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Geophysical methods used to better characterize surface water, alluvial aquifer, and bedrock aquifer interaction in the Cedar River Valley, Iowa

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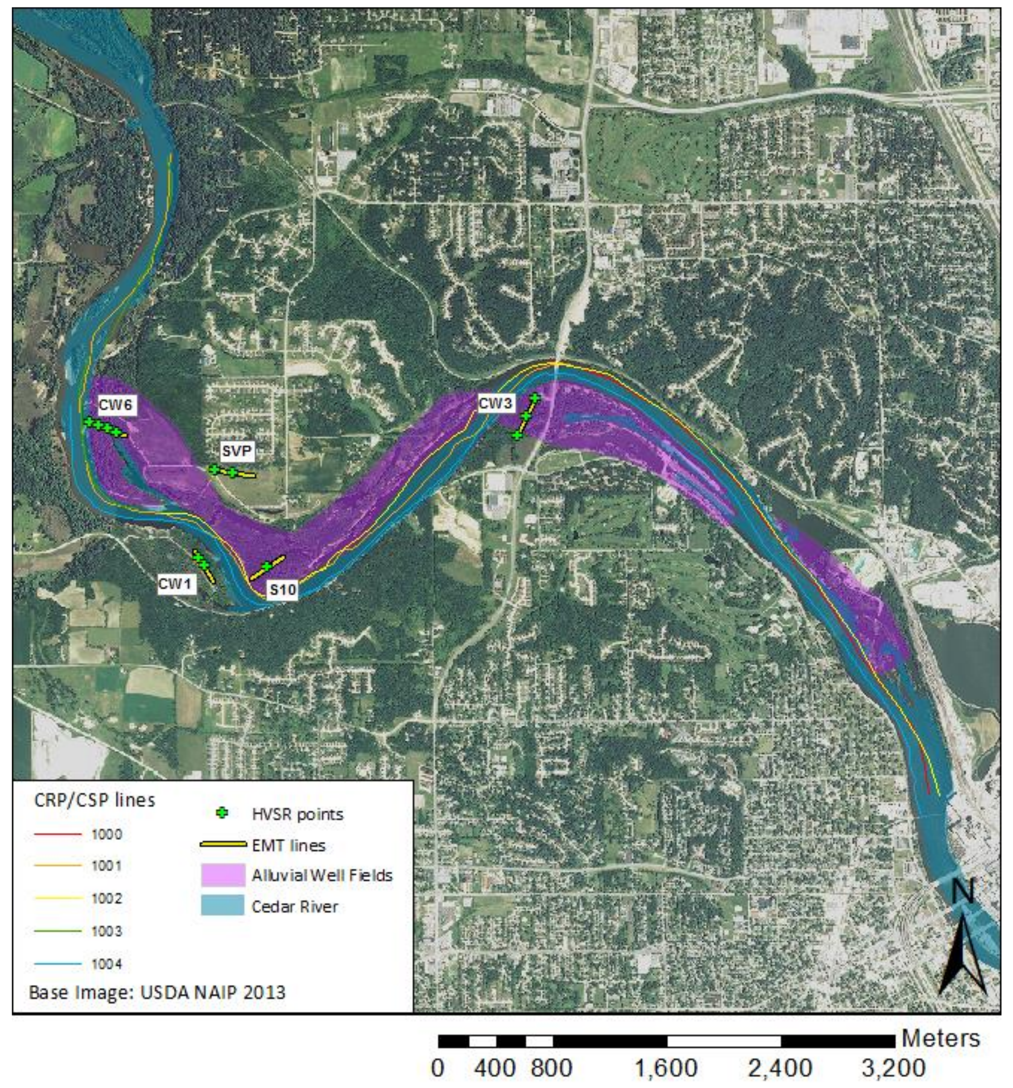
BACKGROUND

Between July 2011 and February 2013, Iowa experienced severe drought conditions (generally referred to as the 2012 drought) that critically affected water availability throughout the state where communities rely on alluvial aquifers to supply their water needs. The City of Cedar Rapids saw pumping levels drop to near cavitation levels in some wells. The City is interested in evaluating prolonged drought condition water-supply availability to determine if surface-water intakes need to be included in their water-treatment capabilities.

The USGS Iowa Water Science Center is charged with building a new groundwater model of the Cedar River alluvial aquifer that can simulate stresses and drawdowns experienced during extreme drought and demand. The new groundwater model considers river connectivity to the aquifer, alluvial aquifer connectivity to the bedrock aquifer, subsurface recharge sources such as tributary inflows and buried valleys, and wetland and oxbow lake connectivity to the alluvial aquifer. A suite of geophysical methods is being employed to efficiently and non-invasively map aquifer thickness and bedrock connectivity for parameterization of this model. These geophysical methods include waterborne and land-based seismic and resistivity surveys and a forthcoming airborne electromagnetic survey.

