CANOE-MOUNTED ELECTROMAGNETIC SURVEY IN AN IOWA RIVER TO DELINEATE STREAMBED CONDUCTIVITY

IOWA
Iowa Geological Survey

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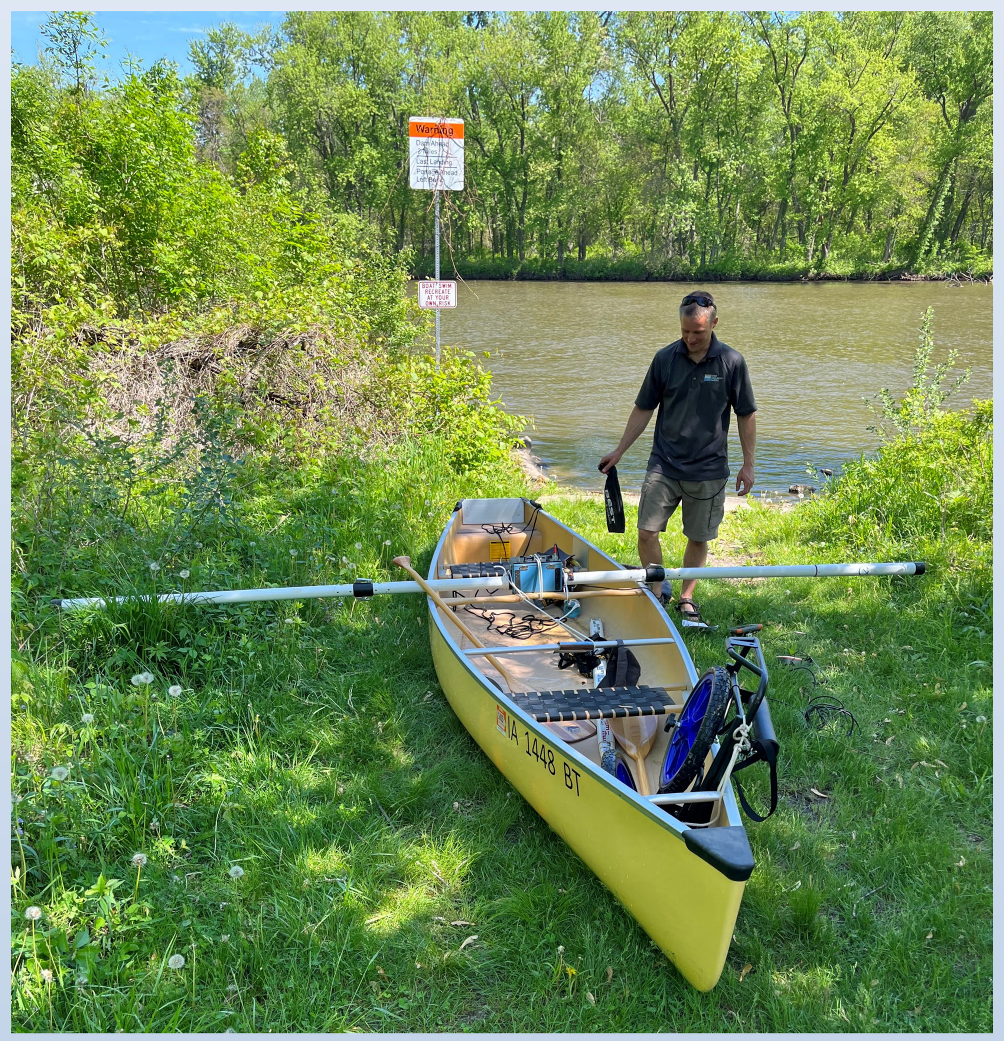
ABSTRACT

The Iowa Geological Survey tested a novel application of electromagnetic geophysical data collection from a water vessel navigating on a large river in Iowa. A Geonics, Ltd. EM-31 MK2 electromagnetic terrain conductivity meter (EM) was mounted to a canoe with the goal to collect conductivity data associated with riverbed sediments in the Iowa River in Iowa City, Iowa. The trial was performed as part of an alluvial aquifer investigation for the City of Iowa City. The boat-mounted EM survey was used to provide ancillary data relative to the induced groundwater recharge potential of the alluvial system.

