

ABSTRACT

Increases in volatile organic compounds (VOC) in developing areas poses risks to aquatic health. Water quality changes in surface waters, if measured, are often only for field parameters of pH, specific conductance, water temperature, and major ions, e.g. Ca²⁺, Mg²⁺, Na, Cl. Elevated VOC concentrations can negatively impact aquatic ecosystems even at low concentrations, but do not cause changes in commonly measured parameters and may go undetected based on monitoring these common parameters. Traditional sampling and benchtop analysis for VOC can be both time and cost prohibitive. Here we demonstrate the use of a low-cost in situ dissolved total VOC measurement platform consisting of a total VOC gas sensor in combination with a dissolved gas marble chamber system. Limitations of the current prototype include portability in remote areas and non-selectivity of specific VOC species. Measurement of total VOC in natural and engineered environments using the described platform, nonetheless, represents an affordable screening tool for potential organic contaminants. Combined with species specific VOC analysis, measurement of dissolved total VOC could provide as a VOC surrogate for high frequency monitoring.

BACKGROUND (continued): Volatile organic compounds in natural waters

VOCs are a diverse group of chemicals originating from both natural and industrial sources. VOCs pose a major risk to water quality and stream ecosystems due to their toxicity and persistence. Despite their environmental significance, data on their distribution in natural waters remain sparse due to analytical constraints, chiefly being cost and time needed for collection. Typical VOC sampling of natural waters requires sampled waters to be transported to dedicated laboratory facilities where gases are extracted from water samples. VOCs can be measured using various methods, including photoionization detectors and gas chromatography-mass spectrometry, however, application of in situ measurement techniques for total dissolved concentrations and species specific VOCs in natural waters are severely limited. The use of a total volatile organic carbon (TVOC) sensor in conjunction with existing dissolved gas sampling methods could enhance our understanding of VOC occurrence.

MATERIALS, METHODS, and STUDY AREA DESCRIPTION

Dissolved gas sampling was made using a marble chamber apparatus.

- For surface waters sampled in this study, water was pumped from a stream using a small, submersible pump into the top of marble chamber column (Figure 2a-b).
- As the fluid flows downward in the chamber, turbulent flow is generated as water moves through void spaces between the spherical surface of the glass marbles, which causes rapid degassing of dissolved gases in the fluid.
- The liquid component of the fluid discharges at the bottom of the marble chamber where several holes are drilled.
- Degassed dissolved gasses accumulate in the headspace of the marble chamber and are circulated in a closed loop to a TVOC sensor where gas measurements are made. The gas stream is then re-circulated into the marble chamber near the base of the marble chamber.
- Over time, the gas concentration in the marble chamber will equilibrate with dissolved gases from surface water sources yielding a gas concentration that is equal to the headspace concentration in equilibrium with the surface water.

Total VOC (TVOC) concentrations were measured using a Renesas TVOC sensor

- The Renesas (Tokyo, Japan) TVOC sensor was selected owing to relatively large TVOC range, low power requirements, and accuracy.
- The water and air pump were ran for ~ 2-3 minutes allowing for sensor warm-up between measurements.
- One warm-up was completed, sampling time was ~ 5 minutes allowing ample time for equilibration.

Study area: Wilson Springs run near the I-49 interchange near Fayetteville, Arkansas (USA)

- Three samples were taken within Wilson Springs Nature Preserve along Wilson Springs run, while one sample was taken from the median area where Wilson Springs is thought to emerge.
- Sample 3 in the Preserve was taken at a culvert where complaints regarding “hydrocarbon vapors” had been previously reported (Fig. 3, Sample 3)

