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ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support -- 1988

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A long-term program for studying possible effects from the operation of the Navy's ELF Communications System is being conducted on biota and ecosystems components in northwestern Wisconsin and the Upper Peninsula of Michigan. Sixteen general types of organisms from three major ecosystems in the ELF system area are being examined. Formulation of an ELF Ecological Monitoring Program was completed in early 1982 by the Department of the Navy, and studies were initiated in late summer of the same year. Beginning in 1983 and continuing during 1984, major activities of the program consisted of characterization of critical aspects of each study, collection of data to validate assumptions made in proposals, and selection of study sites. From 1985 through 1988, activities centered on the operation of full-scale studies. This report documents electromagnetic (EM) field measurements at investigator selected study sites from 1982 through 1988. Other engineering support activities are also described.

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FOREWORD

This report documents measurements of extremely low frequency (ELF) electromagnetic (EM) fields made in support of the U.S. Navy's ELF Communications System Ecological Monitoring Program from late 1982 through 1988. The report also describes other engineering activities in support of these ecological studies. This work was funded by the Space and Naval Warfare Systems Command, Submarine Communications Project Office, under Contract Numbers N00039-81-C-0357, N00039-84-C-0070, and N00039-88-C-0065, to IIT Research Institute (IITRI). IITRI measurement personnel for 1988 were Messrs. D. P. Haradem, J. R. Gauger, R. G. Drexler, M. W. Zankl, J. A. Rubino, and Dr. J. E. Zapotosky.

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CONTENTS

CONTENTS (continued)

FIGURES

FIGURES (continued)

TABLE

ELF COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING PROGRAM:
ELECTROMAGNETIC FIELD MEASUREMENTS AND ENGINEERING SUPPORT--1988

1. INTRODUCTION

1.1 Ecological Monitoring Program

In 1981, concurrent with its decision to complete construction of an Extremely Low Frequency (ELF) Communications System, the Department of the Navy funded an Ecological Monitoring Program. The purpose of the program is to determine whether long-term exposure to electromagnetic (EM) fields produced by the communications system will result in adverse effects on resident biota or their ecological relationships. Monitoring studies have been performed since 1982 by investigators from five universities located in the Great Lakes region.

Accurate data are needed to evaluate cause-and-effect relationships between EM field exposure and biological/ecological end points. As part of the program, IIT Research Institute (IITRI) assists university investigators by making EM field measurements and providing other EM engineering support. This support includes analysis of EM aspects of research protocols; design, fabrication, and installation of special EM field exposure equipment; and review of EM field data presented in annual reports in the context of environmental protection or risk. Each year, IITRI prepares a report to document its engineering activities performed in support of the program's biological and ecological studies. The present report documents engineering support activities performed during 1988 and provides a comprehensive record of EM field measurements from 1982 through 1988.

1.2 ELF Communications System

The complete ELF Communications System consists of two transmitting facilities, one located in the Chequamegon National Forest in Wisconsin and the other in the Copper Country and Escanaba River State Forests in Michigan (see Figure 1). Each facility consists of a transmitter connected to long overhead wires (antennas) with buried ground terminals at their ends. Both the antenna and grounding elements are located in cleared rights-of-way (ROW). The Wisconsin Transmitting Facility (WTF) has two antenna elements, referred to as the north-south (NS) and east-west (EW) elements, each 14 miles

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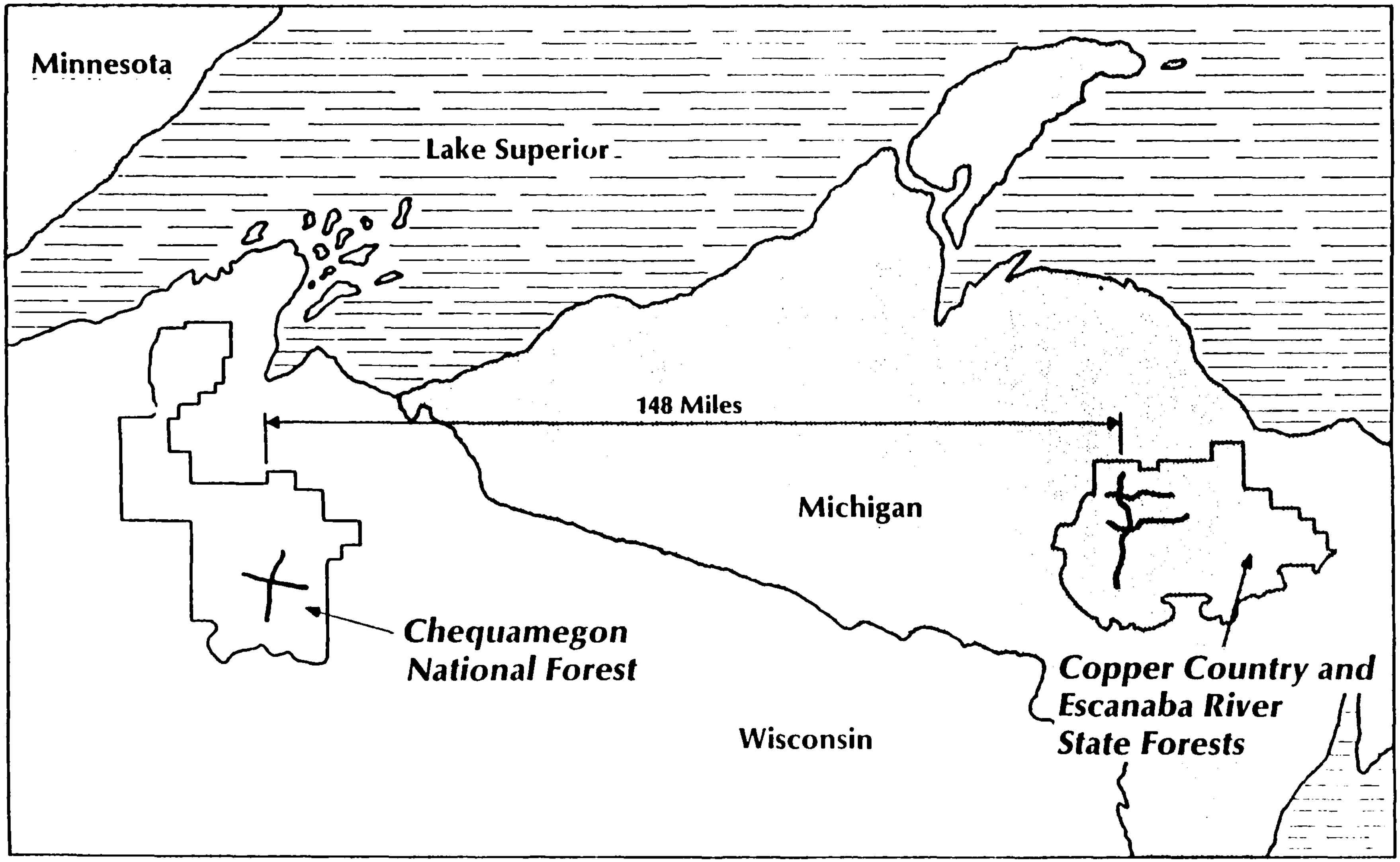

