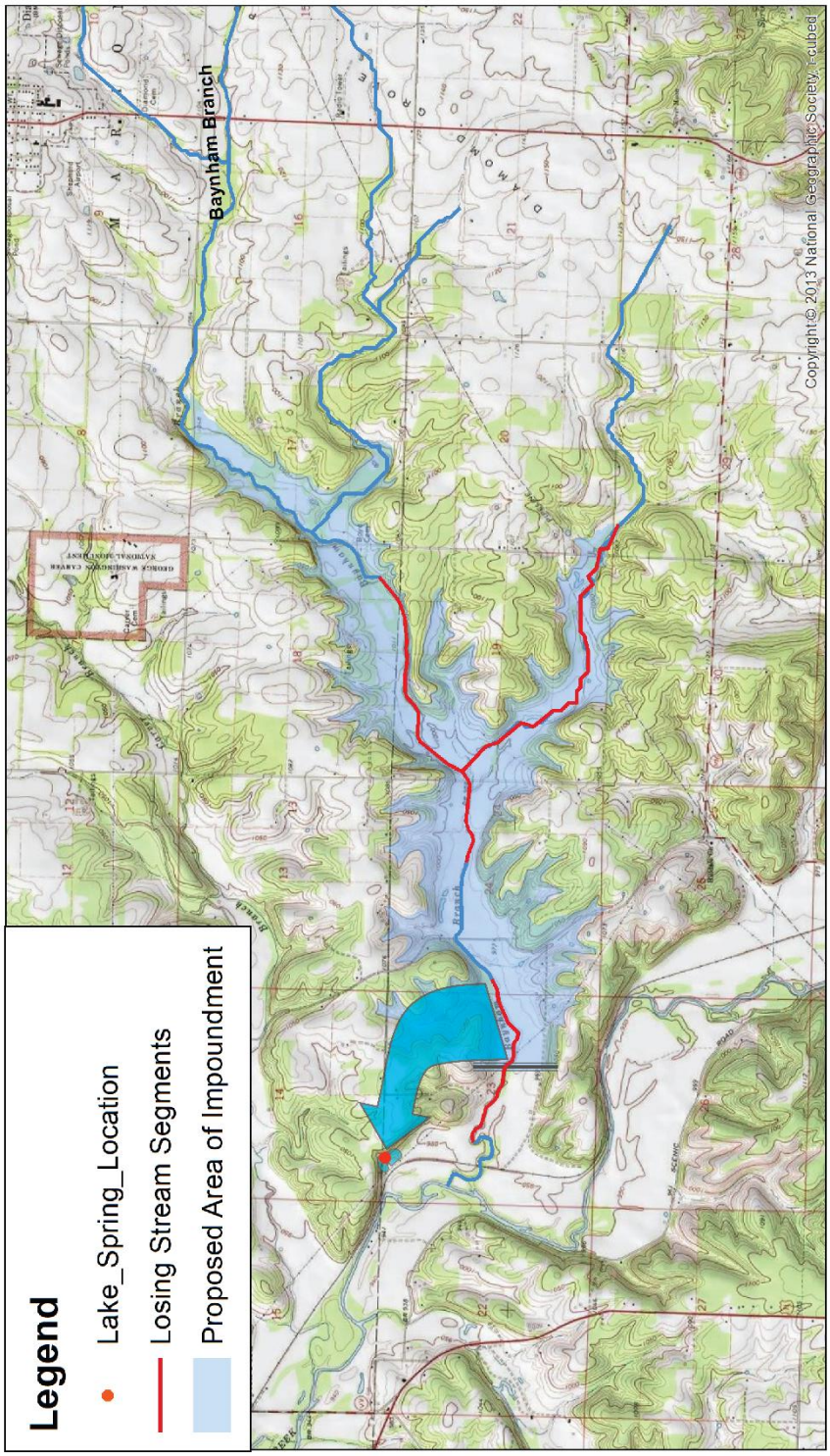

Figure 1. The blue arrow diagrammatically shows that massive groundwater leakage from the floor and sides of the planned reservoir will bypass the planned dam and discharge from the HFP Springs. Validity of the diagram is proven by OUL groundwater tracing and flow rate measurements.

