UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

160 East 7th Street
CHESTER, PA 19013

SUBJECT: Site Assessments with Electromagnetic Induction (EM) Techniques: Macon County, Missouri; 18 June 1993

DATE: 7 July 1993

To: Hugh A. Curry
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Purpose:
To use electromagnetic induction (EM) techniques to assess seepage and potential sources of ground water contamination from an animal-waste pond near Bevier, Missouri.

Participants:
Reese Coulter, Area Engineer, SCS, Hannibal, MO
Jim Doolittle, Soil Specialist, SCS, Chester, PA
Kim Doolittle, Volunteer, SCS, Chester, PA
Richard Pemberton, SCT, SCS, Macon, MO

Activities:
An animal-waste holding pond north of Bevier, Missouri, was surveyed during the afternoon of 18 June 1993. Reese Coulter and Richard Pemberton had established a grid across the site prior to the arrival of the EM equipment. In addition, they had obtained surface elevations at each grid intersect. At the conclusion of the survey, participants returned to the Macon County Field Office to discuss the results.

Equipment:
The electromagnetic induction meter was the EM31 manufactured by GEONICS Limited. Measurements of conductivity are expressed as milliSiemens per meter (mS/m). Two-dimensional plots of the EM data were prepared using SURFER software developed by Golden Software, Inc.

Discussion:
Study Area
The existing waste-holding facility was located on a south-facing backslope to an upland area. A 500 by 300 foot grid was established in a downslope direction of the existing waste-holding pond. The grid interval was 50 feet. The grid included the backslope area and a portion of the high bottomland to Town Creek. Survey flags were inserted in the ground at each of the 77 grid intersect. At each

intersect, relative elevations were obtained with a transit and stadia rod. Within the survey area, relief was about 23 feet (see Figure 1). In Figure 1, the location of a fence line has been indicated. As the fence contained metals, it was a potential source of interference to the EM response. In Figure 1, the location of a soil sampling site (from which a nitrate analysis was made) has been identified with an spot symbol.

The study site included a severely eroded phase of Armstrong soils, map unit 15D3, on 7 to 15 percent slopes. Armstrong is member of the fine montmorillonitic, mesic Aquollic Hapludalf family. This moderately well drained or somewhat poorly drained soil formed in till. Map unit 15D3 is generally assumed to be unsuited to sewage lagoons because of steep slopes.

Also included within the study site is an area of Vesser soils, map unit 66. Vesser is member of the fine-silty, mixed, mesic Argiaquic Argialboll family. This somewhat poorly drained or poorly drained soil formed in alluvium on the lower-lying, high bottomlands. Map unit 66 is generally assumed to be unsuited to sewage lagoons because of wetness and the hazards of flooding.

EM Survey

At the time of the survey, both soils were saturated by recent rains. Because of a higher clay content dominated by montmorillonitic clay minerals, it was anticipated that Armstrong soils would display a higher electromagnetic response than Vesser soils (this deduction was later proven correct).

At each intersect, measurements were obtained with the EM31 meter in both the horizontal and vertical dipole modes. Figures 2 and 3 are two-dimensional plots of the apparent conductivity measurements. In each plot, the interval is 5 mS/m. These plots represent computer simulations of data obtained with the EM31 in the horizontal and vertical dipole modes, respectively. The EM31 meter scans depths of 0-2.75 meters in the horizontal and 0-6.0 meters in the vertical dipole mode.

In Figure 2, values of apparent conductivity are lowest in the southern portion of the survey area. This general pattern reflects the occurrence of Vesser and associated soils with lower clay contents on the high bottomland. In the northern part of the survey area, the higher-lying uplands are dominated by Armstrong soils. Compared with Vesser soils, Armstrong soils have higher clay contents and higher apparent conductivity values.

Patterns of apparent conductivity within the bottomland (southern portion of Figure 2) appear complex. In Figure 2, a conspicuous east-west trending belt of higher apparent conductivity values has been identified with the letter "A." This belt is believed to delineate a filled, former drainageway which paralleled the base of the slope to the upland area. The landowner reported that this relatively shallow drainageway had been filled, in part, with highly conductive waste materials from the swine operation and holding ponds.

