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An Overview of the Reverse Flow Patterns of River Styx in Mammoth Cave, Kentucky: 2009-2012

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Introduction

One of Mammoth Cave's underground rivers is the River Styx. The River Styx flows out of the River Styx Spring and is a tributary to the Green River. The Green River is the primary surface river of the area. Under normal circumstances, the River Styx flows through Mammoth Cave and out the River Styx Spring where it discharges into the Green River. In the late 1950s, USGS scientists studying the Green River and its underground tributaries discovered a stable reverse flow pattern for the River Styx.

Under the stable reverse flow conditions, surface water from the Green River flows into the River Styx Spring and causes the River Styx to flow backwards. The backwards flowing River Styx flows into Echo River, another nearby underground river, and flows out of the Echo River Spring. Echo River Spring is located approximately 1.6 km downstream on the Green River from the River Styx Spring. This stable reverse flow condition is not a flooding event and occurs when the Green River is within its normal range of depths.

Understanding the River Styx's reverse flow patterns is important because the reverse flow events can affect the cave's climate, as well as directly affecting the cave's biological, geological, cultural, and archeological resources. Cave climate impacts include changes to the cave's air temperature, relative humidity, and condensation amounts. These climate impacts can extend significant distances away from the immediate location of the River Styx and cause additional impacts to

the natural and cultural resources found in those parts of the cave.

The timing and duration of the reverse flow events can be influenced by both natural (e.g. precipitation) and anthropogenic (e.g. releasing water from the Green River Dam, Lock & Dam 6) factors. Yet to our knowledge, little research beyond the USGS studies in the 1950s and 1960s has been conducted on the River Styx's reverse flow patterns.

In 2008, a 7th grade science teacher from T.K. Stone Middle School contacted the Mammoth Cave International Center for Science and Learning (MCICSL). She was interested in having her students conduct research at Mammoth Cave National Park. In the fall of 2009, T.K. Stone Middle School and MCICSL partnered to study the River Styx's reverse flow patterns.

Trimboli et al. 2011 provides details about the development of the project and lessons learned from conducting research with middle school students. This paper focuses

on a brief preliminary analysis of the data collected. A more in-depth paper and analysis is being prepared for publication at a later date.

Methods and Results

Students from T.K. Stone Middle School worked with MCICSL staff to collect water temperature data in the River Styx, Echo River, and Green River from October 2009 to October 2012. Water temperatures were collected every two hours using temperature data loggers. The data were used to determine the minimum, maximum, and mean temperature during the study for each river (Table 1).

Water temperature was also used as a proxy for determining the direction in which the River Styx was flowing. During reverse flow events, surface water from the Green River flows into the River Styx and changes its water temperature while Echo River maintains a stable temperature. During back-flooding events, the Green River floods into both the River Styx and Echo River, thus changing the water temperature of both underground rivers. The water temperatures for each river were graphed and the graphs were visually analyzed to determine patterns and identify reverse flow events.

Preliminary analysis of the graphs during times when data was available for all three rivers indicated that the River Styx was in a stable reverse flow condition 15 times and back flooded twice. Most of the reverse flow events occurred in December through March. Reverse flow events in spring and fall may be more difficult to identify using this study’s methods because the Green River temperature tends to be closer to the

Table 1: Minimum, maximum, and mean temperatures in the River Styx, Echo River, and Green River from October 2009 to October 2012. Preliminary data.

	Mean Temperature	Maximum Temperature	Minimum Temperature
River Styx	13.5 °C + 2.5	23.8 °C	3.6 °C
Echo River	13.4 °C + 0.6	14.4 °C	9.2 °C
Green River	15.6 °C + 7.1	29.5 °C	1.3 °C

normal temperatures of the underground rivers. The duration of the stable reverse flow events appeared to vary from only a few days to several weeks.

Gaining a better understanding of the River Styx’s reverse flow events is important because of the impacts that the events can have on Mammoth Cave’s natural and cultural resources. While the current study provides much needed baseline data, more in-depth research is needed.

References

Trimboli, S.R., Toomey, R.S., Weber, K., and Ryan, S., 2011, The Misbehaving Spring: Studying Unique Underground River Flow Patterns with Advanced Middle School Science Students, in Proceedings, George Wright Society Conference on Parks, Protected Areas, and Cultural Sites, p. 311-316.