MAWC was provided with a copy of the OUL report of December 29, 2020 and had over a month to review it. The report clearly showed that the planned reservoir would experience massive leakage. The MAWC response, in a letter to Mr. Glenn Brown of Diamond and signed by Mr. Jeffrey T. Kaiser, Director of Engineering, Vice President of Operations, was that the dye testing results were inconclusive. One hundred and sixty four positive dye detections with multiple sample concentrations that were hundreds to thousands of times greater than the instrumental detection limits are clearly not inconclusive. No rationale was offered by MAWC for adopting this obviously false conclusion. It is unfortunately rather clear that MAWC plans to build the reservoir even if it will not be capable of supplying Joplin with water during dry weather periods when additional water supplies are needed. It will be rate payers in Joplin (rather than MAWC) who will ultimately pay for the project regardless of whether it works or not.

The largest of the HFP Springs (Lake Spring) discharges beneath the surface of a 3.2 acre lake on the Harris Family property and is the primary source of water for this lake. **Figure 2** is an aerial photograph of the lake. The spring that feeds the lake is located near the north shore of the lake at a point northeast of the peninsula that extends into the lake. Discharge from the lake is through a 3-foot diameter culvert at the western margin of the lake. A second spring rises at the base of the bluff and north of the drainage pipe from the lake. Additional springs are in the spring fed drainageway south of the lake. All of the springs have year-around flow. The combined flows from the HFP Springs discharges to Shoal Creek about 100 feet west of the western edge of Figure 2. The OUL has installed flow monitoring equipment at Lake Spring and in the spring-fed drainageway south of the lake.

Rating Table for Lake Spring

Figure 3 shows the lake's discharge pipe, staff gage, and installed transducer that records water depths every 10 minutes. Based on calculated flow rates through the discharge pipe and stream flow measurements the OUL has develop a rating table (**Table 1**) that converts water depth data recorded by the transducer to flow rates in cubic feet per second (cfs) and million gallons per day (mgd). A rating table with water depths and flow rat es at 0.01 foot intervals is used by the UL in calculating flow rates. These values are almost completely groundwater discharge from Lake Spring.