The northeastern corner of the belt of higher apparent conductivity values (A in Figure 1) appears to extend upslope, towards the waste-holding pond. However, as the EM response appears to be detached and to increase away from this structure, this survey does not reveal a strong positive association between the two features.

A fairly restricted zone of relatively high apparent conductivity values (>70 mS/m) appears to emanate from the southeast corner of the animal-waste holding pond (see "B" in Figure 2). This zone is confined to the embankment of the pond and extends away from the structure in a downslope direction (towards the south). Within this zone, values of apparent conductivities decrease in a downslope direction. This is the only area surrounding the waste-holding pond that displays a pattern implying possible seepage and the concentrations of animal wastes in the upper part of the soils. It is noteworthy that the soil sampling site (see spot symbol) was located in an area between the implied plume and filled drainageway.

In Figure 2, the higher apparent conductivity values about and immediately downslope of "C" were unanticipated. The landowner disclosed that a former waste-holding structure had been located in this general area. The higher EM responses near "C" are believed to reflect higher concentrations of soluble salts in the soil profile. These salts would have been introduced into the soil from wastes contained in the former holding structure.

In Figure 2, anomalously low conductivity values along the fence line are believed to reflect "cultural noise." These fairly large, circular patterns are believed to be related to buried metallic objects, proximity of observation sites to the fence line, and/or the coarseness of the grid interval.

The two-dimensional plot in Figure 3 simulates the EM response recorded in the vertical dipole orientation. As with the responses collected in the horizontal dipole orientation (Figure 2), values of apparent conductivity are lowest within the lower-lying bottomlands This pattern reflects the presence of soils with lower clay contents on the bottomlands. In Figure 3, the EM response is highest on upland areas dominated by Armstrong soils. Compared with Vesser soils, Armstrong soils have higher clay contents and higher apparent conductivity values.

In Figure 3, a conspicuous northwest-southeast trending belt (see "A") of higher apparent conductivity values (75 to 90 mS/m) extends across the plot. This feature is detached from and does not appear to be associated with the waste-holding pond. This anomalous feature my represent a filled, former drainageway or a buried pipe line.

The filled, former drainageway which was evident in Figure 2 is no longer evident in the deeper measurements of Figure 3. This lack of definition with the deeper EM measurements could reflect a relatively shallow feature (i.e. filled drainageway) and/or underlying materials with higher conductivities (i.e buried upland soils).

A fairly restricted area of relatively high apparent conductivity values appears to emanate from the southeast corner of the animal-waste holding pond (see "B" in Figure 3) and extends in a downslope direction (towards the south). The maximum downslope extent of this plume-like area from the waste-holding pond is about 75 feet. Within this area values of apparent conductivities decrease in a downslope direction. This is the only area surrounding the waste-holding pond that displays a pattern which suggest possible seepage and concentrations of animal wastes. This pattern replicates a similar feature shown in Figure 2. It is significant that the soil sampling site (see spot symbol) was located adjacent to this plume-like area.

In Figure 3 (as in Figure 2), the influence of materials from a former waste-holding structure is reflected in higher EM responses near "C." The higher values about and immediately downslope of "C" are believed to reflect higher concentrations of soluble salts in the soil profile. These salts have been introduced into the soil from the wastes contained in the former holding structure.

Results:

1. This survey provides an assessment of a waste-holding pond site in Macon County, Missouri. The EM survey provided interpretative maps of variations in apparent conductivity values within the survey area. The enclosed plots provide insight into the variability of subsurface conditions existing within the survey area. Results from this survey are inconclusive and must be verified with field observations. Ground truth verification is needed to confirm the nature and magnitude of the inferences made in this report. Plot should be used to guide interpretations and the selection of further sampling sites.

