Trog Sink and its Hydrologic Effects on Head Waters of East Blackburn Fork River

Todd Wisor, Department of Earth Sciences, Tennessee Technological University, 1 William L Jones Drive, Cookeville, TN, 38505 (tawisor42@tntech.edu).

Abstract

A hydrologic model was developed to predict runoff in an urban watershed in Cookeville, TN. In the study area there resides a massive sinkhole responsible for storing and transmitting storm water to the East Blackburn Fork River. The sinkhole is hypothesized to store excess rain water, and release it at a steady rate. Maintaining a higher baseflow discharge well after storms have passed over the watershed. A rain gauge and two stream gauges were deployed to record water level in the sinkhole and at a spring known to be its outlet. ArcGIS Pro software was used to determine the watershed area and interpret the terrain of the watershed. The hydrologic model HEC-HMS (Army Corps of Engineers) was used to model runoff from a rain event that happened on 12-5-2020. Results showed a normal hydrograph with peak rainfall and a fairly quick return to baseflow estimated at hours compared to the time recorded in field data. Field data showed Trog Sink retaining a large volume of water about 8.5ft in height at its maximum, and not allowing the spring to return to base flow for roughly thirteen days. Further research and modeling are hypothesized to display Trog Sinks retention pattern in a hydrograph, and the delays in observed flow for head waters of the East Blackburn Fork River.

Introduction

My senior thesis project focused on Trog Sink (Figure 1) located just north of the Tennessee Tech campus. The sinkhole is a closed depression that collects runoff in the area due to its natural low elevation in comparison with the surrounding areas. Trog Sink is particularly interesting, because of its karst features that allow groundwater to be transported through the surrounding geology. The water infiltrating into Trog Sink has been dye traced previously, and resurfaces at Big Spring (Figure 2), which is just off Big Springs Circle north of Jere Whitson Elementary School. Big Spring meets other tributaries and flows north to the East Blackburn Fork River. The goal of my study is to determine retention effects of Trog Sink on the river, as well as compare modeled data and observed data between Trog Sink and Big Spring. Water level data was collected by automated stage recorders. Additionally, a water sample was taken from the watershed to determine the quality of the water being transported to the East Blackburn Fork River. Trog Sink acquires trash from surrounding areas due to runoff and may exhibit some pollution results. The city of Cookeville, TN sponsors and hosts a Trog Sink cleanup at least once a year.

Methods

Data collection for the Trog Sink watershed was completed in two forms. I used spatial analysis with GIS software to determine the percentages of impervious surfaces and hydrologic soil types. Slope and topographic data were determined using LiDAR elevation DEM files. Water level data was collected using HOBO water level loggers set at a 5-minute recording interval, and corrected for atmospheric pressure. One Onset tipping bucket rain gauge was installed at a local elementary school, with permission of school administrators. HEC-HMS software (US Army Corps of Engineers) was used to create a rainfall-runoff model to predict peak discharges at Big Spring based on known rainfall data collected by the rain gauge. The model was used to simulate runoff at Big Spring. The model results were then compared to actual water level data collected at Big Spring. The USGS application Stream Stats (https://streamstats.usgs.gov/ss/) was used to delineate the watershed. It was then adjusted based on a drainage divide into Trog's Drainage Area (Figure 3). The city of Cookeville provided GIS data on impervious surfaces (structures and pavement). The rain gauge was placed to collect rainfall data roughly in the center of the two karst features. In addition to the rain gauge, two loggers were installed at Trog and Big Spring to record pressure, temperature, and water level in feet. In order to record water level a reference water level was measured at each logger site. A third logger was placed at Kittrell hall on TTU's campus to record atmospheric pressure to correct the data collected at Trog Sink and Big Spring.

Results

Based on GIS data from Stream Stats, the Trog Sink drainage area was determined to be 0.75 mi². This watershed was composed of Impervious and Non-Impervious surfaces. Percentage of impervious surfaces was calculated in ArcGIS Pro at 44% of the watershed surface, or roughly 0.33 mi². A soils map of the drainage area classified by the Natural Resource Conservation Service into Hydrologic Soil groups was used to help determine a curve number used in runoff calculations and modeling. Soils groups B, C, and a small amount of D were found in Trog Sinks drainage area.

Water Quality

A water sample was taken at Big Spring yielding results showing high levels of E. Coli and Fecal Coliform, suggesting a possible sewage leak which could be in Trog Sink or even somewhere along the path of the groundwater. The E. Coli results were greater than 2420 CFU (Colony Forming Unit), and the Fecal Coliform was also greater than 2420 CFU, both of which are above the maximum contaminant level for human health.