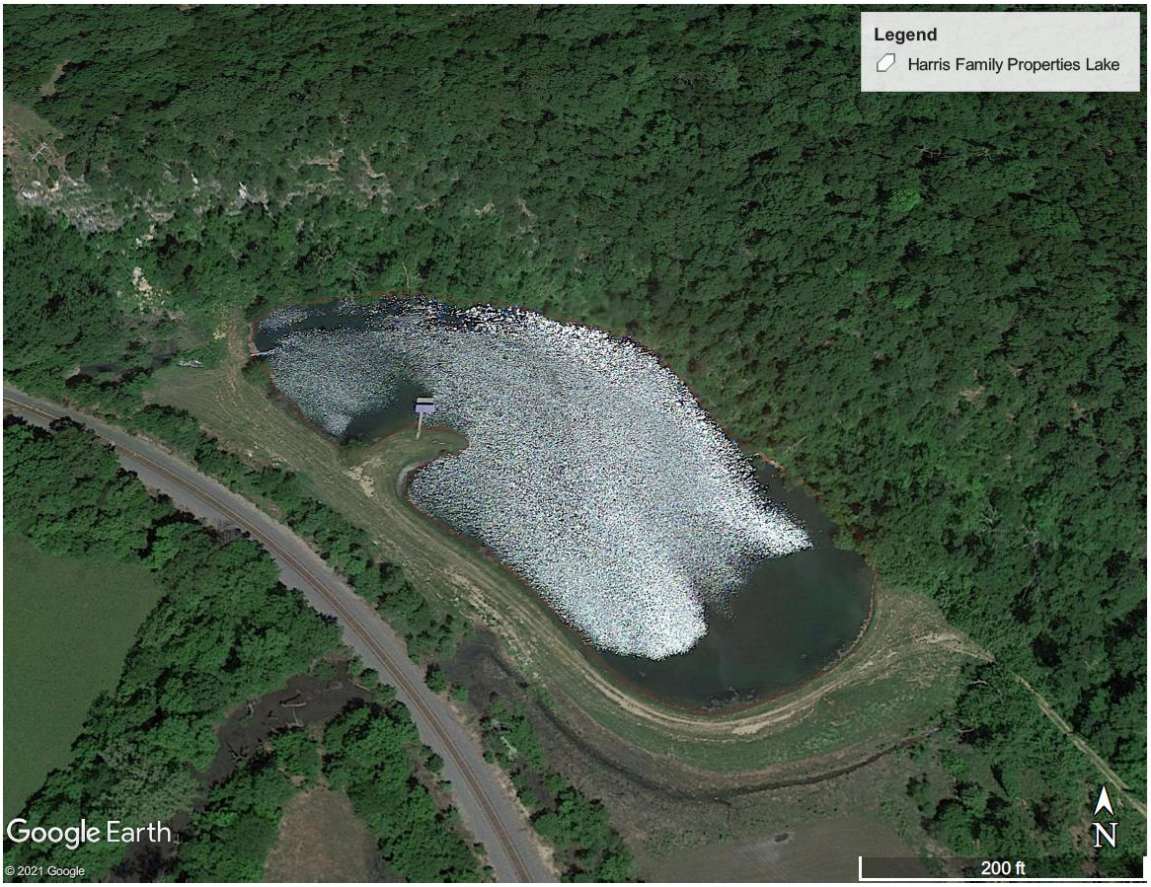

Figure 2. Lake and Harris Family Property Springs.

Figure 3. Flow rate measuring equipment at Lake Spring.

Table 1. Rating table for converting staff gage readings to flow rates from Lake Spring.

Lake Staff Gauge Height (ft)	Discharge (cfs)	Discharge (mgd)
2.3	0.0	0.0
2.4	0.6	0.4
2.5	1.3	0.9
2.6	2.4	1.6
2.7	3.9	2.5
2.8	5.6	3.6
2.9	7.7	5.0
3.0	10.1	6.5
3.1	12.7	8.2
3.2	15.5	10.0
3.3	18.6	12.0
3.4	21.9	14.1
3.5	25.3	16.4
3.6	28.9	18.7
3.7	32.5	21.0
3.8	36.2	23.4
3.9	40.0	25.9
4.0	43.8	28.3
4.1	47.5	30.7
4.2	51.1	33.0
4.3	54.6	35.3
4.4	57.9	37.4
4.5	61.0	39.4
4.6	63.8	41.2
4.7	66.2	42.8
4.8	68.2	44.1
4.9	69.6	45.0
5.0	70.3	45.4
5.1	69.9	45.1
5.2	66.4	42.9

Storm Events of March 11-15, 2021

The Ozark Underground Laboratory (OUL) report of December 29, 2020 included flow rate measurements made under low flow conditions at the HFP Springs. This addendum provides flow rate measurements made under higher flow conditions. These measurements demonstrate that the dissolved out network of natural conduits in the limestone underlying the reservoir floor and beneath the hill lying between Baynham Branch and the HFP Springs are capable of rapidly transporting large volumes of water from the planned reservoir to the HFP Springs. These conduits are located upstream of the planned dam and will not be blocked by that dam.

Figure 4 is a photograph of water discharging from the outflow pipe at Lake Spring. Essentially all of the flow is from the spring. The photo was taken on March 15, 2021 at 12:10 PM and shows a flow rate of 11.57 million gallons per day. Peak spring flow during the period was 23.05 million gallons per day and occurred at 3:47 AM on March 15, 2021. The peak flow rate was almost exactly twice the rate shown in the photograph.

Figure 5 is a graph of measured flow rates from Lake Spring during the period March 9 through 16, 2021. The short duration peaks that last about 40 minutes reflect intense precipitation falling on the lake.

Figure 4. Discharge of 11.57 mgd from the outflow pipe at Lake Spring. This flow is almost completely leakage from the planned reservoir area that would not be prevented by the dam.