FIGURE 1. ELF COMMUNICATIONS FACILITIES IN WISCONSIN AND MICHIGAN.

long. The Michigan Transmitting Facility (MTF) has three antenna elements, a NS element 28 miles long and two EW elements each 14 miles long. The two EW elements are referred to individually as the northern east-west (NEW) and the southern east-west (SEW) elements; references made to the EW element collectively refer to both the NEW and SEW elements. The end of each antenna element is terminated with two to three miles of buried horizontal ground wire.

The transmitters broadcast messages using ELF EM fields; these fields are the operational component to be evaluated by the Ecological Monitoring Program.

During the construction and testing of the ELF Communications System, EM exposure can be conveniently divided into preoperational, transitional, and operational phases. During the preoperational phase, biota receive no EM exposure from the ELF Communications System. The transitional phase begins with the initiation of system testing; EM exposures are intermittent and are often at lower intensities than those anticipated from an operational system. When the system achieves full operational capability, EM exposure will be nearly continuous and at full intensity. The WTF became fully operational during the last quarter of 1985; the MTF is expected to become fully operational during the last quarter of 1989.

The EM fields produced by the ELF Communications System are:

- a magnetic field, essentially the same in air and the earth, that is generated by the electrical current in the antenna elements and ground terminals
- an electric field in the earth that is the sum of the fields induced by the magnetic field and the current flowing from the buried ground terminals
- an electric field in air that is produced as a result of the difference in potential between the antenna element and the earth

The frequency produced by an operational ELF Communications System is modulated using minimum shift keying (MSK), a special form of frequency shift keying. An important aspect of MSK modulation is that minimal energy is generated outside the signal bandwidth. The transmitted message is digital. If a zero is to be transmitted, the frequency of the current is 72 Hz; for a one, the frequency is 80 Hz. The center frequency is therefore 76 Hz. The planned frequency for routine operation of the ELF Communications System is centered at 76 Hz (72 to 80 Hz range); however, the system can also transmit at other frequencies in the 40 to 48 Hz range.

In their assessments, investigators must consider such EM variables as exposure intensity and duration, and the frequency of other EM exposures (e.g., harmonic frequencies). Commercial electric power transmission and distribution lines also generate EM fields of a frequency (unmodulated 60 Hz) and intensity similar to those produced by the ELF Communications System. Hence a complex of variables, particularly those related to electric power distribution, has been considered in characterizing the EM environment at study sites.

1.3 Paired Site Concept

It is not known if bioeffects are produced by the operation of the ELF Communications System. In order to examine for possible effects, the monitoring program employs a paired site design. This design compares a control site that receives significantly less EM exposure (76 Hz fields) with a test or treatment site. Paired treatment and control sites have matched biotic and environmental factors, but purposely dissimilar 76 Hz EM exposures. The control site is used to measure the effects of ambient environmental factors, while the treatment site measures the effects of environmental factors as well as possible effects from higher 76 Hz EM fields.

Dissimilar 76 Hz EM exposures were attained by situating treatment sites relatively close to the ELF Communications System while placing control sites at a greater distance. In order to ensure significant 76 Hz EM differences between sites as well as ensuring the dominance of these ELF Communications System EM fields over commercial power fields (60 Hz), exposure criteria were established for the selection of study sites.

The EM exposure criteria used in site selection are expressed in equation form as follows:

$$T\ (76\ \text{Hz})\ /\ C\ (76\ \text{Hz}) > 10 \qquad (1)$$

$$T\ (76\ \text{Hz})\ /\ T\ (60\ \text{Hz}) > 10 \qquad (2)$$

$$T\ (76\ \text{Hz}) / C\ (60\ \text{Hz}) > 10 \tag{3}$$

$$0.1 < T\ (60\ \text{Hz}) / C\ (60\ \text{Hz}) < 10 \tag{4}$$

where T (76 Hz) = test site exposure due to ELF Communications System
T (60 Hz) = test site exposure due to power lines
C (76 Hz) = control site exposure due to ELF Communications System
C (60 Hz) = control site exposure due to power lines

The criteria sought to ensure that the intensities of the 76 Hz EM fields at treatment sites were significantly greater than those at control sites (Equation 1); that the 76 Hz EM field intensities at treatment sites were significantly greater than the 60 Hz EM field intensities at both treatment sites (Equation 2) and control sites (Equation 3); and that there was no significant difference in 60 Hz EM fields between treatment and control sites (Equation 4).

Almost all site pairs met or exceeded the criteria. A few exceptional pairs came close to meeting the criteria; however, they could not be relocated to fully meet EM exposure criteria without also impacting matched biotic considerations.

At the MTF, temporal comparisons will be made between the preoperational and operational phases of the ELF Communications System in addition to the spatial comparisons of treatment and control sites. Only spatial comparisons will be made at the WTF because the transmitter has been operating since 1969 and no preoperational data base exists.

In Wisconsin, field work for the slime mold and wetlands studies was completed in 1987; only the bird species and communities study remains active in that state. Study investigators in Michigan have collected their preoperational data and are moving toward the operational phase of their studies as the MTF test currents are increased and operation becomes more frequent.

1.4 Annual Measurements of Electromagnetic Fields

IITRI performs an annual survey to measure the EM fields at each study site. Annual measurements of 60 Hz and 76 Hz EM fields are required in order to document changes in EM exposure at study sites from year to year. Ambient

60 Hz EM fields may change due to the construction of new power lines, the local use of electric power, or the presence of the ELF antennas themselves, which have been shown to couple and reradiate 60 Hz EM fields. The 76 Hz EM field intensities produced by the ELF Communications System may change due to the upgrading of antenna elements or because of testing at different antenna currents. Three recent changes have been documented in the MTF antenna configuration: the connection of the two EW antenna elements in parallel, a change in the grounding condition of unenergized antenna elements, and the tuning of antenna/amplifier matching networks.

