

## Background

Phosphorus (P)-laden runoff has been associated with lake eutrophication throughout the upper Midwest United States. Although P has been considered immobile in groundwater systems, investigation at UW-Eau Claire suggests P is highly mobile in groundwater. This impact has implications on land-use practice and lake management. This study seeks to quantify P loading through groundwater discharge in Mud Lake in Barron County, WI. Mud Lake was selected as a site of interest for the following reasons:

1. High groundwater P concentrations in Chetek identified by Bartnik et al. (2016) and Wiest et al. (2017)
2. Seasonal eutrophication events in the lake
3. Practical lake size (332 acres)
4. Easy access and landowner cooperation
5. Typical land use/geology for the region



Figure 1. Location of Mud Lake in Barron County, WI.

## Methods



Figure 4. Map showing mini-piezometer locations and representative lake segments for each piezometer.

- (1) Ten (10) mini-piezometers (5 ft length, 1/2" ID, 4" screen) were installed around the perimeter of the lake. Mini piezometer locations (Fig 4) were selected based on land-owner permission, ease of access, and achieving well-distributed spacing.
- (2) Hydraulic conductivity at each site was determined through slug and constant head tests (one time following well installation).
- (3) Water levels inside and outside the piezometers were collected using a water level meter.
- (4) In situ water quality was measured for surface and groundwater using an Aqua TROLL 600 Multiparameter Sonde.
- (5) Surface and groundwater samples were collected through low flow sampling, (filtered and preserved in the field using a 0.45 µm filter and nitric acid).
- (6) Lake bottom sediments were collected for analysis of sediment chemistry and phosphorus sorption. Sediments were dried in a low temperature oven for 24 hours.
- (7) A de-ionized water extraction was performed by shaking dry sediment in DI water (ratio of 1:5) for 20 minutes. The DI water was then filtered and acidified to measure P concentrations held loosely in the sediment pore space.



## ANALYSIS

- (1) All water samples were analyzed for phosphorus, iron, and manganese on ThermoFinnigan Element2 High Resolution Inductively Coupled Plasma Mass Spectrometer (HR-ICPMS).
- (2) Using water level measurements (dh/dl), hydraulic conductivity (K), and the area of lake segments represented by each well (A), groundwater discharge (Q) into the lake was calculated using Darcy's Law:

$$Q = KA \frac{dh}{dl}$$

- (3) Total phosphorus flux was calculated by multiplying P concentration by groundwater discharge.