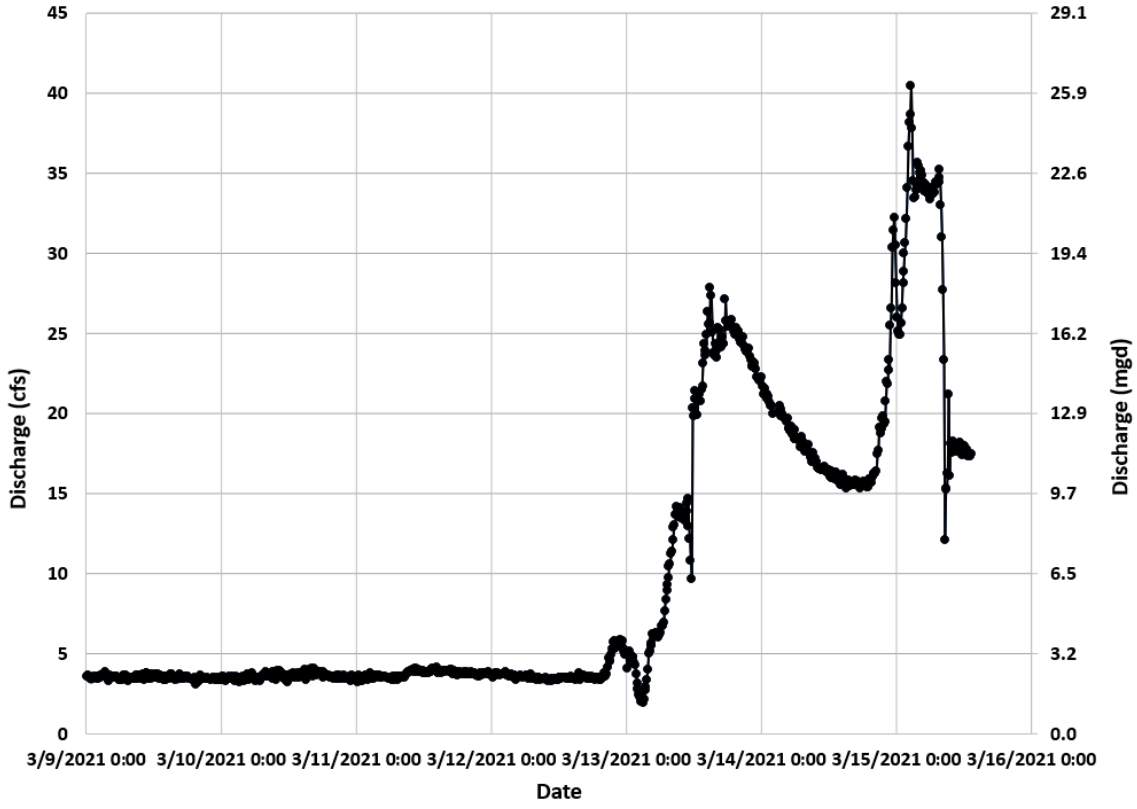

Figure 5. Water flow rates from Lake Spring, March 9 to 16, 2021.

The leakage rates measured during natural storm flow events of March 2021 demonstrate that the planned reservoir will be incapable of maintaining anything close to a full pool and incapable of supplying water at a rate of 30 million gallons per day to Joplin under dry-weather conditions.

Precipitation sufficient to raise the stage on Baynham Branch by 5 to 7 feet along the Baynham Branch stream segment between Lime Kiln Road and the planned dam site occurred during the afternoon and evening of March 14 and may have persisted into the early morning hours of March 15, 2021. Throughout this stream segment this peak flow was generally less than bank-full. The OUL made a site visit to the HFP Springs and nearby portions of Baynham Branch on March 15, 2021 to observe flow conditions after these precipitation events.

Previously measured flow rates from the spring in the pond and a second spring downstream of the pond and near the pond spillway at the HFP Springs were as follows:

- 11/5/20. 1.29 million gallons per day (mgd)
- 11/19/20. 2.31 mgd
- 12/1/20. 3.23 mgd

Recent flow rate measurements included the following:

- 3/12/21. Peak flow 3.80 mgd at 22:57 hours; did not include any water from spring near lake spillway.
- 3/13/21. Peak flow 16.37 mgd at 16:17 hours; did not include any water from spring near lake spillway. Short duration peaks due to precipitation on the lake were not included in determining peak flow.
- 3/14/21. Peak flow 19.71 mgd at 23.47 hours plus spring near lake spillway. Short duration peak due to precipitation on the lake was not included.
- 3/15/21. Peak flow 23.05 mgd at 03:47 hours plus spring near spillway with an estimated flow rate of 1.5 mgd. Short duration peaks due to precipitation on the lake were not included.

In the OUL report of December 29 (page 48) we noted that Mr. Hunley (our contact person for the HFP Springs) measured the flow of the spring at 20 million gallons per day under spring conditions. We concluded this was reasonable with a 5-foot increase in head in the losing stream portions of Baynham Branch between Lime Kiln Road and the centerline of the planned dam. Flow measurements on March 15, 2021 confirmed (and exceeded) this previously measured flow rate.

Block Diagrams

The OUL has prepared two block diagrams showing important hydrological characteristics of the area between Lime Kiln Road and the centerline of the proposed MAWC dam. **Figure 6** shows conditions under existing natural conditions with no dam in place and with the flow in Baynham Branch approximately at bank-full stage. **Figure 7** shows the same area under reservoir conditions assuming that a pool level of 1,051 could actually be reached by pumping water out of Shoal Creek. Such pumping is part of the MAWC plan for operating this planned reservoir.