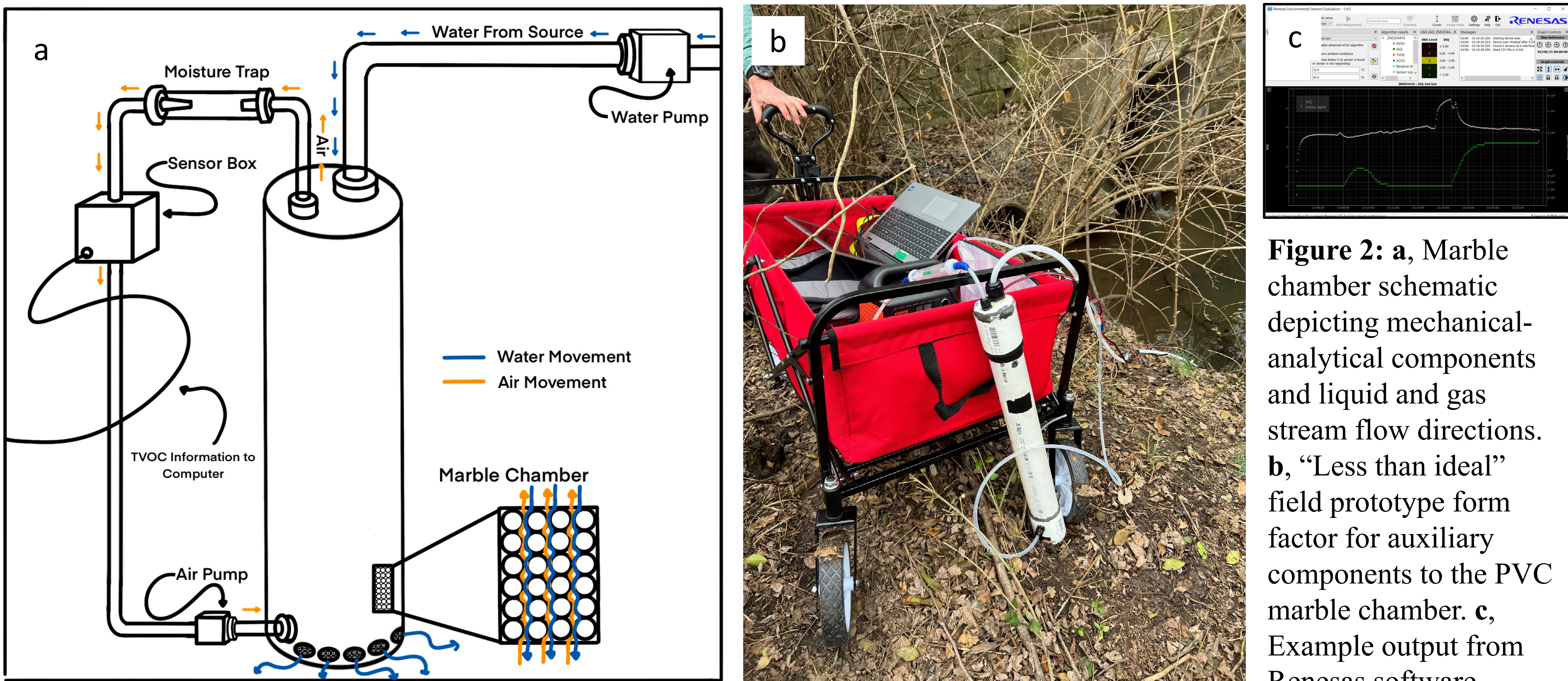


Figure 2: a, Marble chamber schematic depicting mechanical-analytical components and liquid and gas stream flow directions. b, “Less than ideal” field prototype form factor for auxiliary components to the PVC marble chamber. c, Example output from Renesas software.

