TOWED TIME-DOMAIN ELECTROMAGNETIC INDUCTION (tTEM) - AN EFFICIENT METHOD FOR SHALLOW AQUIFER CHARACTERIZATION

1st Baghdad International Water Conference
13-14 March 2021

John W. Lane, PhD
U. S. Geological Survey, ESPD Hydrogeophysics Branch, Storrs, Connecticut
Aquifer Characterization:

Drilling

~$10^2$ Boreholes

Airborne Geophysics

~$10^5$ Airborne EM Models

Source: https://www2.usgs.gov/water/lowermississippigulf/map/shellmound_SM.html
Time-Domain Electromagnetics (TEM)

- Current loop generates EM field; induces EM field in subsurface conductors
- Size of loop and electrical current proportional to depth of investigation (DOI)
- DOI ~100-400+ m.

(Williams et al., 2017)
Why Airborne Geophysics?

Airborne Electromagnetics
~ 100 km / hour

Ground-based Resistivity
~ 1 km /day

Lake talik
permafrost
Ground-Based Vs Airborne Geophysical Methods: Scale/Cost Gap

- Project Scale (local to regional) / Funding / Logistical Constraints
- Unmet need for continuous imaging / profiling at medium scales

← Another Mobile Method? →
Towed TEM (tTEM): Rapid Subsurface Imaging

Limitations:
- Electromagnetic coupling (powerlines, pipelines, fences)
- Subsurface structure (conductive targets)
- Site access
tTEM: Links Ground-Based And Airborne Geophysics Scales
Aarhus University tTEM System (Commercialized)

Other international vendors entering the market (e.g., Australia)
Searching for safe water sources using a towed transient electromagnetic (tTEM) system – examples from refugee camps and the surrounding host communities in western Tanzania

Denys Grombacher¹, Pradip Maurya¹, Johan Lind¹, John W. Lane² and Esben Auken¹

¹Hydrogeophysics Group, Department of Geoscience, Aarhus University, Denmark
²Hydrogeophysics Branch, United States Geological Survey
tTEM Case Study: Western Tanzania

- Host community
- Refugee camp

[Map of Western Tanzania with markers for host communities and refugee camps]
Nyarugusu Refugee Camp (UNHCR)

Population: ~80,000

- Democratic Republic of the Congo (DRC)
- Burundi

Civil War
Natural Disaster
Poor Economic Conditions
Host Community Water Stress
Nyarugusu tTEM Survey
Nyarugusu tTEM Profiles

Red profile

Blue profile
Nyarugusu tTEM Profiles

Red profile

Blue profile
Nyarugusu tTEM Survey: 3D interpretation
tTEM Production Rates: Western Tanzania

Average >13 km/day

<table>
<thead>
<tr>
<th>Refugee Camp</th>
<th># of days</th>
<th># of kms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nyarugusu</td>
<td>4</td>
<td>56.1</td>
</tr>
<tr>
<td>Nduta</td>
<td>4</td>
<td>65.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Host Community</th>
<th># of days</th>
<th># of kms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaguruka</td>
<td>1</td>
<td>12.2</td>
</tr>
<tr>
<td>Kigadye</td>
<td>1</td>
<td>12.1</td>
</tr>
<tr>
<td>Kitagata</td>
<td>1.5</td>
<td>14.4</td>
</tr>
<tr>
<td>Makere</td>
<td>1.5</td>
<td>11.8</td>
</tr>
<tr>
<td>Muzye</td>
<td>1</td>
<td>17</td>
</tr>
</tbody>
</table>
## Method Comparison

<table>
<thead>
<tr>
<th></th>
<th>TEM</th>
<th>tTEM</th>
<th>AEM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acquisition time</strong></td>
<td>1 S/hour</td>
<td>4-5 km/hr</td>
<td>20-30+ km/hr</td>
</tr>
<tr>
<td><strong>Lateral resolution</strong></td>
<td>1 Sounding (S)</td>
<td>3 m</td>
<td>10-50 m</td>
</tr>
<tr>
<td><strong>Depth Resolution</strong></td>
<td>Shallow-Deep</td>
<td>Shallow-med.</td>
<td>Deep</td>
</tr>
<tr>
<td><strong>Depth of investigation</strong></td>
<td>100-400+ m</td>
<td>80+ m</td>
<td>~100-600 m</td>
</tr>
<tr>
<td><strong>Cost of deployment</strong></td>
<td>$</td>
<td>$$</td>
<td>$$$</td>
</tr>
<tr>
<td><strong>Cost per sounding</strong></td>
<td>$$$</td>
<td>$</td>
<td>$$</td>
</tr>
<tr>
<td><strong>Limitation</strong></td>
<td>Labor Intensive</td>
<td>ATV /Boat Access</td>
<td>Flight Access Logistics</td>
</tr>
</tbody>
</table>
tTEM Summary

• Shallow Aquifer Characterization (0-100m)
• Efficient Mobile Method (ATV/Boat Towed)
• Addresses Scales between Ground-based and Airborne Surveys
• Emerging Commercial Market and Instruments

Limitations
• Electromagnetic Coupling
• Open Access
• Electrically Resistive Terrains
QUESTIONS?

Author gratefully acknowledges contributions to this presentation by:
USGS - Carole Johnson, Burke Minsley, and Eric White
Aarhus University - Denys Grombacher, Pradip Maurya, Johan Lind, and Esben Auken

References:
Burton, B.L., Minsley, B.J., Bloss, B.R., Rigby, J.R., Kress, W.H., and Smith, B.D., 2019,
Airborne electromagnetic, magnetic, and radiometric survey, Shellmound, Mississippi, March 2018:
U.S. Geological Survey data release, https://doi.org/10.5066/P9D4EA9W.

Burton, B.L., Minsley, B.J., Bloss, B.R., Kress, W.H., Rigby, J.R., and Smith, B.D., 2020,
Highresolution airborne geophysical survey of the Shellmound, Mississippi area: U.S. Geological

Some images extracted from: https://www2.usgs.gov/water/lowermississippigulf/map/shellmound_SM.html