Dye tracing and flow rate measurements clearly demonstrated that the HFP Springs are the primary discharge points for water from the major losing stream segment located between Lime Kiln Road and the centerline of the planned MAWC dam. An increase in head of 5 to 7 feet in the channel of Baynham Branch was responsible for flow at Lake Spring increasing from 2.3 mgd to 23.0 mgd. If the dam impounded a minimum of 10 feet of water over all the leakage zones downstream of Lime Kiln Road (far less than the 85 feet of impounded water MAWC plans) leakage from the reservoir even at that minimal water depth would still greatly exceed the 30 mgd delivery rate to Joplin that MAWC plans. The data clearly show that MAWC is planning a very leaky lake that will be incapable of providing 30 mgd of water to Joplin during low flow conditions on Shoal Creek. An equally important fact is that the project will cause significant natural resource damage and disrupt the lives of those who live and use the land and natural resources within the 1,200 acre planned impoundment area.

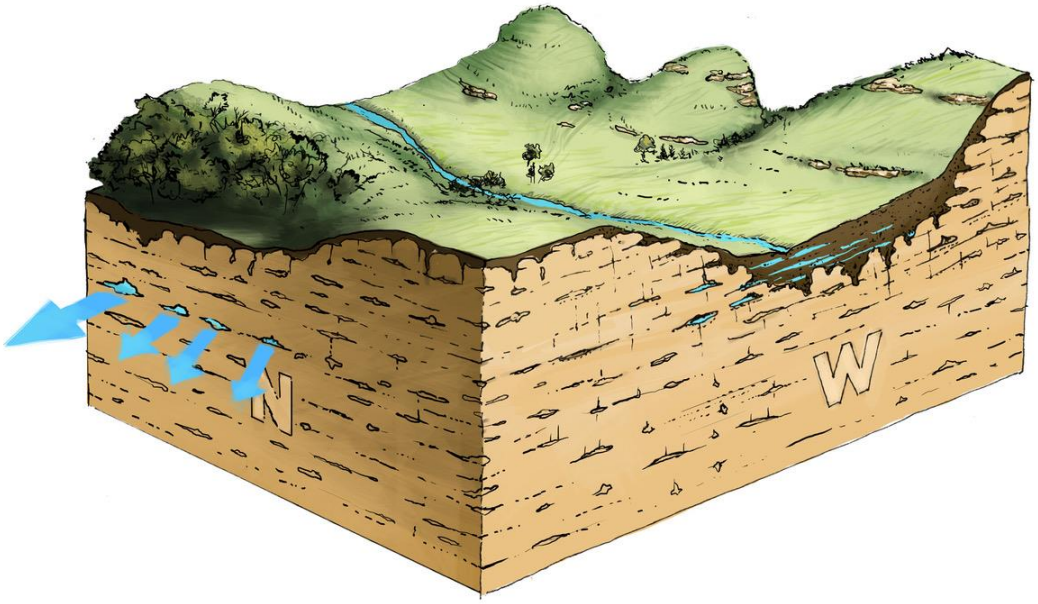

Figure 6. Block diagram of Baynham Branch between Lime Kiln Road and planned dam site under existing natural conditions. The west side of the block is through the dam centerline.

1. This diagram includes one of the three major losing stream segments on Baynham Branch within the planned reservoir area.
2. The limestone on the hillsides and beneath the valley is cavernous and very rapid groundwater flow at hundreds of feet per hour occurs through dissolved out bedrock openings. Cutters and pinnacles as described by Fellows (1965) are expected beneath the valley but may not be detected without very extensive drilling.
3. There is year-round flow at Lime Kiln Road. The stream sinks at numerous points downstream of that road as shown by measurements of stream flow rates. From mid-summer through early fall the entire flow of the stream usually enters groundwater before reaching the dam site.
4. Three separate dye tracing studies have shown that the water sinking in this area flows underground through the hill on the north side of the diagram and discharges from HFP Springs. Lake Spring is the largest of these. The blue arrows depict a few of the multiple flow routes. The planned dam would not block these groundwater flow routes.
5. The stream in the diagram is flowing at close to bank-full conditions such as existed on March 15, 2021 when peak flow from Lake Spring was 23.05 million gallons per day.
6. With very limited exceptions the soils in this valley have been mapped by the US Department of Agriculture (Aldrich, 1989) and found to have "Severe Limitations for Reservoir Areas Due to Severe Seepage". This is consistent with the loss of large volumes of surface water into groundwater under bank-full flow conditions.