2. The site has a complex history. Some waste materials may have been used to fill a former drainageway which paralleled the base of the uplands. In addition, a former waste-holding structure was located in the northeast corner of this site. The EM survey revealed the presence and general locations of these features. High levels of nitrates detected in surrounding soils may be from these features and not from the waste-holding pond.

3. High levels of nitrates have been detected near the present waste-holding pond. However, the EM survey revealed complex subsurface patterns and little evidence to support extensive seepage from the existing waste-holding pond. A limited zone of subsurface seepage in the southeast corner of the waste-holding pond is suggested by the EM response.

4. Results from this study support the use of EM techniques for the assessment of seepage and potential ground water contamination from animal waste-holding structures. Additional studies in Missouri are encouraged. These studies should assess the extent of seepage from waste-holding structures.

It is my pleasure to work in Missouri and with the members of your fine staff.

With kind regards.

James A. Doolittle
Soil Specialist

cc:
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Figure 1.

RELATIVE TOPOGRAPHY
MACON COUNTY SITE
CONTOUR INTERVAL = 2 FEET

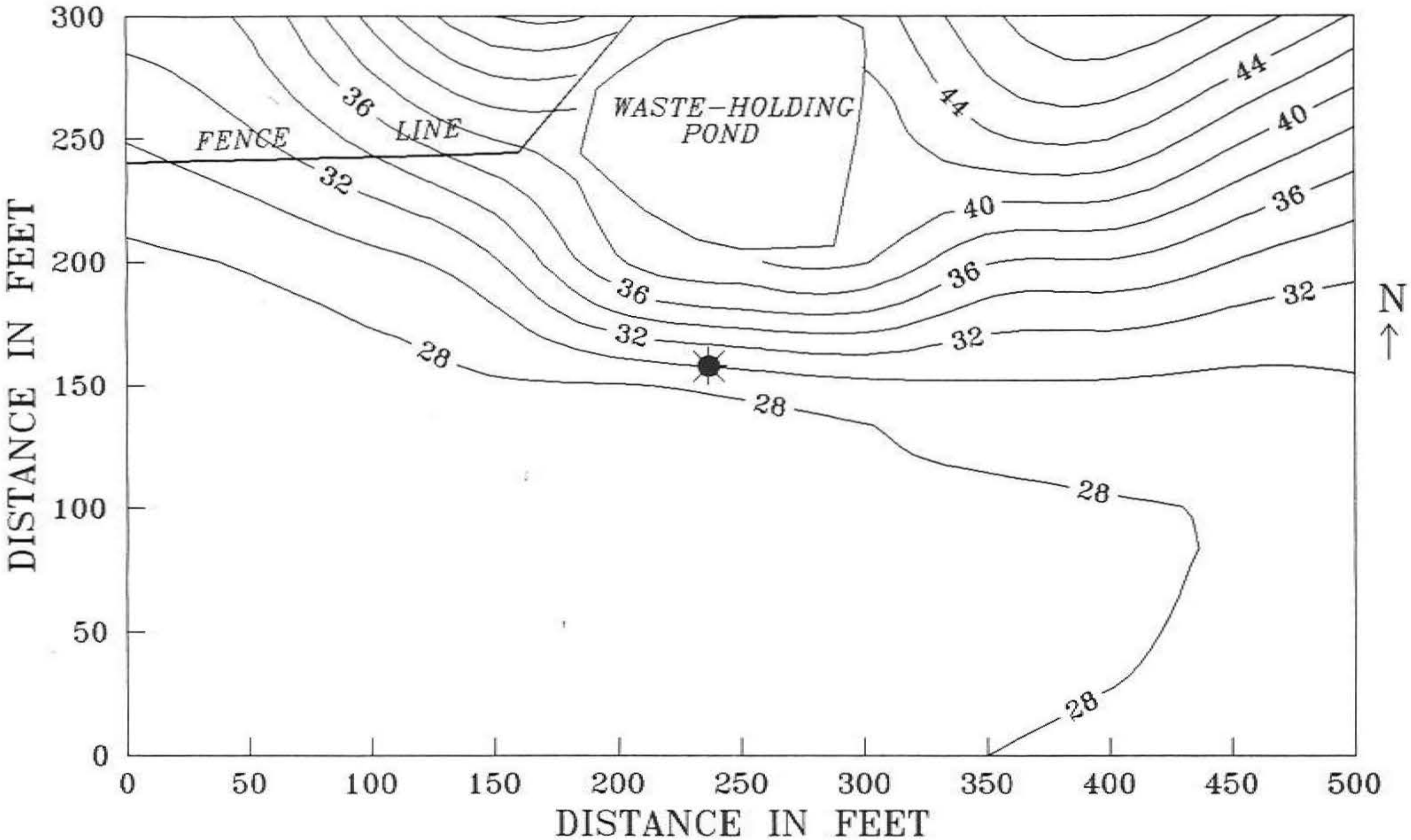


Figure 2.