Other EM aspects examined during the annual surveys have included measurement of 60 and 76 Hz harmonics, EM field levels produced at Michigan study sites due to the operation of the WTF, and EM field values as a function of the phase angle between antenna legs. The former two aspects were examined and found to be below detection levels or so low that they are not considered to be a confounder in treatment versus control comparisons. The latter aspect--the effects of the antenna phase angle on EM exposures at the WTF--are treated in Appendix I. Because antenna elements at the MTF have not yet operated simultaneously, the effects of the antenna phase angle on EM exposure at Michigan study sites have not been characterized. These will be determined after the MTF begins simultaneous, phased operation of the antenna elements.

1.5 Engineering Support

IITRI has provided engineering support ranging from the design and fabrication of equipment to the creation and maintenance of a computer data base available to study investigators. Some of those support activities are described here; details appear in Section 4.

The soil amoebae studies use buried culture cells that isolate study organisms from the surrounding soil. IITRI personnel reviewed the proposed design of the culture cells in 1983, and found two areas of concern to be the matching of internal to external EM fields and the measurement of internal EM fields. IITRI subsequently designed and fabricated the culture cell exposure control apparatus to address the field-matching problem, and assisted the study investigator with field setup and installation. In 1988, IITRI fabricated and installed improved exposure control equipment and also designed, fabricated, and installed microprocessor-controlled data loggers at each study site. The data loggers made hourly measurements of the voltage and current of each culture cell, the temperature in the partially buried data logger housings, and the longitudinal electric fields at each site. The data logger monitoring provides documentation of any variations in the culture cell electric fields or current densities that might result from factors such as rainfall, changes in temperature, or changes in the conductivity of the culture cell growth medium.

IITRI also provided special assistance in 1988 to the upland flora and soil microflora studies, which use extensive and sophisticated ambient monitoring systems at each of their study sites. Analyses were conducted to estimate the magnitudes of ELF voltages that would be induced on cabling and equipment, the impact of these voltages on personnel safety, and the possibility of ELF Communications System interference to the monitoring systems. Field measurements of the induced ELF voltages were made at low-power antenna operation to verify the analyses. Work was then performed at the study sites to eliminate potential safety problems and mitigate ELF interference.

IITRI also conducted an extensive design analysis of the lightning protection required for the monitoring systems, made recommendations for reconfigurations of system grounding, and provided specifications for terminal protection equipment. IITRI then assisted the study investigators in implementing the system reconfigurations and installing the protection devices.

The study investigators for the small mammals and nesting birds studies expressed concern in 1988 about the possibility that EM field anomalies along flight paths could be disrupting the homing behavior of tree swallows during displacement tests. IITRI responded to these concerns by making EM measurements at capture and release sites, documenting nearby power line locations, acquiring electric utility power generation data, visually inspecting the homing flight path from a small plane, and providing sources for and copies of geomagnetic maps.

The bird species and communities studies use 20 census transects, each of which is 200 m (600 ft) wide and 4.5 km (2.7 mi) long. Ten such transects are located in the WTF system area and 10 near the MTF. The study investigators requested information on the variability of the EM fields along the study transects, and also on the EM field gradients as a function of distance to an antenna element out to a distance of 400 m. During the annual EM measurements in 1988, IITRI personnel measured the EM field gradients along a line perpendicular to a WTF antenna element. They also made EM field measurements at regular intervals along one randomly chosen test and control transect pair in Wisconsin.

Temporal variations over the course of a year of the EM fields at study sites are of concern because most study biota remain on the study sites throughout the year. IITRI addressed this question in 1988 by installing six sets of fixed longitudinal electric field probe electrodes at the soil amoebae study sites. Data loggers used to monitor culture cell exposures were also used to measure the longitudinal electric fields at these electrodes. (A preliminary analysis of the longitudinal electric field variations near an antenna ROW and a ground ROW for the second half of 1988 is presented in Section 4.5.) The ELF magnetic fields at study sites are expected to show little or no seasonal variation because they are dependent only on fixed antenna parameters and are not affected by surrounding soil or vegetation.

In order to accommodate fleet operations, the testing of new hardware, and the testing of utility interference mitigation, both the WTF and MTF have operated at numerous frequency, modulation, and power conditions. IITRI maintains a computer data base of operation data and provides summaries to investigators. The operational summary, in conjunction with annually measured EM field values at the study sites, is intended for use by investigators to construct EM exposure regimes.

2. ECOLOGICAL MONITORING STUDY SITES

2.1 Summary of Site Status

Selection of test and control sites in both Wisconsin and Michigan began in 1983 under the criteria described in Section 1.3. In Wisconsin, actual measurements of 60 Hz and 76 Hz EM fields were used to check adherence of the candidate sites to the established criteria. Because sites in Michigan were chosen prior to the completion of the MTF antenna, their selection was based on measurements of 60 Hz EM fields and preoperational estimates of the 76 Hz EM fields that were calculated using engineering models of the MTF ELF Communications System. The MTF antenna was completed in 1986, and 76 Hz measurements were then possible for the first time. Measurements made in 1986 verified the acceptability of the Michigan test and control sites: all sites were confirmed to be either acceptable or conditionally acceptable, as defined in Appendix H.

Some studies use other sites in addition to treatment and control sites. The small mammals and nesting birds studies use a holding facility for animals awaiting physiological characterization, and pine and maple foliage for litter decomposition studies are collected from locations other than study sites. The ambient EM environment was characterized at these additional sites, and 60 Hz EM fields were found to be relatively high vis-a-vis the site selection criteria. It is not known *a priori* that ELF EM fields at the intensities measured will affect the variables under study, nevertheless, 60 Hz EM fields are considered as contaminants and the steps described below were taken to address the exposures.

In late 1987, new locations were examined for the small mammals and nesting birds holding facility. Only 60 Hz EM fields were measured at that time, and the intensities were found to be acceptable at all sites. Early in 1988, a holding facility was established at one of the sites and was placed in use. Both 60 Hz and 76 Hz EM fields were measured at that site during the third quarter of 1988, and the exposures were considered acceptable for continued use of the facility. The EM field intensities at the holding facility will be characterized annually.

The native bees studies measure nest parameters and monitor emergence of adult bees at a laboratory remote from the study sites. Some specimens are rereleased at the study sites after emergence. In 1988, ambient EM field measurement locations were established at this laboratory. The 60 Hz EM fields measured at the laboratory were found to be high relative to those measured at study sites. IITRI is working with the study investigators to lower laboratory ambient field exposures and reduce the length of time that study specimens are at the laboratory.