RESULTS

TVOC Concentrations and Hydrogeologic Conceptual Model

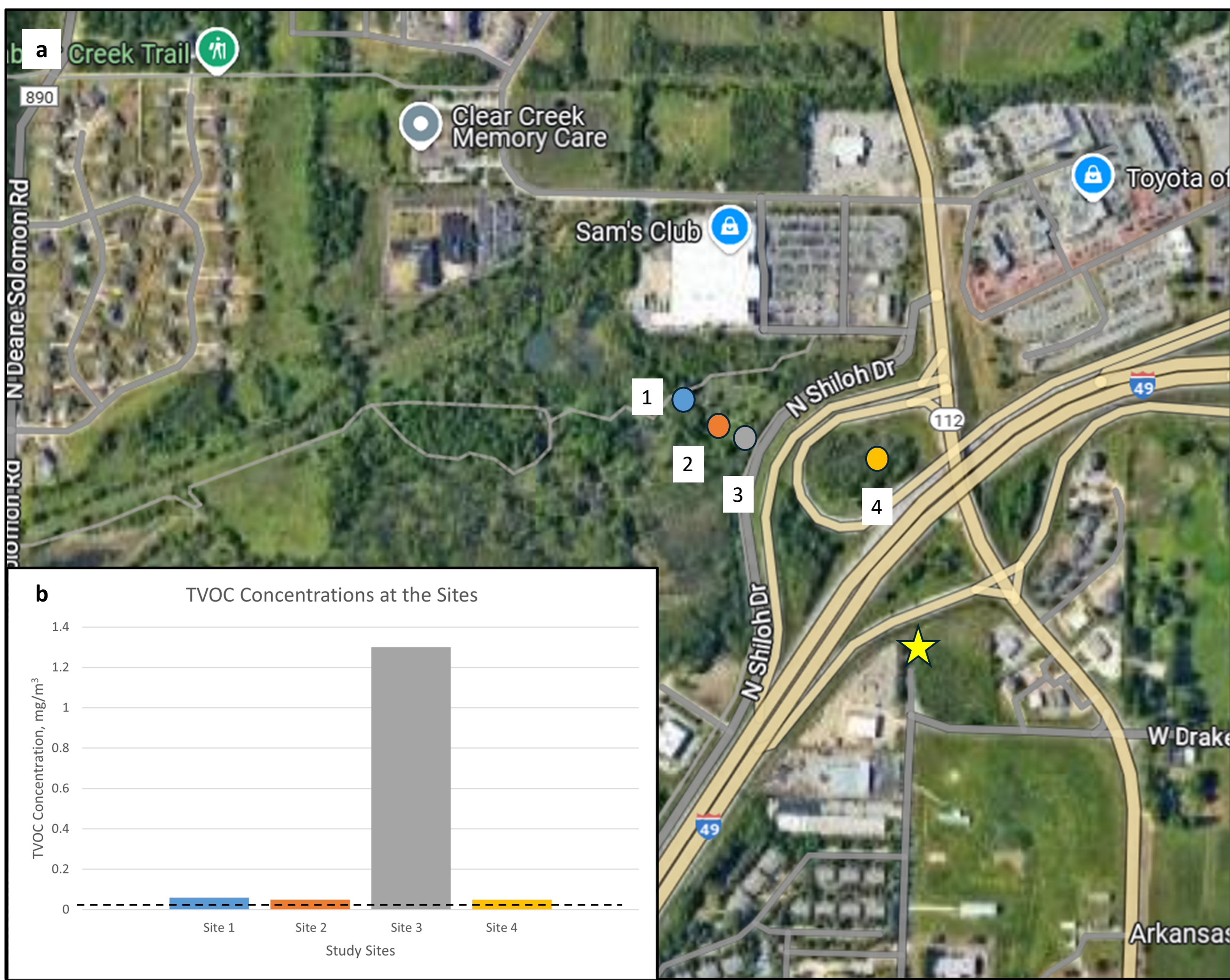


Figure 3: **a**, Aerial image of study area with labeled sites and location of photograph documenting artesian conditions (Google Maps, 2025). **b**, TVOC concentrations for respective sites.

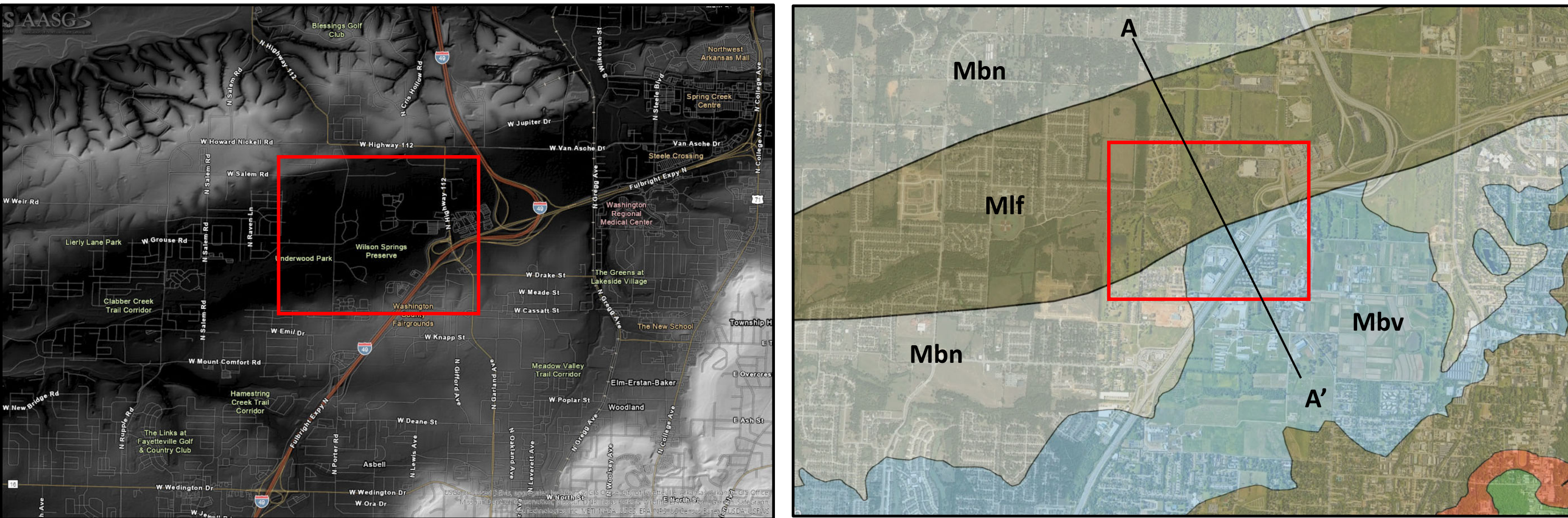


Figure 4: Shaded relief image of lidar data showing study area.

Figure 5: Geologic map (King, et al., 2001) of study area showing approximate location of conceptual model.