HEC-HMS Model

Observed and model data for the 12-5-2020 rain event is displayed in Figure 4. The observed water level at Big Spring was lower than that estimated by the model, due to the retention effects of Trog Sink. Multiple sets of data were recorded in an excel spreadsheet for future analysis, and the creations of new models and hydrographs. With a combination of field and GIS measurements, HEC-HMS features were calibrated for a simulated rain event. The blue line indicates modeled flow, while the black line is observed data showing how Trog Sink reacts with the amount of rainfall received. Precipitation levels are displayed by the bar graph (Figure 4).

Stage and Rainfall Data

Based on the initial data the figures below display rainfall over time, and water level for two rain events at Trog Sink and Big Spring. The rainfall for November (Figure 5) also depicts the spikes in the rainfall between 11-11-2020 and 11-15-2020. Analysis on 11-11-2020 and 11-15-2020 shows a larger amount of rainfall occurring on 11-11-2020 (Figure 6). Big Spring displays a gradual return to baseflow after rainfall peak, but Trog Sink displays a delayed characteristic. On 11-11-2020 the height of rainwater in the sinkhole reached over 3ft, a 56% increase in water level maximum height from 11-15-2020 (Figure 7). With this amount of rain in Trog Sink we begin to see that the sinkhole has a limit that it can discharge to Big Spring. It took over 10 hours to drain the 11-11-2020 rain event. Recession started around 2pm on 11-11-2020 and continued into the early hours of 11-12-2020. Peak water level at Trog Sink on 11-11-2020 reaches Big Spring in approximately 1hr 15min, on 11-15-2020 the peak level occurs in approximately 1 hr. This data suggests the larger the rain event, the longer the time it will take for peak water level to travel downstream, due to retention of water in Trog Sink. In conclusion Trog Sink retains rainfall from rain events providing a constant elevated flow to head waters of the East Blackburn Fork River. These results suggest that flash floods downstream are affected by the water detained in Trog Sink.

Study Area

Figure 1, Trog Sink Flooded 12-5-2020.

Figure 2, Big Spring Flooded 12-5-2020.