2.2 Summary of Site Locations

The locations of study transects for the Wisconsin bird species and communities studies relative to the WTF antenna are shown in Figure 2. IITRI field crews have characterized the ELF EM fields at at least two locations along each transect annually. In 1988, two randomly chosen test and control transects (10T8 and 10C7) were examined in more detail to determine typical EM field variability along study transects. Measurements were also taken along a line perpendicular to study transect 10T8 to characterize EM field gradients as a function of distance from the antenna wire. These additional measurements are discussed in Section 4.4 and Appendix G.

The locations of field sites for the Michigan studies relative to the MTF antenna are shown in Figure 3. The seven studies for which EM field measurements were made are identified in the upper left-hand corner of the figure. IITRI field crews characterized the ELF EM fields at each of these study sites. The collection sites for red maple leaves and pine needles do not appear in the figure because they are beyond the range of the map shown.

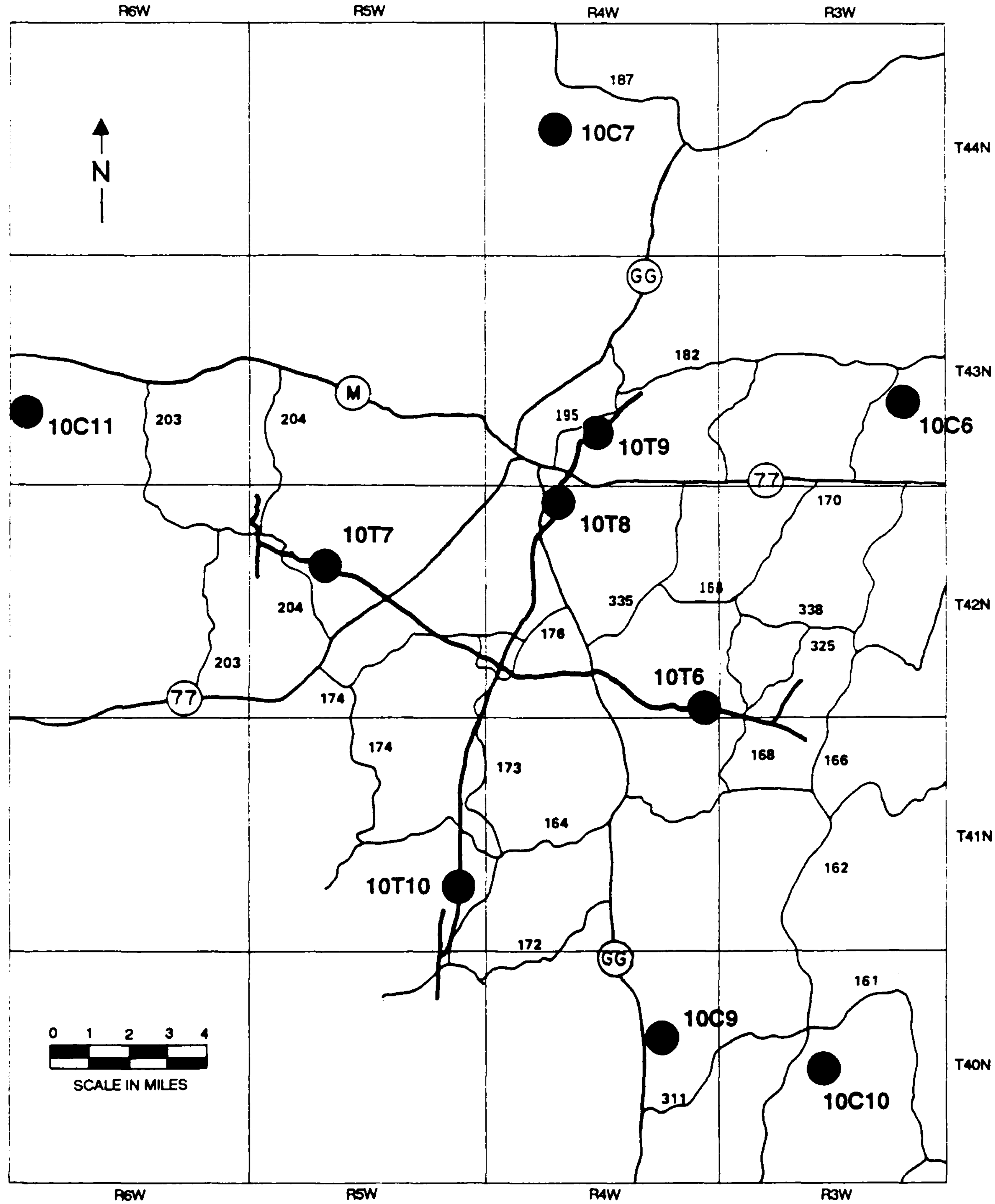

FIGURE 2. FIELD SITES FOR WISCONSIN BIRD SPECIES AND COMMUNITIES STUDIES.