Results from the survey indicated streambed conductivity ranged from 17 to 205 mS/m, with most values falling between 20-50 mS/m. Distinct patterns of higher and lower conductivity were observed in the river sediment coinciding with sands and fines, respectively. Future work correlating water depth and ground-truthing riverbed sediment will be crucial in quantifying how the EM survey performed with respect to delineating streambed sediments.



Top: A photo of the EM mounted transversely to the canoe. The photo shows the location on land where the EM was calibrated. A two-wheeled cart is shown secured to the bow of the canoe for use during portages.
Bottom: A zoomed-in photo showing how the EM was secured to the canoe. Note the tablet in the grass in the upper right which was used to record continuous measurements and was connected to a sub-meter GPS (not pictured).

Introduction

The Iowa Geological Survey tested a novel application of EM geophysical data collection from a water vessel navigating on a large river in Iowa. A Geonics, Ltd. EM-31 MK2 electromagnetic terrain conductivity meter (EM) was mounted to a canoe with the goal to collect conductivity data associated with riverbed sediments in the Iowa River in Iowa City, Iowa. The trial was performed as part of an alluvial aquifer investigation for the City of Iowa City. The boat-mounted EM survey was used to provide ancillary data relative to the induced groundwater recharge potential of the alluvial system.

The use of boat-mounted EM surveys has the potential to efficiently characterize riverbed sediments in water bodies with shallow water column depths. The EM unit used has an imaging depth of approximately 6 meters. Typically, this imaging depth is shown as distance below ground since EM surveys are usually conducted over land. However, in this study, we wanted to determine if the unit can capture: 1) changes in the electrical properties of the surface water present below the device, 2) changes in the electrical properties of the riverbed sediments, or 3) electrical properties related to a quantifiable mix of water column changes and riverbed sediments.

While this canoe-mounted EM survey may be novel in a large, Iowa-based river setting, others have done work with EM surveying on rivers (Baierlipp, 2012, Butler, et al., 2004, Butler et al., 2006, Christenson et al., 2004, Nadeau et al., 2003, Nadeau et al., 2004) , wetlands (Christenson, 2018), bays (Greenwood, 2004, Sandberg et al., 2005), or through the use of different technology (Sambuielli, et al., 2007).

Methods

A Geonics Limited (Geonics) EM-31 MK2 ground conductivity meter was utilized for this investigation. The EM is 3.5 m in length with one end containing a transmitter coil and the other a receiver coil. The transmitter coil produces an alternating current, which induces circular eddy loops into the subsurface. The receiver coil then intercepts a portion of the magnetic field from the eddy loops and records the value as an output voltage that is converted to apparent conductivity. The EM produces average conductivity (quadrature component, mS/m) and in-phase (metal component, ppt) to approximately 6 m below the ground surface.

The EM unit was mounted transversely near the center of a fiberglass and polyester canoe. A Wenonah Backwater 15 canoe was used for the study. The first attempt to install the EM in line with the length of the canoe was unsuccessful, perhaps due to the aluminum trim's proximity to the boom ends. After mounting the EM transversely, the unit was calibrated using methods established by Geonics on a vegetated shoreline while mounted to the canoe. The purpose of the calibration was to mask metal from the canoe and luggage, set a reference baseline for the data to be collected, and prepare the unit for collection. While calibration on the water was preferred, affixing the transmitter and receiver over water was not feasible due to the transverse EM mounting method. Once on water the calibration was reviewed and readings were found to be withing an appropriate range.

