1.0 Scope and Applicability

1.1 The GEM-2 broadband electromagnetic geophysical sensor can be used to identify areas of elevated soil conductivity that may be associated with buried waste materials or releases of hazardous substances. Depending on circumstances and site conditions, GEM-2 geophysical surveys may help facilitate the following site assessment activities:

- Locating suspected underground storage tanks (USTs) and other buried objects or structures (e.g., drums, voids or foundations)
- Placing soil borings and monitoring wells where waste materials or hazardous substances are more likely to be present (e.g., the presence of landfilled material)
- Understanding site geology (e.g., differentiating fill from native soil, identifying lateral changes in soil type)

1.2 The GEM-2 operates by transmitting a low frequency electromagnetic field into the ground. When contacted by the primary field, subsurface materials spontaneously generate secondary electromagnetic fields that are measured by the GEM-2 receiver (Figures 1 and 2). Based on the relationship between the transmitted field and the received field, GEM-2 data can be used to estimate the bulk (apparent) conductivity of soil or fill materials. In addition, GEM-2 data can be used to estimate magnetic susceptibility, which is a measure of the ability of soil or fill materials to become magnetized. Magnetic susceptibility data are similar to magnetometer data and can be used to locate materials or structures that contain ferrous (iron-bearing) metal.

1.3 GEM-2 data should be used for site screening purposes only. Geophysical data are always open to interpretation and never provide definitive answers regarding subsurface conditions.

1.4 GEM-2 surveys are performed by DERR-SIFU staff who have received specialized training to properly operate and maintain the instrument. GEM-2 data evaluation and reporting are performed by DERR personnel who have received specialized training in geophysical surveying techniques.

2.0 Definitions

2.1 Anomaly: an area of relatively high or low conductivity (compared to background conditions) that may be related to a target of interest, e.g., buried drums

2.2 Apparent Conductivity: conductivity (mS/m) measured at a given height above the earth; in general, apparent conductivity is less than the conductivity measured at the ground surface due to the airspace between the GEM-2 and the ground; apparent conductivity is also a measure of the bulk conductivity of the earth below the instrument
2.3 Conductivity: the ratio of electrical current flow to the applied voltage per unit length, measured in millisiemens/meter (mS/m)

2.4 Electromagnetic Induction: a geophysical technique in which the primary electromagnetic field of a transmitter induces an electrical current in the earth, which produces a secondary electromagnetic field that is measured by a receiver

2.5 Magnetic Susceptibility (or Permeability): a response from the reorientation of the magnetic domains in the earth induced by the primary field of the GEM-2 receiver, which is a measure of the ability of the earth to become magnetized (dimensionless property)

2.6 Primary Field: the electromagnetic field transmitted into the ground by the GEM-2

2.7 Secondary Field: the electromagnetic ground response received by the GEM-2

3.0 Health and Safety Considerations

3.1 Follow the site-specific health and safety plan (HASP) if one is available. Otherwise follow the health and safety procedures provided by FSOP 1.1, Initial Site Entry.

3.2 Dress appropriately for anticipated weather conditions, and always have ample drinking water available when working in hot weather. Insect repellant may be needed for protection from ticks, mosquitoes, and other biting insects in heavily wooded areas.

3.3 Use caution when clearing brush or removing other obstacles from survey areas, and wear appropriate personal protective equipment (PPE), including but not limited to safety glasses or goggles, hard hats, steel-toed boots.

4.0 Procedure Cautions

4.1 The GEM-2 should never be used for subsurface utility clearance. The instrument is not designed for this purpose, and DERR staff are neither authorized nor trained to perform utility clearance. Refer to FSOP 1.2, Utility Clearance to clear locations for drilling or excavation.

4.2 The GEM-2 may not operate properly under rainy weather conditions or high humidity.

4.3 GEM-2 surveys are difficult to perform (and may not provide usable data) under the following site conditions:
   - Steep slopes
   - Heavily wooded areas with thick brush
   - Areas within buildings or other structures

---

1 Clearing brush for surveys may require a significant amount of time.
- Areas with high levels of electromagnetic interference, e.g., junkyards or the central areas of landfills
- In close vicinity to large metal objects/structures or operating equipment that create high levels of electromagnetic interference, e.g., vehicles, metal buildings, generators

5.0 Personnel Qualifications

5.1 Ohio EPA personnel working at sites that fall under the scope of OSHA’s hazardous waste operations and emergency response standard (29 CFR 1910.120) must meet the training requirements described in that standard.