EM31 SURVEY OF ANIMAL-WASTE POND

MACON COUNTY SITE

HORIZONTAL DIPOLE ORIENTATION

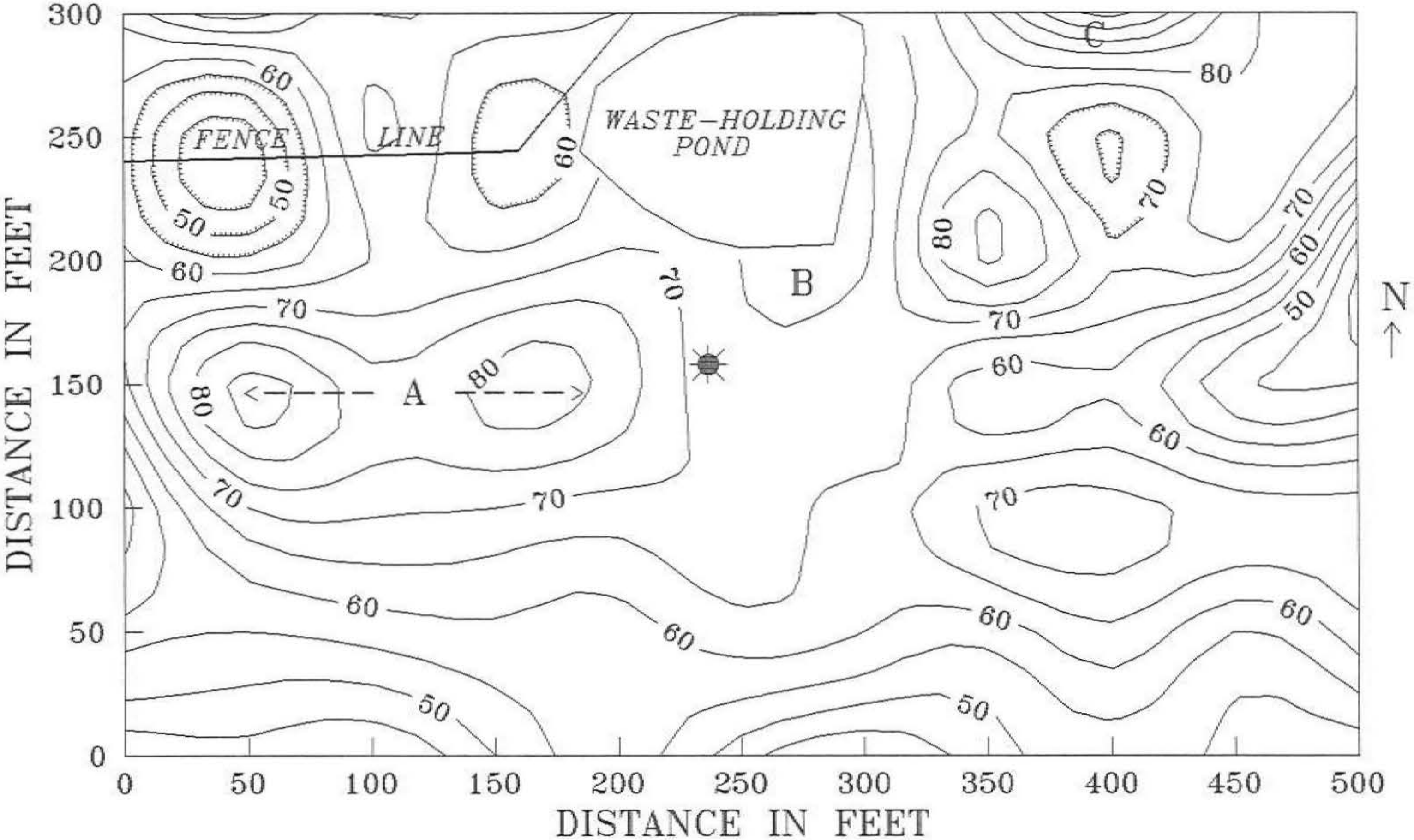
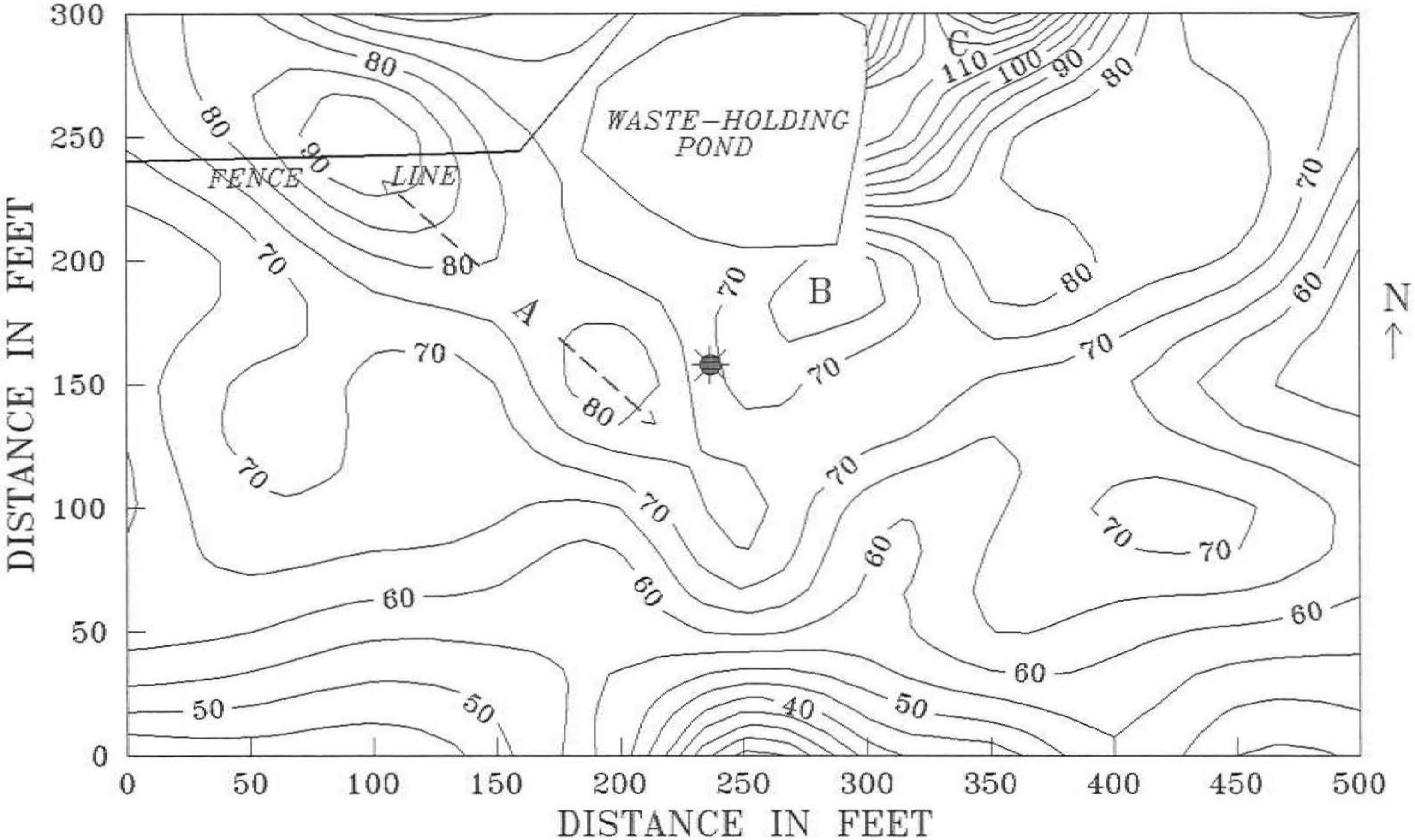