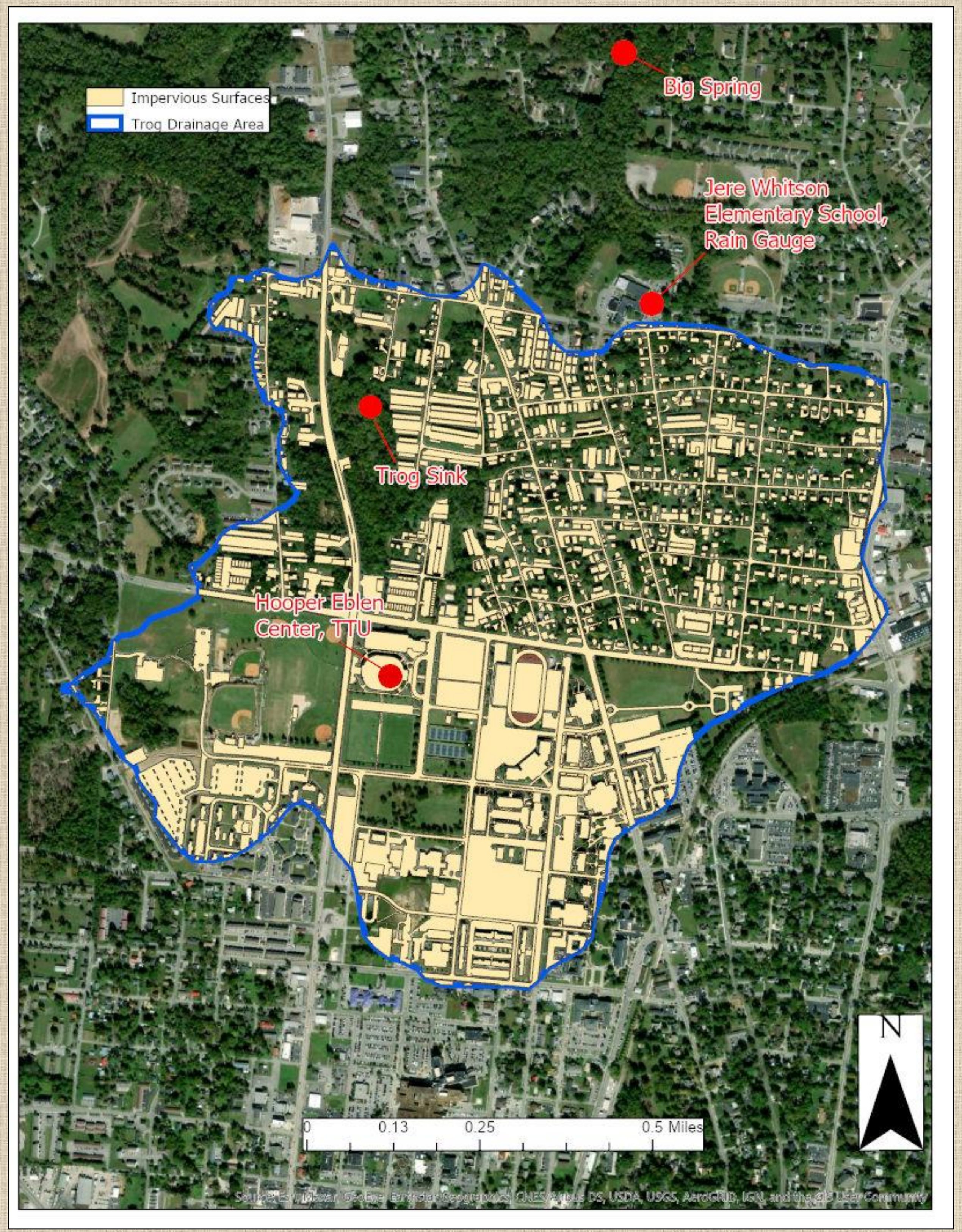

Figure 3, Aerial Photograph of Trog Sink Drainage Area and Impervious Surfaces.