## Results

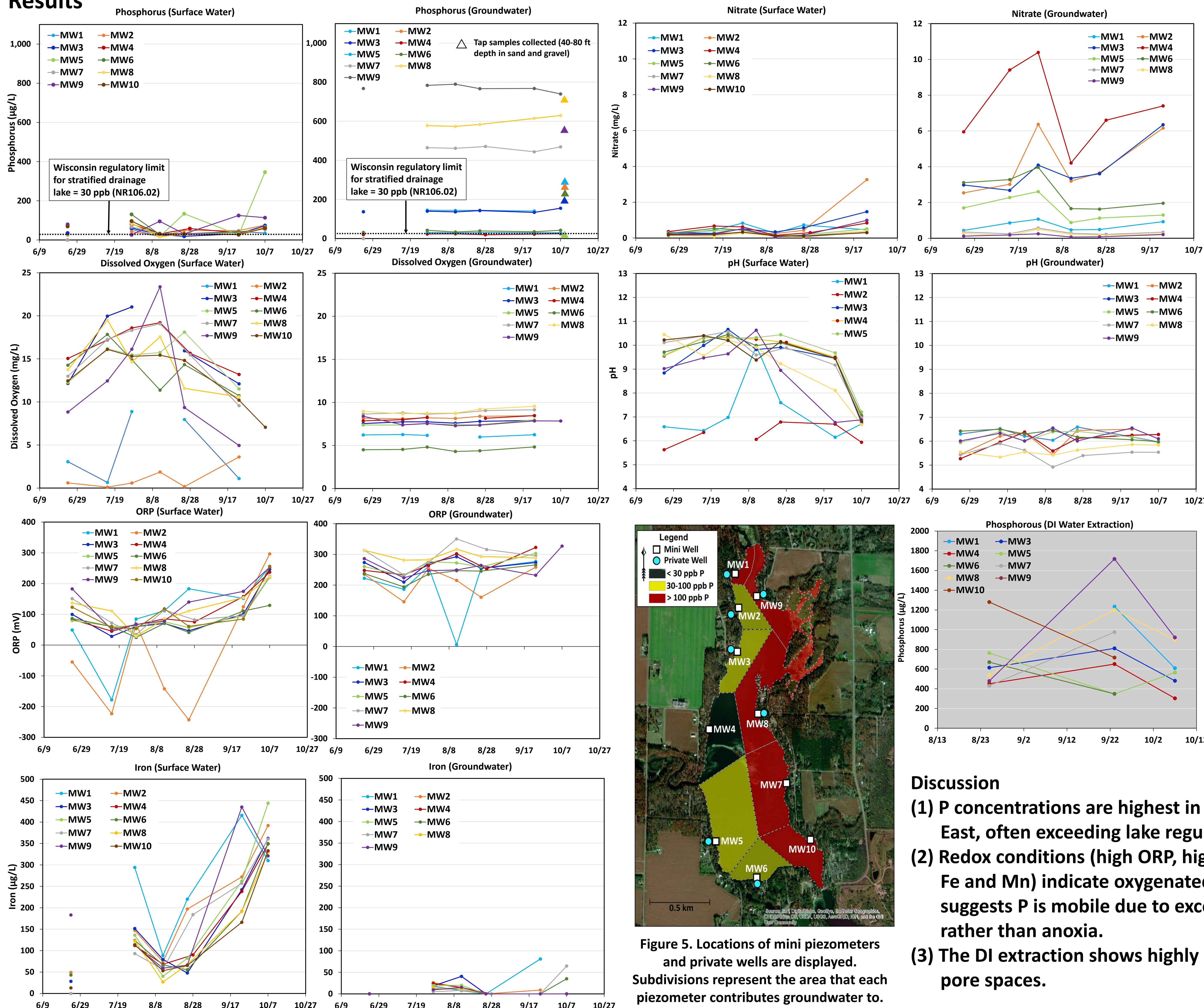


Table 1. Average P flux (P concentrations multiplied by groundwater discharge for each representative area)

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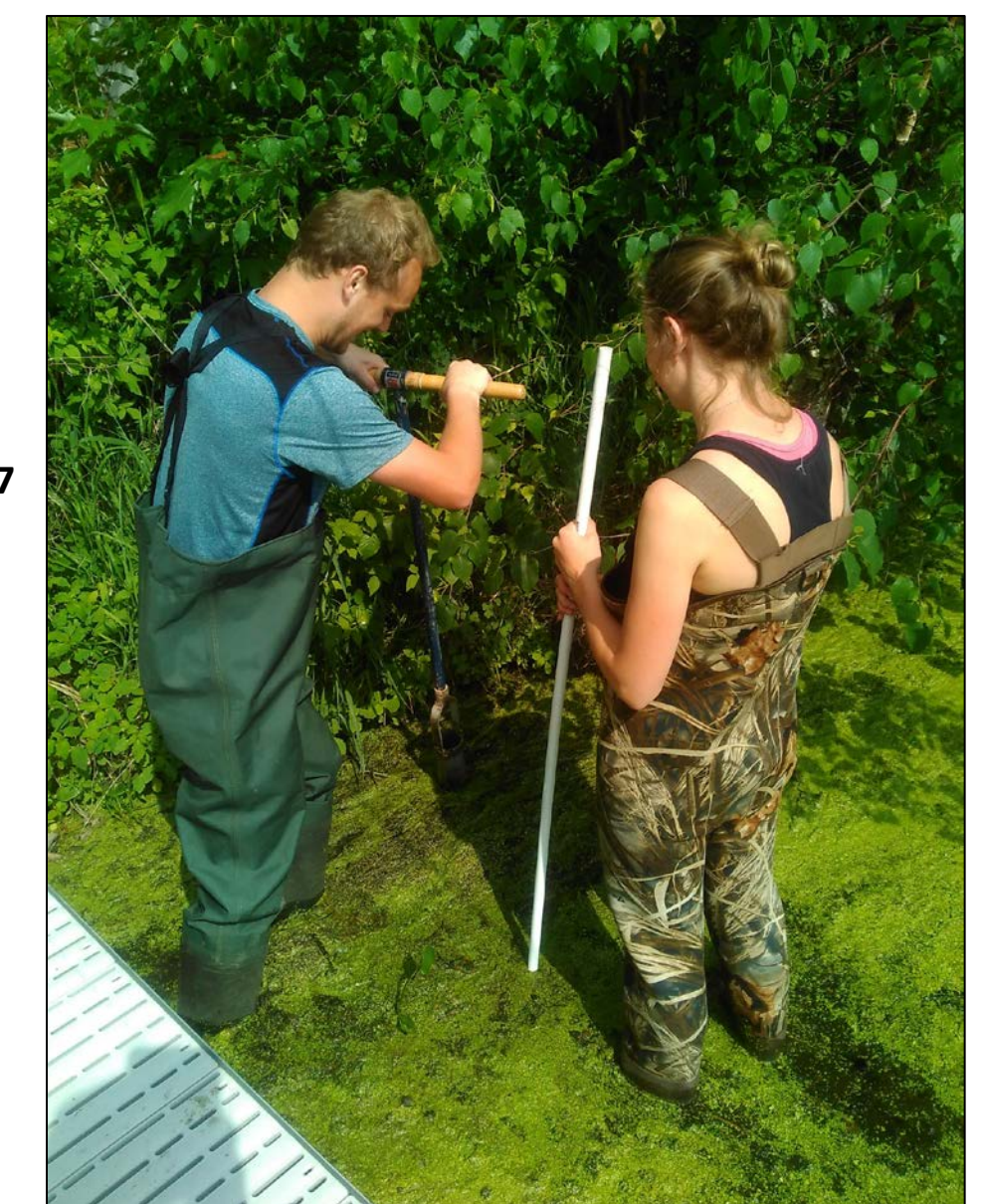


Figure 6. Installing mini piezometers around the perimeter of Mud Lake using an auger and a rubber mallet.