Figure 3.

EM31 SURVEY OF ANIMAL-WASTE POND

MACON COUNTY SITE

VERTICAL DIPOLE ORIENTATION



Review of Electromagnetic Induction Methods

Electromagnetic inductive (EM) is a surface-geophysical method in which electromagnetic energy is used to measure the terrain or apparent conductivity of earthen materials. This technique has been used extensively to monitor groundwater quality and potential seepage from waste sites (Brune and Doolittle, 1990; Byrnes and Stoner, 1988; De Rose, 1986; Greenhouse and Slaine, 1983; Greenhouse et al., 1987; and Siegrist and Hargett, 1989)

For surveying, the meter is placed on the ground surface or held above the surface at a specified distance. A power source within the meter generates an alternating current in the transmitter coil. The current flow produces a primary magnetic field and induces electrical currents in the soil. The induced current flow is proportional to the electrical conductivity of the intervening medium. The electrical currents create a secondary magnetic field in the soil. The secondary magnetic field is of the same frequency as the primary field but of different phase and direction. The primary and secondary fields are measured as a change in the potential induced in the receiver coil. At low transmission frequency, the ratio of the secondary to the primary magnetic field is directly proportional to the ground conductivity. Values of apparent conductivity are expressed in milliSiemens per meter (mS/m).

Electromagnetic methods measure the apparent conductivity of earthen materials. Apparent conductivity is the weighted average conductivity measurement for a column of earthen materials to a specified penetration depth (Greenhouse and Slaine; 1983). The averages are weighted according to the depth response function of the meter (Slavich and Petterson, 1990).

Variations in the meters response are produced by changes in the ionic concentration of earthen materials which reflects changes in sediment type, degree of saturation, nature of the ions in solution, and metallic objects. Factors influencing the conductivity of earthen materials include: (i) the volumetric water content, (ii) the amount and type of ions in soil water, (iii) the amount and type of clays in the soil matrix, and (iv) the soil temperature. Williams and Baker (1982), and Williams (1983) observed that, in areas of salt affected soils, 65 to 70 percent of the variation in measurements could be explained by the concentration of soluble salts. However, as water provides the electrolytic solution through which the current must pass, a threshold level of moisture is required in order to obtain meaningful results (Van der Lelij, 1983).

The depth of penetration is dependent upon the intercoil spacing, transmission frequency, and coil orientation relative to the ground surface. Table 1 list the anticipated depths of measurements for the EM31 meter. The actual depth of measurement will depend on the conductivity of the earthen material(s) scanned.

TABLE 1

Depth of Measurement

Meter	Intercoil Spacing	Depth of Measurement Horizontal	Vertical
EM31	3.7 m	2.75 m	6.0 m

The conductivity meters provide limited vertical resolution and depth information. However, as discussed by Benson and others (1984), the absolute EM values are not necessarily diagnostic in themselves, but lateral and vertical variations in these measurements are significant. The seasonal variation in soil conductivity (produced by variations in soil moisture and temperature) can be added to the statement by Benson. Interpretations of the EM data are based on the identification of spatial patterns in the data set appearing on two-dimensional contour plots.

References

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