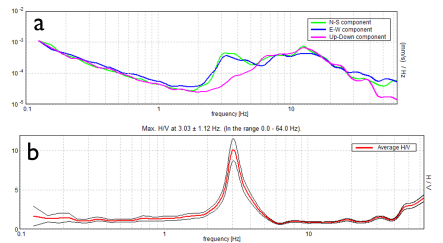
PROJECT AREA



LAND-BASED METHODS

Passive Seismic Horizontal-to-Vertical Spectral Ratio (HVSR)

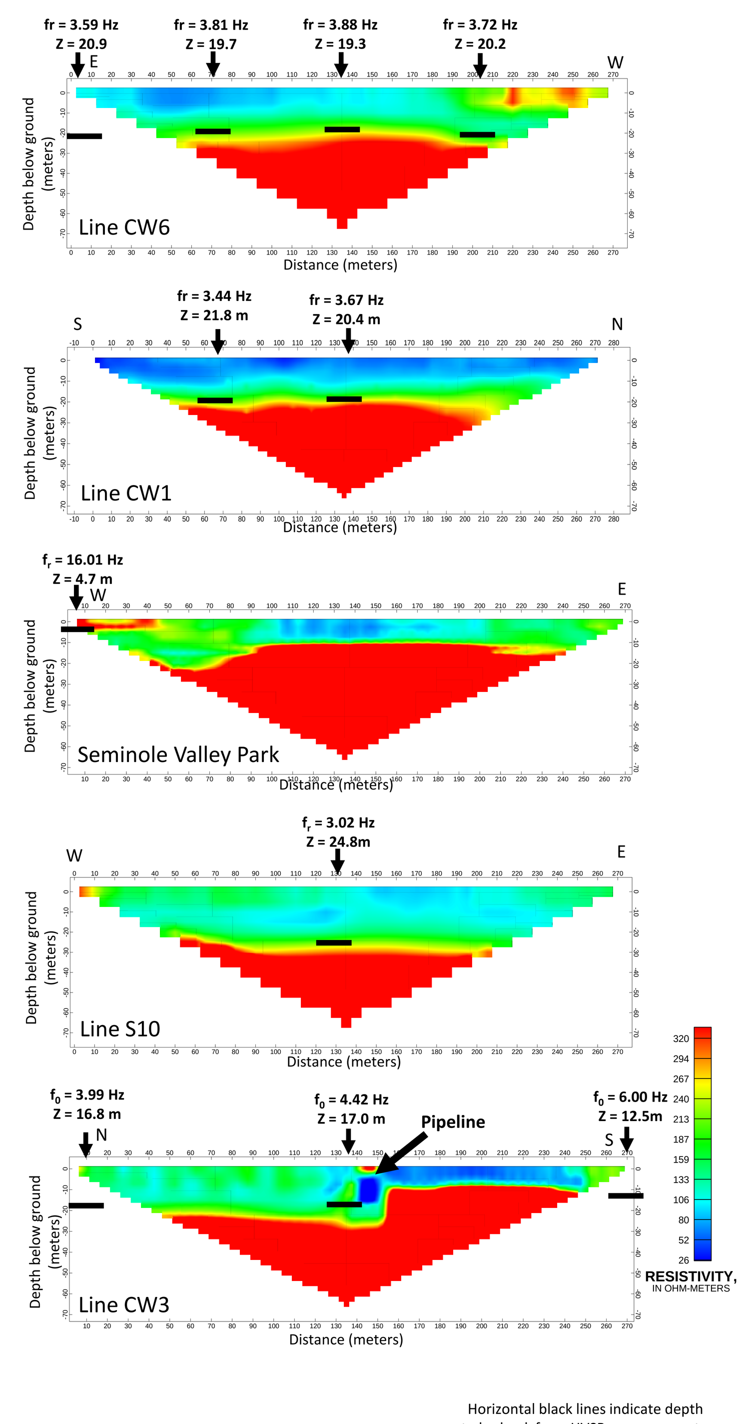
- Unit records ambient seismic wavefield using 2-horizontal and 1-vertical component; peak H/V frequency ratio is resonant frequency (F_r) of surficial material
- F_r related to seismic shear wave velocity (V_s) and depth to bedrock (Z) by the equation $V_s = 4F_rZ$
- Cedar River alluvium average V_s (300 m/s) calculated from measurements at 5 wells with known depth to rock
- Results depend on strong acoustic contrast between sediment and bedrock, good coupling of unit to ground surface, absence of anthropogenic noise



Sample HVSR data: (a) horizontal and vertical component frequency spectra, (b) horizontal to vertical frequency ratio.