5.2 Personnel must receive specialized training to operate and maintain the GEM-2 or to evaluate GEM-2 data and prepare reports.

6.0 Equipment and Supplies

6.1 GEM-2 electromagnetic sensor and associated equipment (Trimble unit, additional charged batteries)
6.2 Field laptop computer with cables to download GEM-2 data files
6.3 Geophysical field notebook, GEM-2 electromagnetic survey field forms, pens and markers
6.4 Power inverter (to run laptop)
6.5 Traffic cones
6.6 300 ft measuring tapes (at least four)
6.7 Flags, survey pins and marking paint
6.8 Hand tools to clear brush (axes, saws, machetes)
6.9 Tool box
6.10 Other surveying supplies as needed based on site conditions
6.11 GPS unit

7.0 Procedures

7.1 Scope of Work Development and Project Planning

7.1.1 Prior to performing a GEM-2 survey, the survey requestor needs to develop project objectives and a scope of work. DERR-SIFU staff can assist with this task, and scheduling a project pre-meeting (or conference call) is recommended. The initial contact is the DERR-SIFU supervisor.

---

2 Electrical fields from overhead power lines and transformers do not adversely affect GEM-2 surveys because the frequencies used by the instrument are out-of-phase with power line frequencies.
7.1.2 DERR-SIFU will provide an estimated cost for the survey.

7.1.3 The survey requestor will arrange site access and provide DERR-SIFU staff a copy of the access agreement. Geophysical surveying work cannot be performed until consent to access is obtained.

7.1.4 The survey requestor and DERR-SIFU will agree on survey and deliverable (report) dates.

7.2 Surveying

7.2.1 GEM-2 surveys will be conducted on the agreed-upon dates unless surveying cannot be performed due to inclement weather (heavy rain), site access or other unforeseen circumstances.

7.2.2 DERR-SIFU staff will design and perform the survey based the requestor’s objectives and scope of work. Surveys are performed in a manner that maximizes the potential for locating targets of interest (anomalies) while minimizing potential electromagnetic interference. Typically, survey areas are gridded using measuring tapes and traffic cones or flags. The GEM-2 is capable of simultaneously running multiple frequencies (primary fields) to evaluate multiple depth intervals, and DERR-SIFU staff select frequencies based on the project objectives and site conditions. The maximum depth of investigation ranges between 15 and 100 feet depending on the frequencies used and the site conditions. DERR-SIFU staff generally can survey between two and four acres of area per eight-hour day, depending on site conditions.

7.3 Data Evaluation and Reporting Options

7.3.1 Field-Screening Only:
The “field-screening only” option includes in-field evaluation of GEM-2 data using a laptop computer. DERR-SIFU staff can prepare “real time” maps of apparent conductivity and magnetic susceptibility during surveying to locate anomalies (examples provided in Figures 4 and 5). A report is not prepared, but maps generated during the survey can be provided to the requestor in electronic format if requested. If requested, copies of raw data files will also be provided in electronic format.

7.3.2 Field Screening with Report:
The “field-screening with report” option includes field-screening activities as described above and a short report that includes a brief narrative describing the results of the survey, maps of apparent conductivity and magnetic susceptibility, photographs (as needed for supporting documentation), and copies of field notes. The report will be provided in electronic format. If requested, copies of raw data files will also be provided in electronic format.
8.0 Data and Records Management

Please refer to FSOP 1.3, Field Documentation.

9.0 Quality Assurance and Quality Control

9.1 DERR SIFU follows the manufacturer's (Geophex's) recommendations for GEM-2 maintenance and repair.

9.2 DERR management and staff provide peer-review of draft reports.

10.0 Attachments

Not applicable

11.0 References

FSOP 1.1, Initial Site Entry
FSOP 1.2, Utility Clearance
FSOP 1.3, Field Documentation


Won, I.J., and Huang, H., May 2004, Magnetometers and electro-magnetometers (Tutorial): The Leading Edge


Figure 1: GEM-2 Electromagnetic Induction Survey in Progress

Figure 2: GEM-2 Electromagnetic Induction Survey in Progress
Figure 3: Example GEM-2 Geophysical Survey Map
(Evaluating Former Landfill Limits of Waste Placement and High-Conductivity Target Areas for Sampling)
Figure 4: Example GEM-2 Geophysical Survey Map
(Evaluating High-Conductivity Target Areas for Sampling, Residential Neighborhood Constructed over Former Landfill Area)