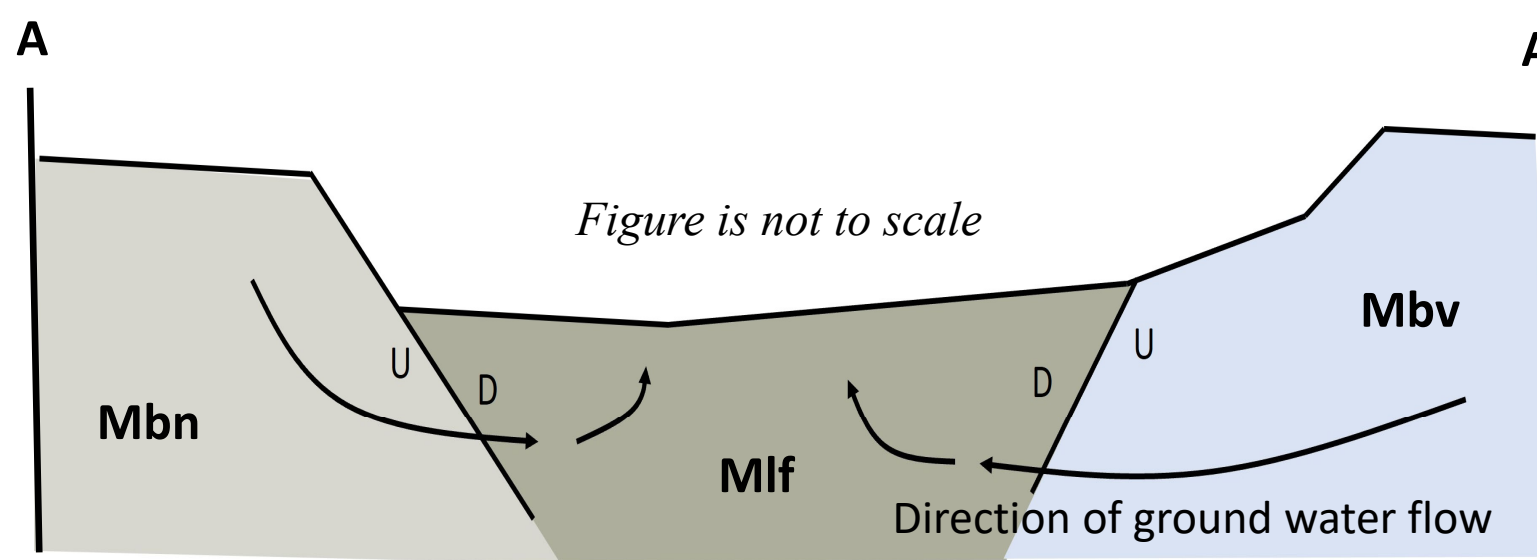


Figure 6: Conceptual model of Wilson Springs Preserve showing groundwater movement and faults present in the area.

DISCUSSION and FUTURE RESEARCH

- Measurement of TVOC is feasible using a marble chamber and TVOC sensor.
- Artesian flow observed near the study site suggests similar hydrologic conditions may exist throughout the valley, potentially influencing groundwater and VOC transport.
- The source of the VOCs at Wilson springs originating from site three remains poorly constrained.
- Future research should focus on developing a more portable detection system, refining unit conversions for consistency with established studies, and conducting a detailed source identification.

REFERENCES

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- U.S. Geological Survey (USGS), 2024, Annual NLCD Collection 1 Science Products: U.S. Geological Survey data release, <https://doi.org/10.5066/P94UXNTS>
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Figure 1: **a**, State of Arkansas general geology map (Haley, et al., 1993). **b**, Regional geology of Fayetteville, AR area. Land use-land cover in northwest Arkansas in **c**, 1985 and **d**, 2023 (USGS, 2023). Note that red and pink colors represent urban and built-up environments while yellow and green colors represent pastureland and forest, respectively.

BACKGROUND: Increasing built-up environments in Northwest Arkansas and volatile organic compound risk

Increases in urban and built-up environments associated with land use changes in Northwest Arkansas have introduced new potential sources of volatile organic compound (VOC) contamination. Rapid urban expansion, increased industrial activity, and infrastructure development have replaced once-rural landscapes, leading to the potential for increased instances of fuel storage, solvent use, and manufacturing byproducts, which can act as point sources of VOCs. These land use-land cover changes and increased potential for VOC point source contamination highlight the need for rapid, in field analytical assessments of potential contamination. However, limited low-cost options exist for VOC assessments in natural waters. Nonetheless, documentation of VOC occurrence in natural waters of Northwest Arkansas are needed to assess the long-term environmental effects of land use transitions on freshwater ecosystems.



Figure 7: Artesian flow at the entrance of the main culvert that flows to site 3.