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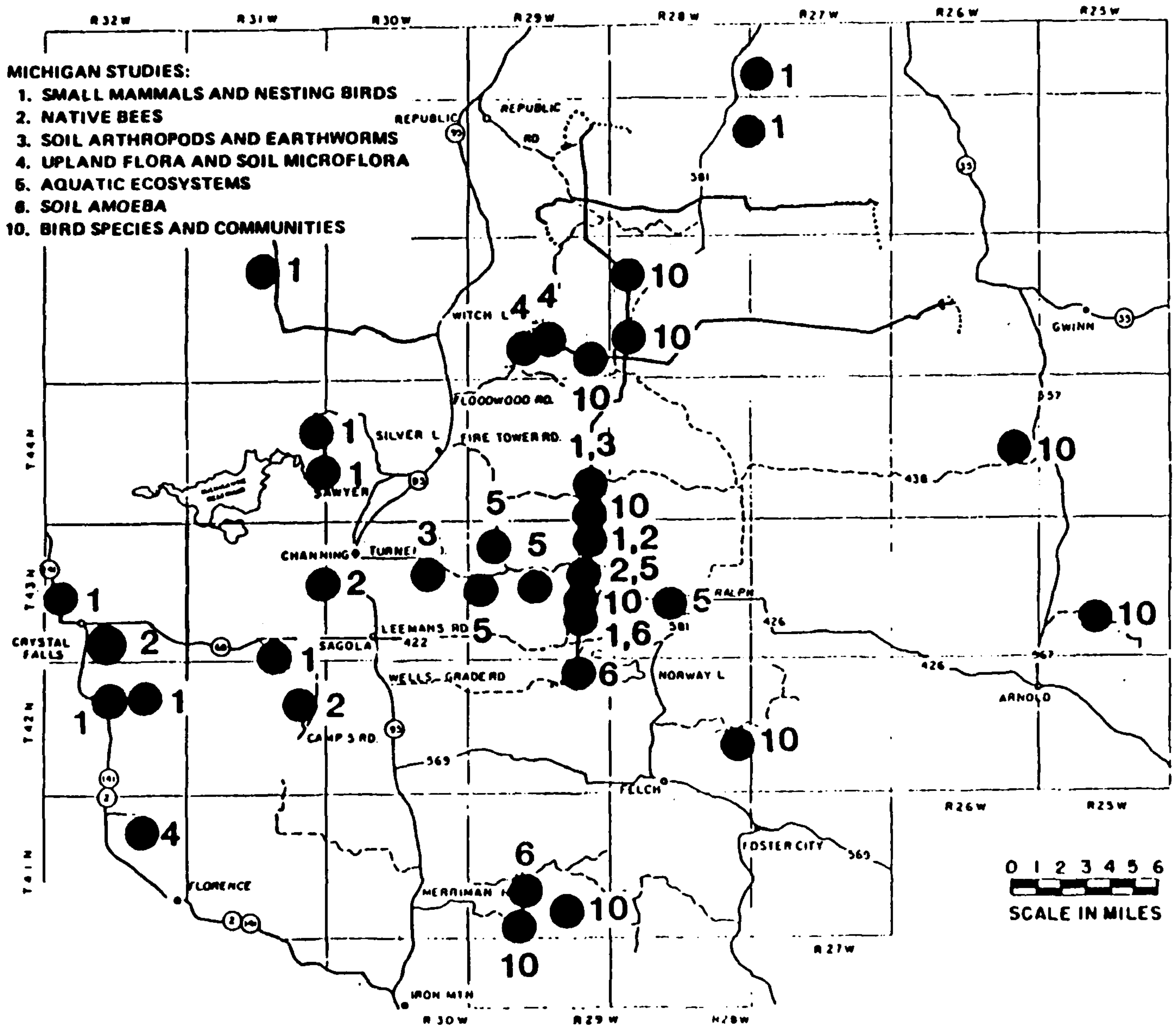

FIGURE 3. FIELD SITES FOR MICHIGAN ECOLOGY STUDIES.

3. ANNUAL MEASUREMENTS OF ELECTROMAGNETIC FIELDS

3.1 Description of Electromagnetic Fields

The three EM fields under investigation in this program are the magnetic field, longitudinal electric field, and transverse electric field.

A magnetic field is generated by current passing through a conductor. The ELF Communications System and power lines both produce consistent and predictable magnetic fields that are generally unaffected by the physical environment such as vegetation, soil, and nonmetallic structures. Magnetic fields are unchanged at such boundaries as air/earth or air/water. Thus, measurement techniques need not consider shielding, enhancements, or perturbations of the magnetic field from the local environment. This local uniformity of the magnetic field allows precise measurements over time, provided that the field source--in this case, the antenna current--remains constant.

The longitudinal electric field in the earth is measured as a difference in potential at the surface of the earth. The two sources of longitudinal electric field associated with the ELF Communications System are (1) that induced by the magnetic field and (2) that generated by the ground terminal currents. 60 Hz longitudinal electric fields produced by power lines are generated by the lines' magnetic fields and by unbalanced 60 Hz currents flowing in the earth. The uniformity of longitudinal electric fields is affected by the conductivity of soil and other factors such as large rocks, tree roots, and pools of water. Generally, the intensity of longitudinal electric fields is fairly uniform and measurements are repeatable when anomalies are avoided. Some year-to-year variations may occur because of changes in soil moisture content, which affect soil conductivity.

The transverse electric field in the air is generated as a result of the operating voltage of the ELF antenna with respect to ground or as a by-product of the longitudinal electric field. Power lines generate a transverse electric field in a similar manner. The operating voltage of the overhead antenna wire (or power line) with respect to the earth's surface sets up a vertical (transverse) electric field. This vertical field is limited to the ROW and other nearby cleared areas. Trees, vegetation, and other conductive objects act as a shield.

A difference in potential between two grounded objects such as trees can be set up by the longitudinal electric field. This difference in potential in turn generates a horizontal electric field in the air. The horizontal and vertical fields are perturbed by vegetation, people, and instrumentation, all of which are more conductive than air. The perturbations of the field may take the form of an enhancing of the ambient field near objects or a shielding effect on the surroundings. This results in a high variability of the transverse electric field over a small area. The transverse electric field is measured in open areas in an effort to obtain a typical unperturbed measurement.

3.2 Electromagnetic Field Probes and Measurement Equipment

The magnetic flux density, transverse electric field intensity, and longitudinal electric field intensity are measured using directional field probes designed and calibrated by IITRI. Each of these probes, when placed in the existing electric or magnetic field, outputs a voltage proportional to the field intensity. The value of the applied field can be obtained by means of individual sets of calibration factors for each probe.

The magnetic field probe is composed of a multiturned coil of wire wound on a ferrite core and shunted by appropriately chosen resistors to obtain a flat frequency response. The probe outputs a voltage proportional to the magnetic flux density parallel to the axis of the core. The voltage is converted to the magnetic flux density by means of a calibration factor determined prior to each field outing. Two of the magnetic field probes are shown in Figure 4.

The transverse electric field probe consists of a spherical sensor/transmitter, a fiber-optic data link, and a receiver. An insulating styrofoam and plastic shell is placed over the probe during measurements made in cold weather. The probe outputs a voltage proportional to the transverse electric field along the primary axis of the spherical sensor/transmitter. The voltage is converted to the electric field intensity by means of a calibration factor determined prior to each field outing. The calibration factor and probe operation are periodically checked using a portable electric field probe calibrator. The transverse electric field probe is shown in Figure 5.