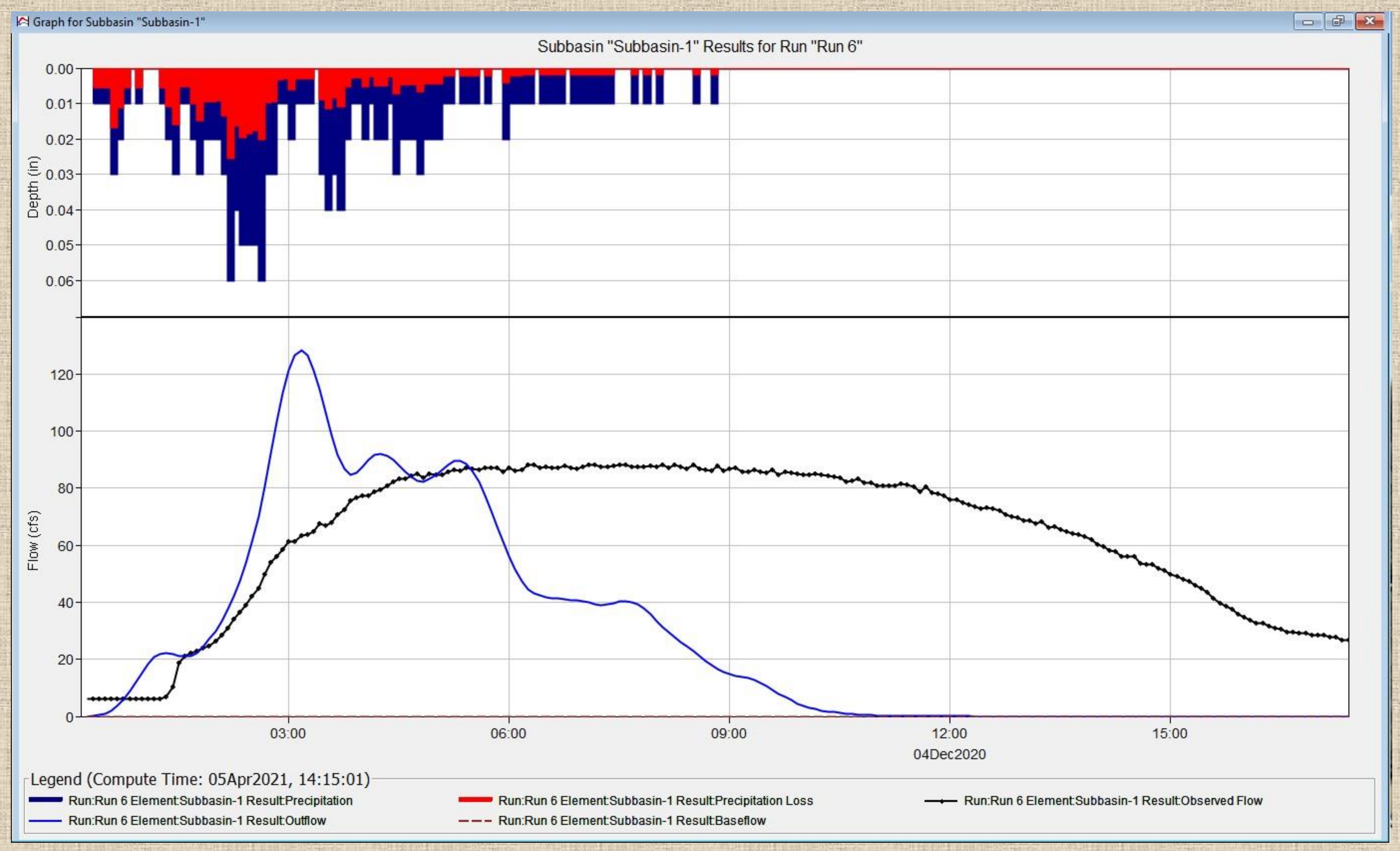

Figure 4, HEC-HMS Model Results.