Electrical Resistivity Tomography (ERT)

- Survey performed with Supersting R8
- Used dipole-dipole, Schlumberger, and inverse Schlumberger arrays
- Modeled resistivity ranges from 25 to 325 ohm-m
- Data affected by pipeline in line CW3

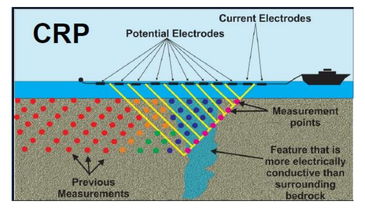


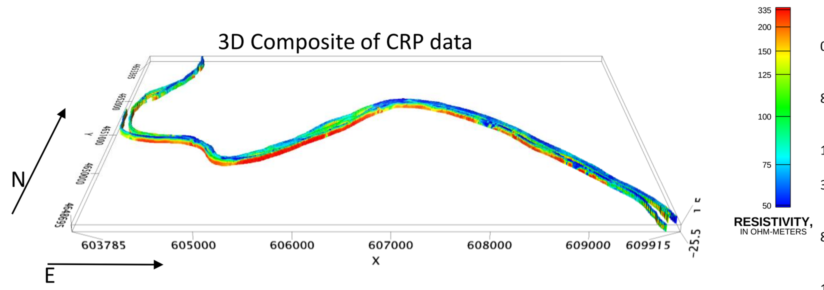
Horizontal black lines indicate depth to bedrock from HVSR measurements.

WATERBORNE METHODS

Continuous Resistivity Profiling (CRP)

- 8-channel resistivity system and 11-electrode streamer with 10-m spacing
- Depth of investigation ~16m
- Resistivity range: 30 to 300 ohm-m