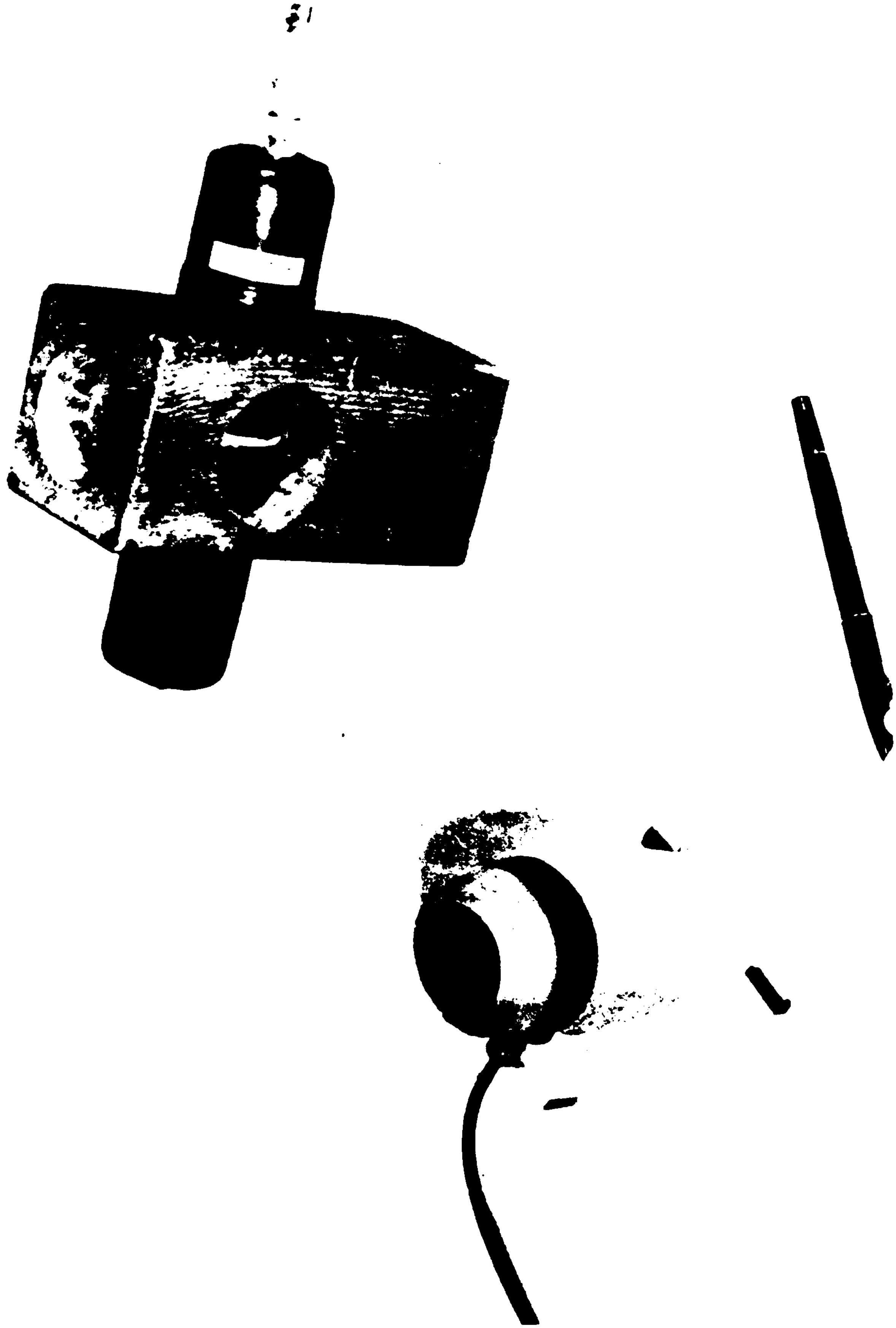

FIGURE 4. MAGNETIC FIELD PROBES.

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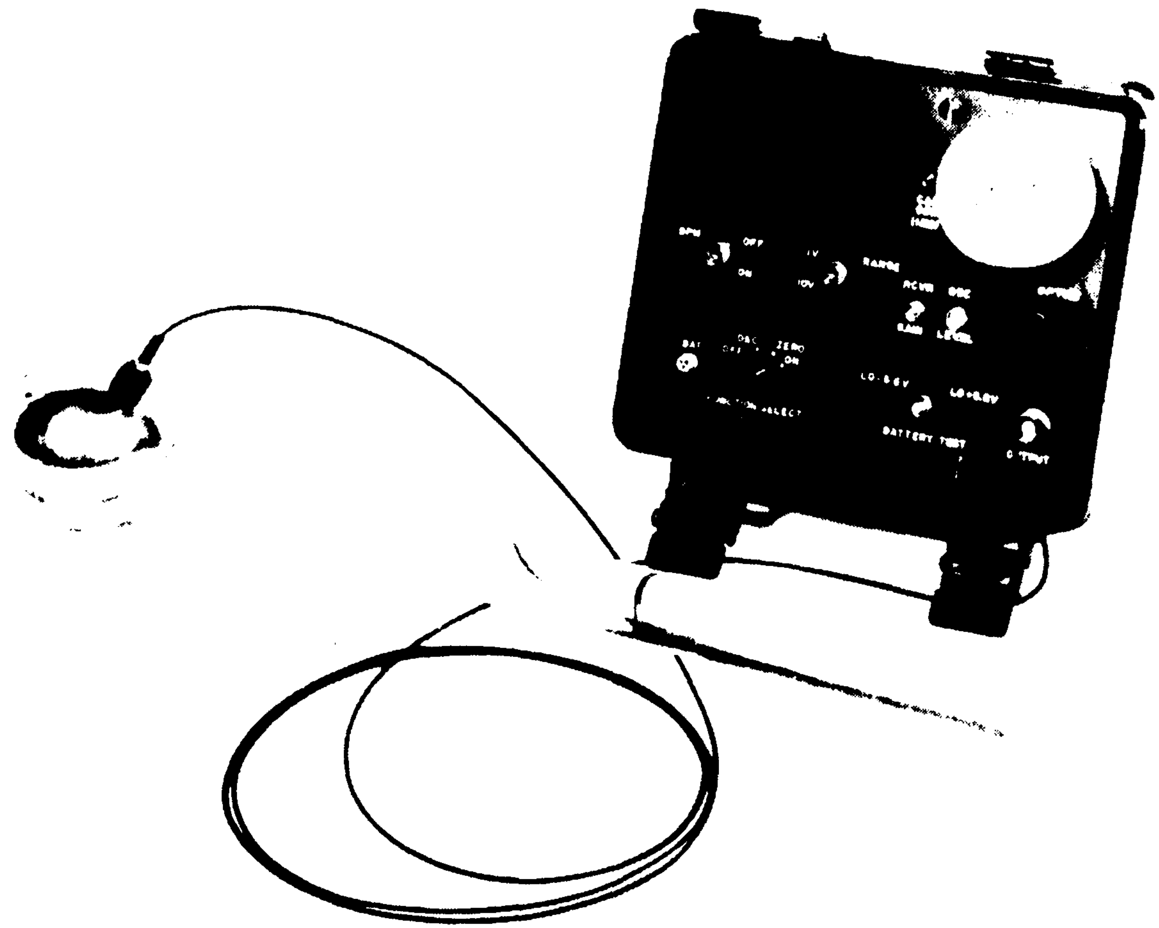


FIGURE 5. TRANSVERSE ELECTRIC FIELD PROBE.