While paddling the canoe between 0-10 kilometers per hour, conductivity and in-phase data were recorded continuously on a field tablet at a rate of five readings per second (approx. 90,000 measurements). Each measurement was tied to a geographic location using a Juniper Systems Geode sub-meter precision GPS positioned near the EM unit. The data were collected on May 16, 2023, and were obtained by paddling from a starting location at the northeast part of the study area (Dubuque St. bridge), traveling along a line between the centerline of the river and the north shore. Data collection was paused while portaging around a low-head dam (Peninsula Park bridge) and resumed once on the water downstream of the dam. Readings were once again paused when the canoe reached the end of the study area (Park Rd. bridge). The canoe was trailer-driven back to the starting location (Dubuque St. bridge) and collection resumed similar to the first run, except data were collected by traveling along a line between the centerline of the river and the south shore. This collection method effectively allowed for two evenly spaced surveys to be completed along the river in the study area. For the purposes of this investigation, only conductivity is presented in the figures, as it is the most applicable to streambed conductivity surveying. However, in-phase data (proximity to metal) were also collected to determine areas of interference. Field data were processed using the Geonics DAT31W application and ESRI mapping software. Color raster images were created, showing how conductivity varied along the imaged area.

Results

Results from the survey indicated streambed conductivity ranged from 17 to 205 mS/m, with most values falling between 20-50 mS/m. Distinct patterns of higher and lower conductivity were observed in the river sediment coinciding with sands and fines, respectively. Higher conductivity values, including the unit's calibrated maximum value of approximately 205 mS/m, were observed when traveling near or beneath anthropogenic structures, such as bridges, utilities, or other infrastructure. See the callouts below and to the right for descriptions and interpretations of conductivity results.

Conductivity values in this area are lower than locations up and downstream. Rip-rap was observed along the cut-bank in this stretch.

This is the deepest part of the Iowa River in the study area with water depths of up to 4 m. Conductivity values ranging from 30-50+ mS/m were observed here.

Obvious interference was observed in areas like this, when the unit was paddled under a prominent bridge (I-80 in this location).

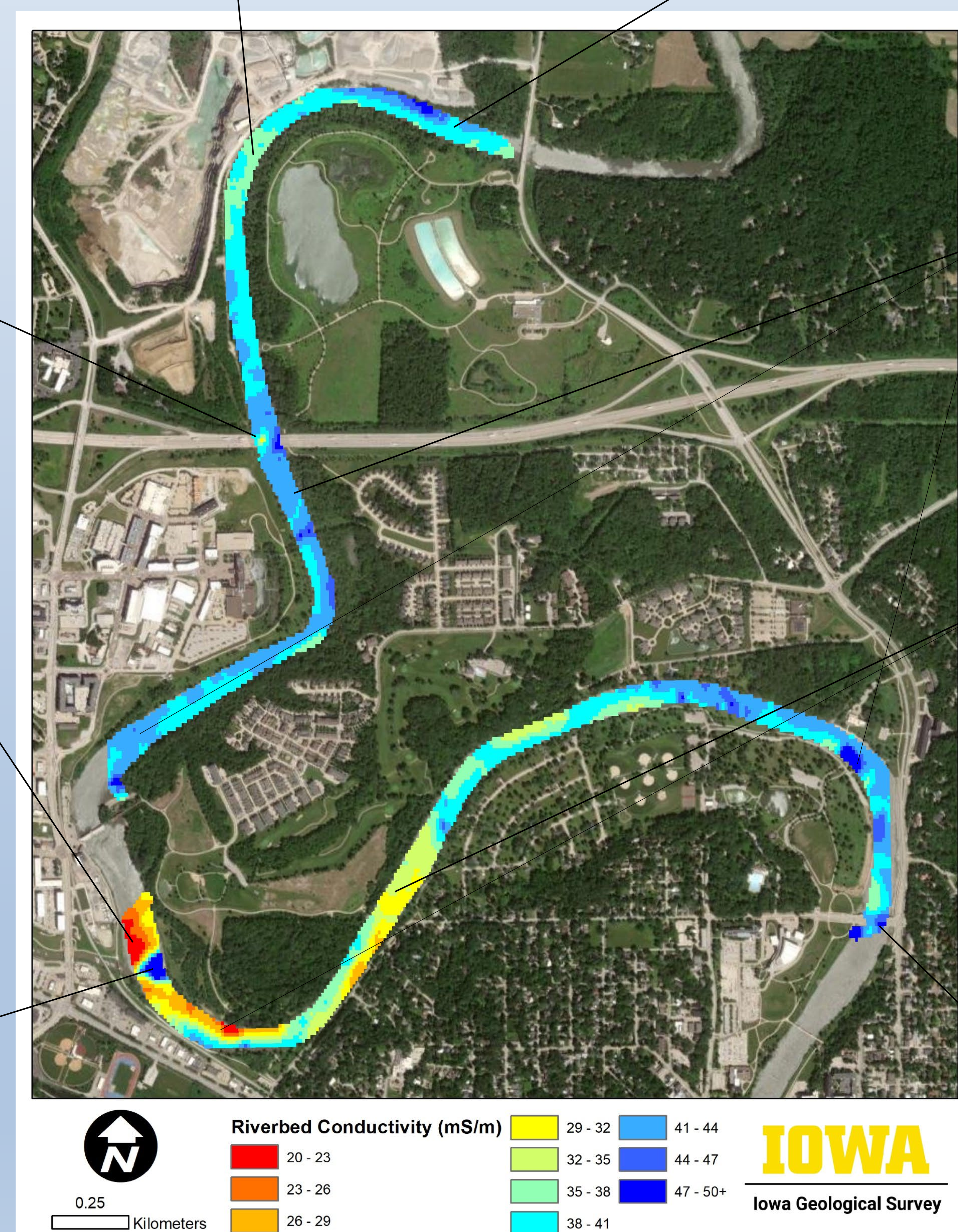
These sections showed high conductivity relative to the remainder of the study area, suggesting the presence of fine-grained bedload sediments.