## Discussion

- (1) P concentrations are highest in groundwater from the East, often exceeding lake regulatory limit of 30 ppb.
- (2) Redox conditions (high ORP, high dissolved oxygen, low Fe and Mn) indicate oxygenated conditions. This suggests P is mobile due to excessive concentrations rather than anoxia.
- (3) The DI extraction shows highly elevated P in sediment pore spaces.

Figure 2. Land use practice and drainage basins in the Chetek Lakes watersheds. Mud Lake's watershed mainly drains from the E/NE. Land use is mainly deciduous forest and cultivated crops (Chetek Lakes Comprehensive Management Plan, 2015)

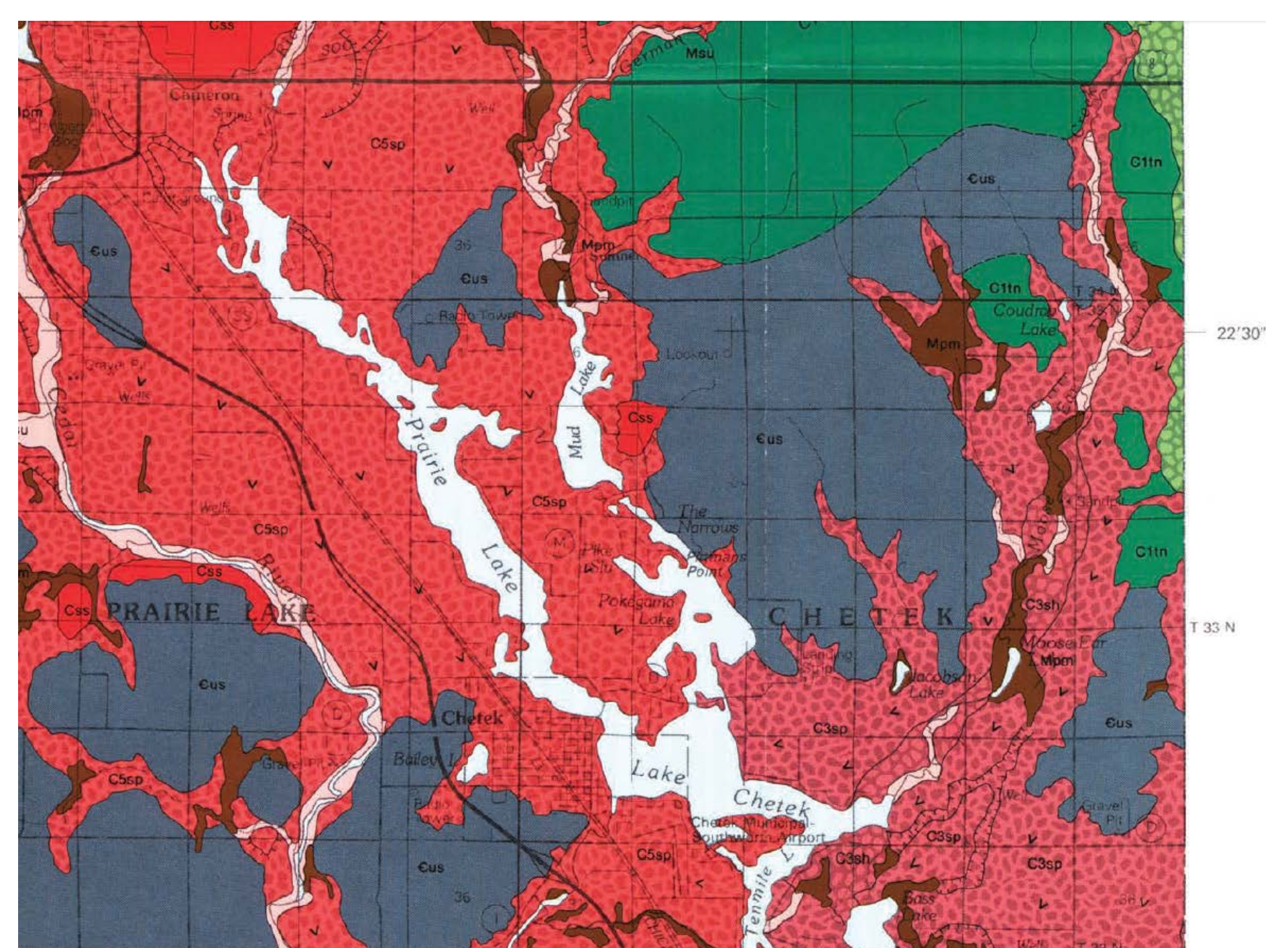


Figure 3. Geology of the Mud Lake region (Johnson, 1986), characterized by glacial deposits and exposed sandstone.

## Acknowledgements

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