The longitudinal electric field probe consists of three electrodes mounted on a fiberglass frame so as to form two orthogonal 1-m-spaced electrode pairs. The electrodes are pushed into the earth, and a switch connects a voltmeter across one pair of electrodes at a time. The voltage measured across each pair of electrodes is equal to the longitudinal electric field in the given direction. This probe is shown in Figure 6. Note that a compass and a cradle are mounted atop a 1-m vertical stalk that is hinged at the juncture of the probe legs. The compass aids in alignment of the probe legs prior to raising the stalk. The cradle is designed to hold the magnetic field probe in three orthogonal positions at a 1-m height and orient the probe precisely with the legs of the longitudinal electric field probe.

IITRI has developed a computer-driven system for calibrating electric and magnetic field probes over their usable frequency range (see Figure 7). At the heart of the system are:

- a Hewlett-Packard 86B computer equipped with an IEEE 488 instrument interface bus
- a Hewlett-Packard 3421A data acquisition unit
- a Valhalla 2703 precision ac calibrator

The system generates a uniform electric field between a pair of 1-m-square, 1/3-m-spaced parallel plates with guard rings. A uniform magnetic field is produced over a large volume by a set of 1-m-radius Helmholtz coils. The calibration system produces a table of each probe's calibration factors and a plot of the probe's transfer function versus frequency. The transverse electric field probe and magnetic field probe are calibrated before and after each use, and records are kept of all calibrations.

The electrical stability of the transverse electric field probe is better than ±5% over a one-year period. There is little difference in the calibration of this probe with or without the insulating styrofoam and plastic shell. Portable electric field calibration plates are used during field measurements so that the probe operation can be verified periodically. The electrical stability of the magnetic field probe is better than ±1% over a one-year period. The probe is constructed solely of passive components, making routine calibration checks during field measurements unnecessary. The longitudinal

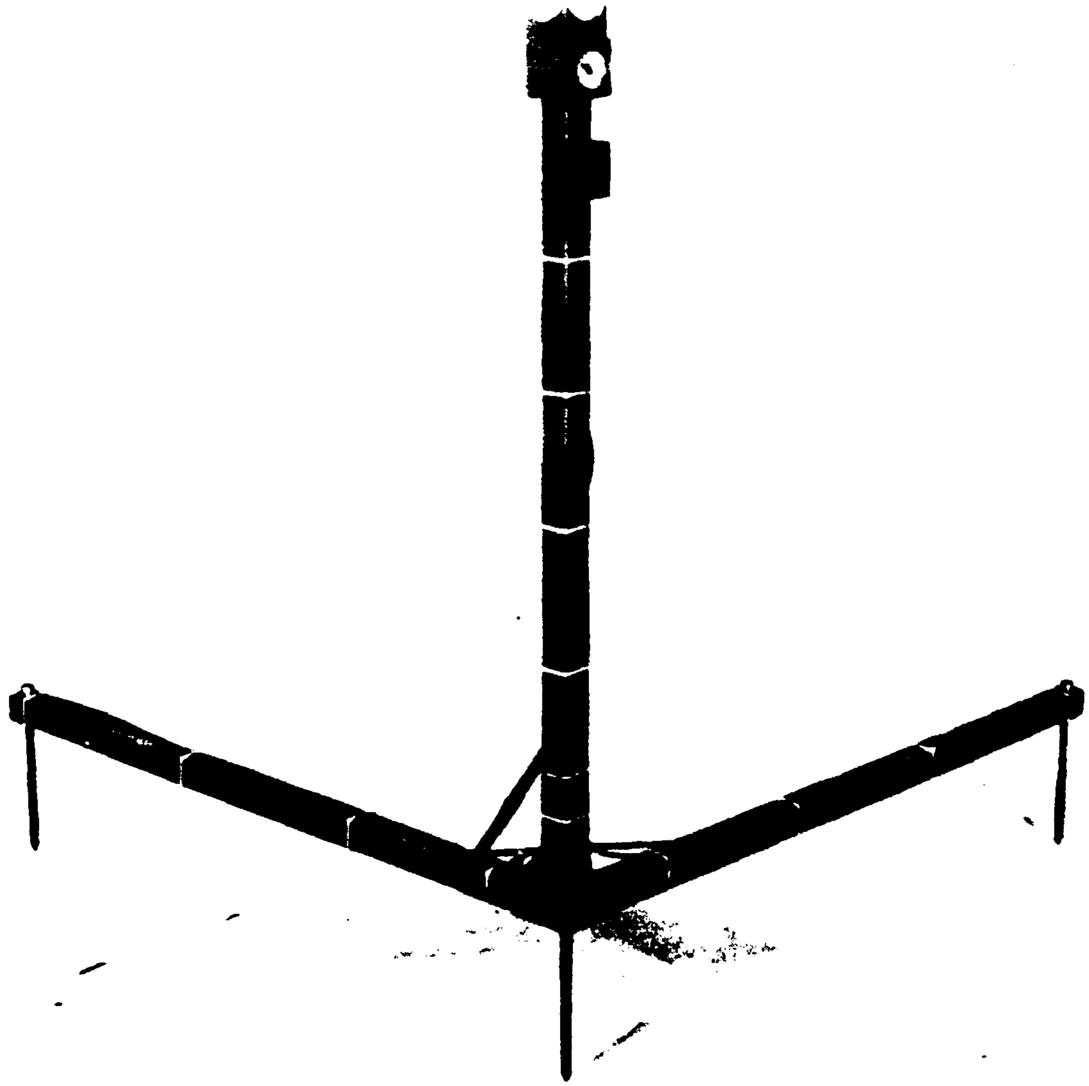


FIGURE 6. LONGITUDINAL ELECTRIC FIELD PROBE.