This was the shallowest section of the Iowa River in the study area with depths of approximately 0.5 m. Conductivity values in this area were very low, in the 20-30 mS/m range, suggesting the presence of coarse-grained bedload sediments which was visually field-verified.

These sections showed low conductivity relative to the remainder of the study area, suggesting the presence of coarse-grained bedload sediments, which are desirable for groundwater recharge to the aquifer.

Considerable interference was observed in this area, as shown by maximum conductivity values as calibrated (205 mS/m) and high in-phase readings. This is also a complex riverbed sediment area, as Clear Creek joins the Iowa River in this location.

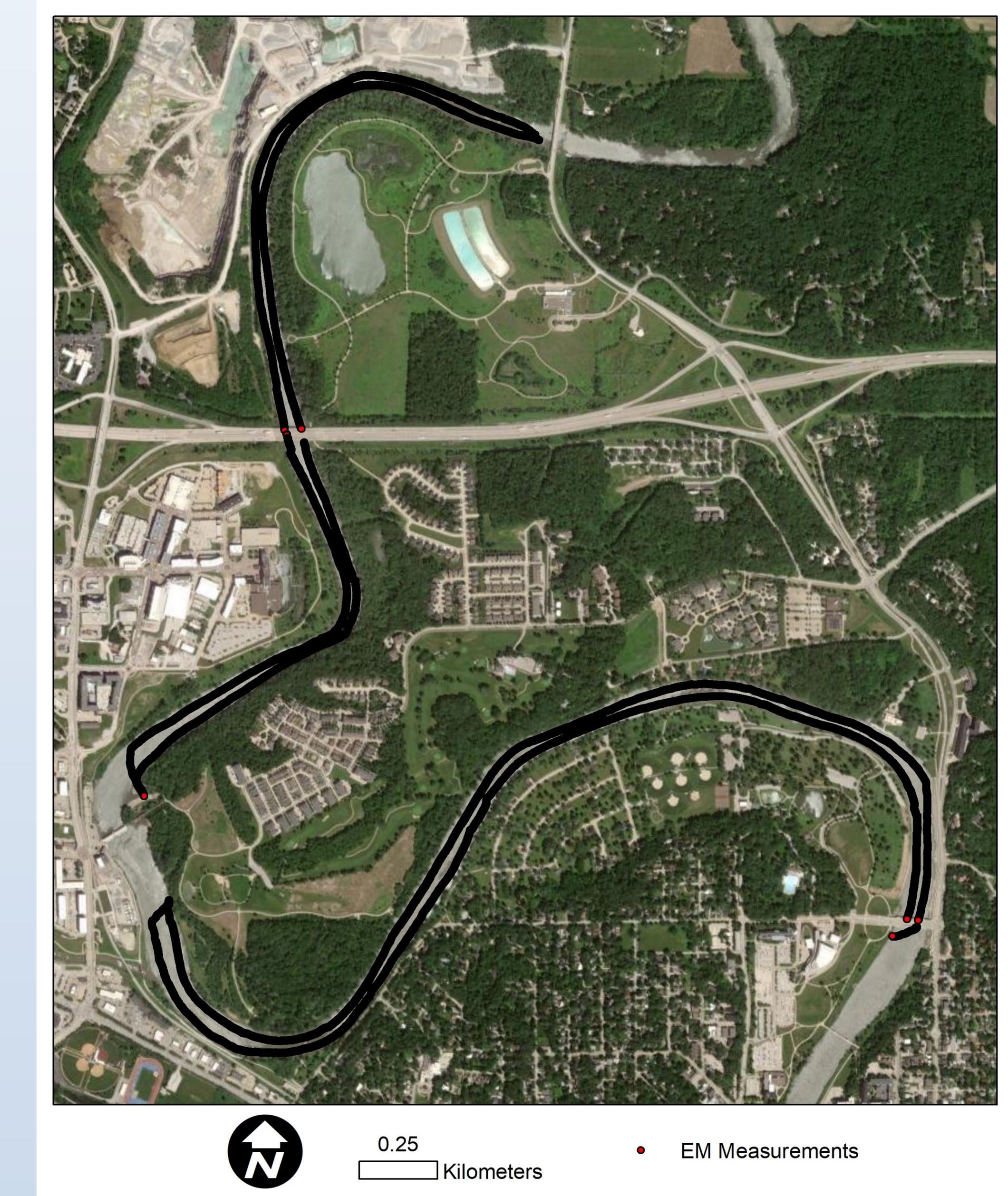
Obvious interference was observed in areas like this, when the unit was paddled under a prominent bridge (Park Rd. bridge in this location).



Discussion and Future Work

Results from the boat-mounted EM survey look promising and have the potential to efficiently characterize bedload sediments. Quantifying groundwater induced from rivers is often a valuable component in assessing and modeling alluvial aquifers. This rapid, field-based approach to mapping changes in riverbed sediments can be used to inform groundwater assessments by identifying changes in vertical hydraulic conductivity in these systems, which controls the hydraulic connectivity between the river and aquifer.

The first phase of the study, collection of EM survey data, is complete. To further the work, we need to determine if the unit can capture: 1) changes in the electrical properties of the surface water present below the device, 2) changes in the electrical properties of the riverbed sediments, or 3) electrical properties related to a quantifiable mix of water column changes and riverbed sediments. To address these questions, future work has been planned to ground-truth the EM results with the collection of physical riverbed sediment samples and comparison of river bathymetric data. Physical samples of bedload materials will be collected in select locations within the study area. Use of a Vibecore sediment coring device will allow core samples to be collected when bedload sediments are fine enough to allow penetration of the unit. If sediments are too coarse for Vibecore collection methods, the use of a dredge or similar sampling device may be required. Bathymetric data already collected within the study area will be used to compare with the EM survey results to determine how water depth may be impacting results. After careful analysis of the newly collected sample and water depth data and comparison to the EM survey data, we expect to synthesize final results in a future publication.



A figure showing the locations of EM point data collected in the study area. Note the entry points in the upper right, the low-head dam portage area in the lower left, and the exit points in the lower right.

Photos showing field data collection. Careful attention was given to ensure the boom ends didn't become submerged.

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