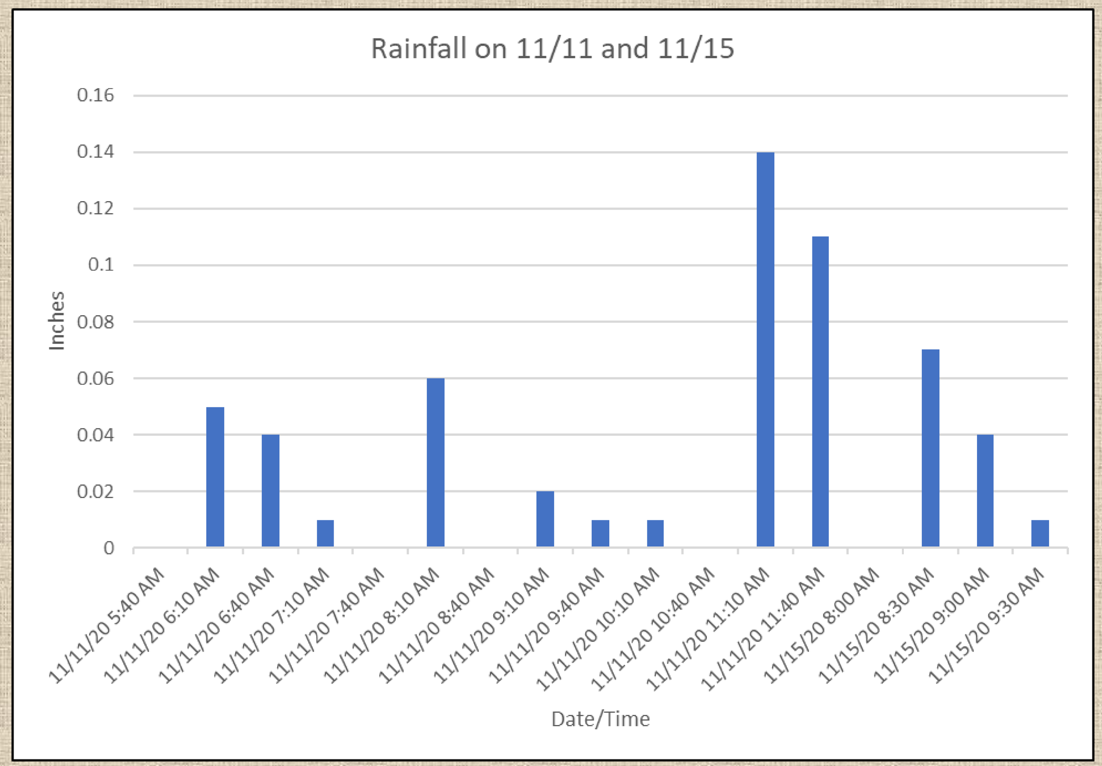

Figure 5, Rainfall for November

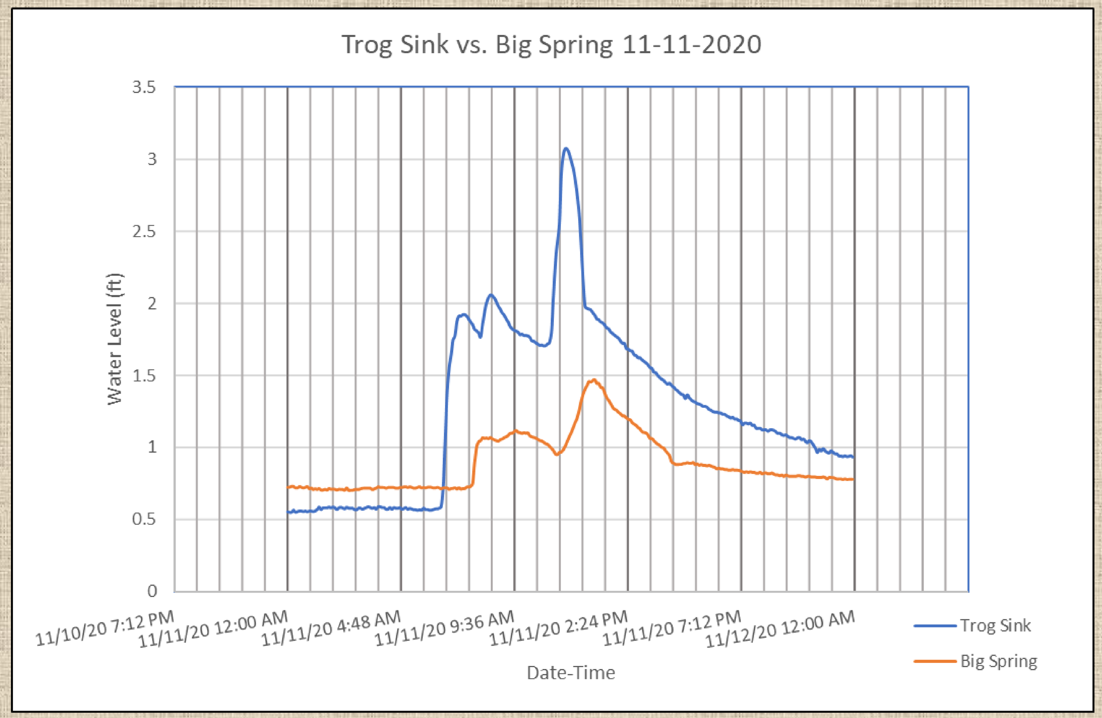

Figure 6, Hydrograph for 11-11-2020

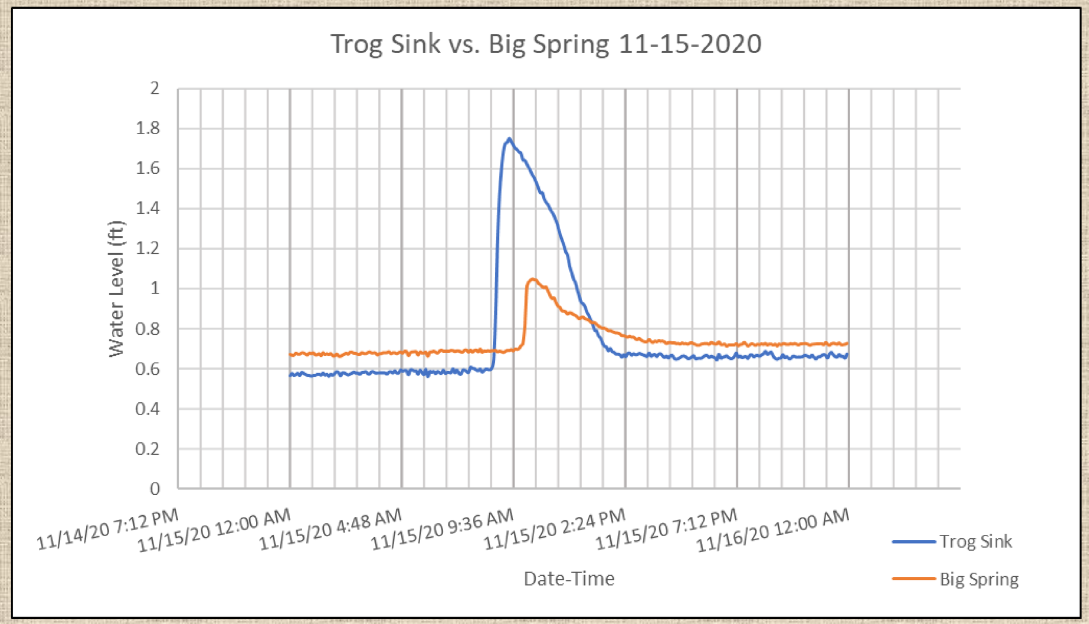

Figure 7, Hydrograph for 11-15-2020