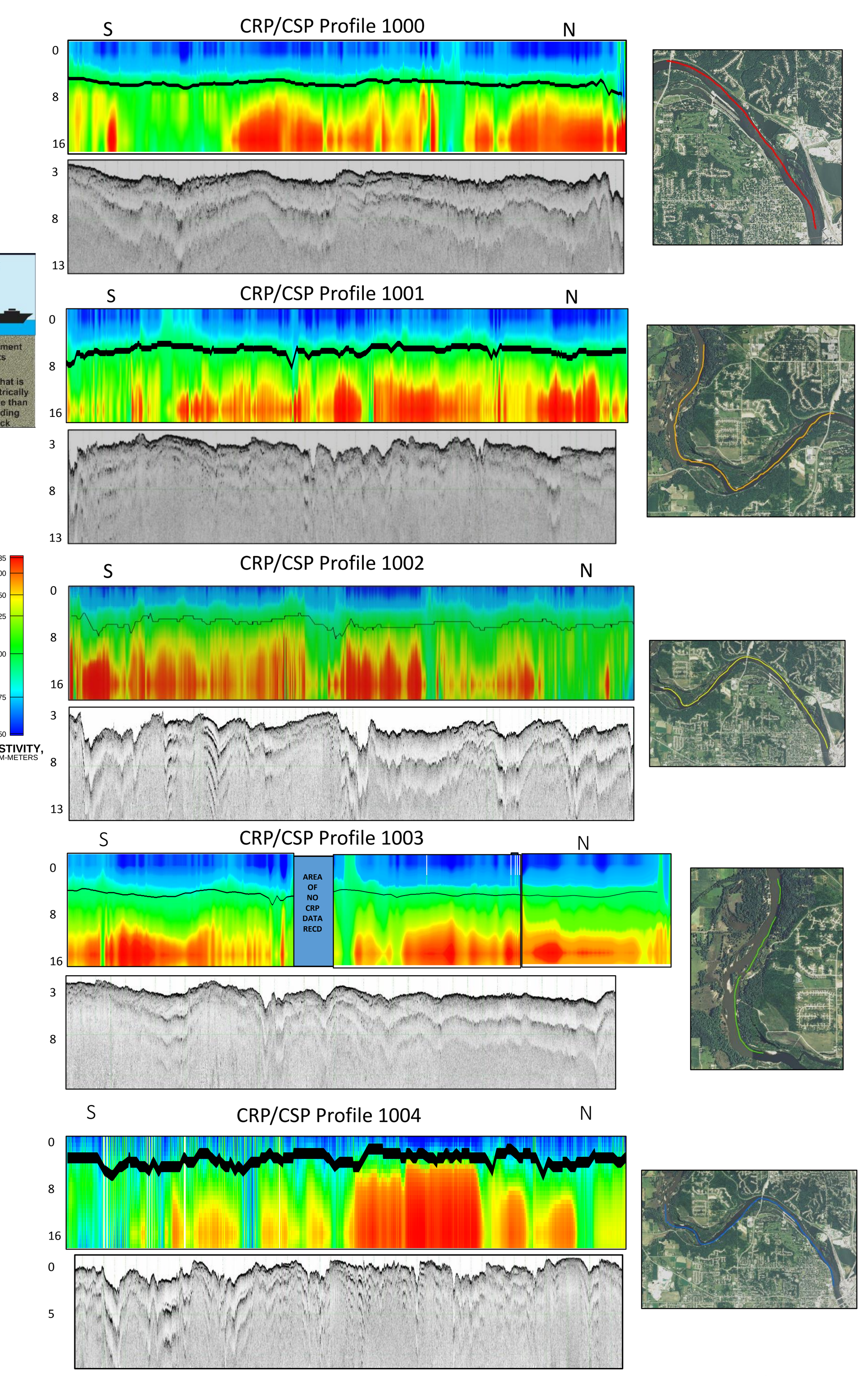




Continuous Seismic Profiling (CSP)

- 4 - 24 kHz Chirp system
- Subsurface penetration ~5m
- Water bottom multiples present in all records

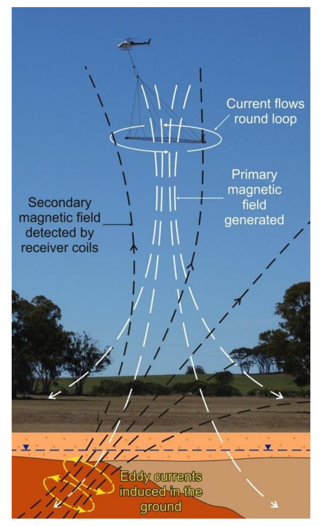
EdgeTech Sub-bottom Profiler



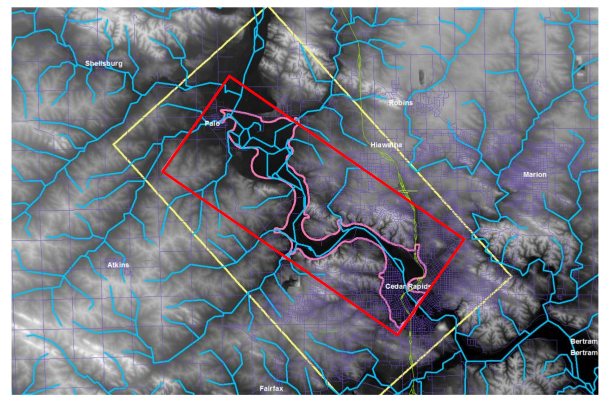
Black lines in CRP profiles indicate interpreted bedrock surface.

FUTURE WORK

- Airborne electromagnetic (AEM) survey spring 2017
- AEM will be calibrated to previous geophysical work and well data
- AEM will provide far more comprehensive and continuous data for an improved model
- AEM will be complemented with additional land-based seismic and ERT surveys, as well as new boreholes

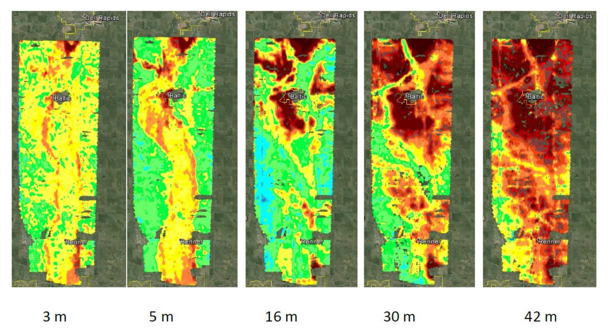


Cedar Rapids model area (yellow) and AEM survey area (red)



Example AEM data from Sioux Falls aquifer study. Warm colors represent more resistive material, preliminarily interpreted as quartzite.

Preliminary inversion model resistivities at different depths below ground surface



INTERPRETATIONS AND SUMMARY

Land-based surveys help characterize the extent and geophysical properties of floodplain sediments.

- HVSR useful for interpreting depth to bedrock in this area, with clear resonance peaks for bedrock mapping in most attempted surveys
- HVSR sensor coupling key to success
- ERT results match well to HVSR data
- Study area bedrock depths range from 5 to 28m
- ERT shows clear unconsolidated/bedrock transition
- ERT shows some shallow high-resistivity zones overlying less resistive materials (attributed to saturation, grain-size, or cementation differences)
- ERT and CRP resistivity ranges and structures similar
- Results will be used to calibrate AEM

Waterborne surveys provide information about channel sub-bottom, an area inaccessible to other methods.

- CRP and CSP methods delineate common sub-bottom features across multiple survey lines
- Shallow subsurface reflectors observed in CSP correlate with resistive zones observed in CRP.
- Shallow CSP reflectors interpreted as hard surface or fine/coarse transition
- Electrically resistive zones interpreted as hard/cemented materials or coarse-grained materials
- Results suggest possible buried valleys and regions of bedrock connectivity

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