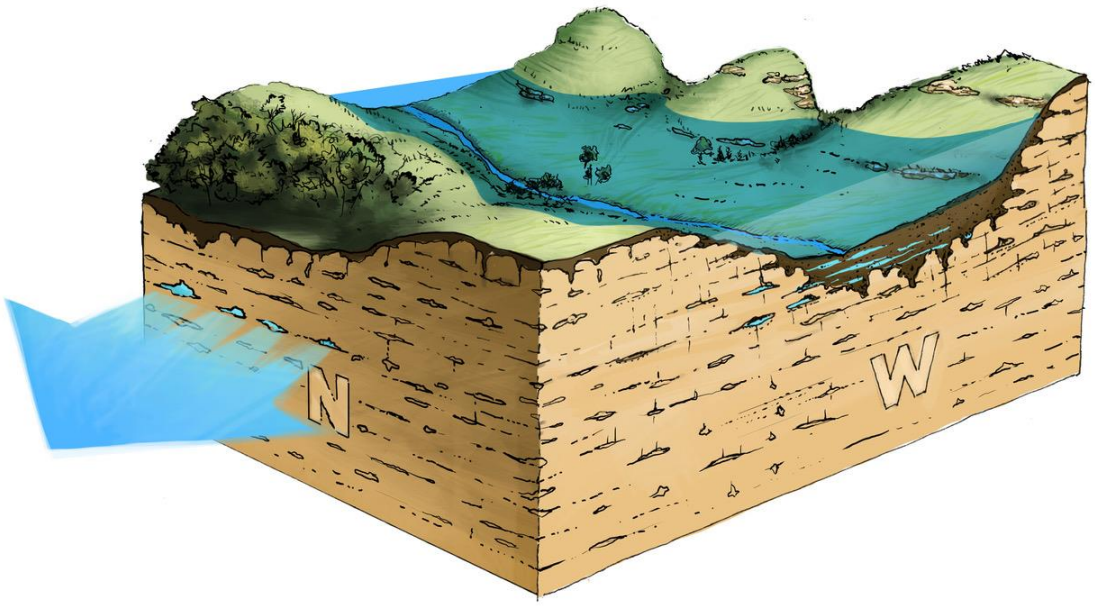

Figure 7. Block diagram of Baynham Branch between Lime Kiln Road and planned dam site under reservoir conditions.

1. If the reservoir operated as planned the depth of water at the dam would be approximately 100 feet. The elevation of the "normal pool" would be at an elevation of 1051 feet.
2. The leakage rate would dramatically increase over existing natural conditions as indicated by the large blue arrow. Water leaking from the reservoir through this losing stream segment will discharge from the HFP Springs and possibly additional locations.
3. Based on standard groundwater equations, pumping of water from Shoal Creek into the reservoir at rates in excess of 150 million gallons per day and for prolonged periods would be required to reach a "normal pool" level of 1051 feet. Pumping of water from Shoal Creek would be permitted only under high to moderately high flow conditions. Due to massive leakage from the reservoir it could not continuously supply 30 million gallons of water per day to Joplin water users under dry weather conditions.
4. There will be a net loss of water from the Shoal Creek basin due to evaporation from the planned 1,200 acre reservoir.
5. Low dissolved oxygen in bottom waters of the reservoir would kill Ozark cavefish populations within the impoundment area. This is a federally-listed Threatened Species.
6. With very limited exceptions the soils in this valley have been mapped by the US Department of Agriculture (Aldrich, 1989) and found to have "Severe Limitations for Embankments, Dikes, and Levees". Building a high earth fill dam in a losing stream segment underlain by cavernous limestone units where excessive leakage is documented represents an unwise and risky undertaking (Aley et al., 1972).

References

Aldrich, Max W. 1989. Soil survey of Newton County, Missouri. U.S. Dept. of Agriculture. 123p. + maps.

Aley, Thomas and David Woods. 2020. Evaluation of a selected site for a proposed Joplin water supply reservoir on Baynham Branch. Ozark Underground Laboratory contract report to Glenn Brown. 55p. plus appendixes. Copies available from Contact@ozarkundergroundlab.com.

Aley, Thomas; James H. Williams; and James W. Massello. 1972. Groundwater contamination and sinkhole collapse induced by leaky impoundments in soluble rock terrain. Engineering Geology Monographs, Series 5. Missouri Geological Survey and Water Resources. 32p.

Fellows, Larry D. 1965. Cutters and pinnacles in Greene County, Missouri. Bulletin of Nat'l Speleological Society, Vol 27:4, pp. 143-150.

Missouri American Water Company. 2019. Joplin water supply reservoir. Section 404 pre-application. Prepared by Black and Veach & Olsson. 18p.

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