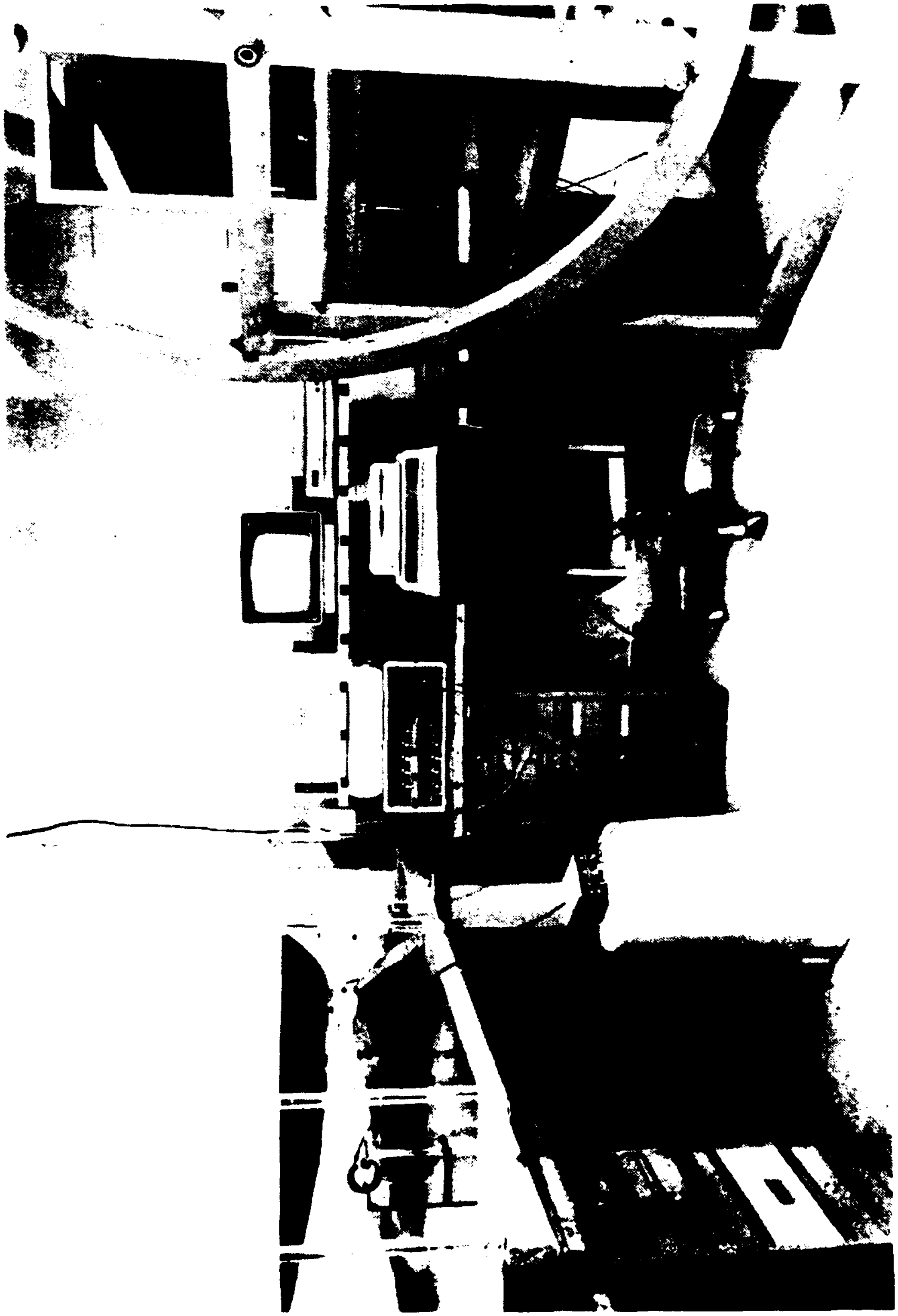


FIGURE 7. COMPUTER-DRIVEN ELECTRIC AND MAGNETIC FIELD PROBE CALIBRATION SYSTEM.

electric field probe, which consists solely of a perpendicular pair of 1-m-spaced electrodes, requires no calibration. The electrical stability of this probe is excellent.

The meter used to measure the output voltages of the probes is a Hewlett-Packard 3581A signal wave analyzer. The HP 3581A functions as a frequency selective rms-calibrated voltmeter with factory modifications for battery and 1 Hz bandwidth operation. A 3 Hz bandwidth is used to measure 60 Hz and unmodulated ELF signals, but a wider bandwidth is needed to measure modulated ELF signals. Because the wider bandwidth will include 60 Hz signals produced by power lines, an IITRI-fabricated active notch filter is placed in series with the wave analyzer when the 60 Hz and ELF signals are of similar magnitudes in order to remove the 60 Hz signals and their harmonics.

3.3 Electromagnetic Field Measurement Techniques and Protocols

3.3.1 Measurement Techniques

The magnitude of EM fields is determined by the measurement of orthogonal field components. This requires field measurements along three orthogonal axes. For simplicity and repeatability, the axes chosen are the north-south, the east-west, and the vertical. The longitudinal electric field intensity (electric field measured in the earth) has no vertical component; therefore, only the north-south and east-west directional components are measured. In the case of the transverse electric field and the magnetic flux density, all three orthogonal field components are measured. The orthogonal measurements are then used to compute a vector sum or maximum. A drawback to this method is that it yields the correct field maximum only when a single field source is present or dominates. When more than one field source is present, the computed vector sum will be conservative; that is, it will be greater than or equal to the actual maximum.

The following summarizes the technique of orthogonal field measurement:

(1) The magnetic field probe and transverse electric field probe are used to measure three orthogonal components using a compass bearing and the plane of the earth's surface as references. The magnetic field and the transverse electric field are measured in north-south, east-west, and vertical orientations.

(2) The longitudinal electric field is of interest near the surface of the earth, where it will come in contact with biota under study, and has no vertical component. Therefore, only the north-south and east-west orientations are measured.

A geometric presentation of the measurement and summation of orthogonal components is shown in Figure 8. The figure presents the two-dimensional longitudinal electric field geometry and the three-dimensional magnetic field and transverse electric field geometry. The resultant, R, in each case is the vector sum of the individual orthogonal components and is the value reported in data tables.

3.3.2 Wisconsin Measurement Protocols

The WTF was built in the late 1960s to be used as a test facility for ELF communications.

Before 1985, the WTF operated intermittently at numerous frequency, modulation, and intensity conditions with either the NS, the EW, or both antenna elements being powered. During this period, the antenna was generally under local control, and specific conditions of antenna current, modulation, frequency, and phase angle could be requested for measurements and testing.

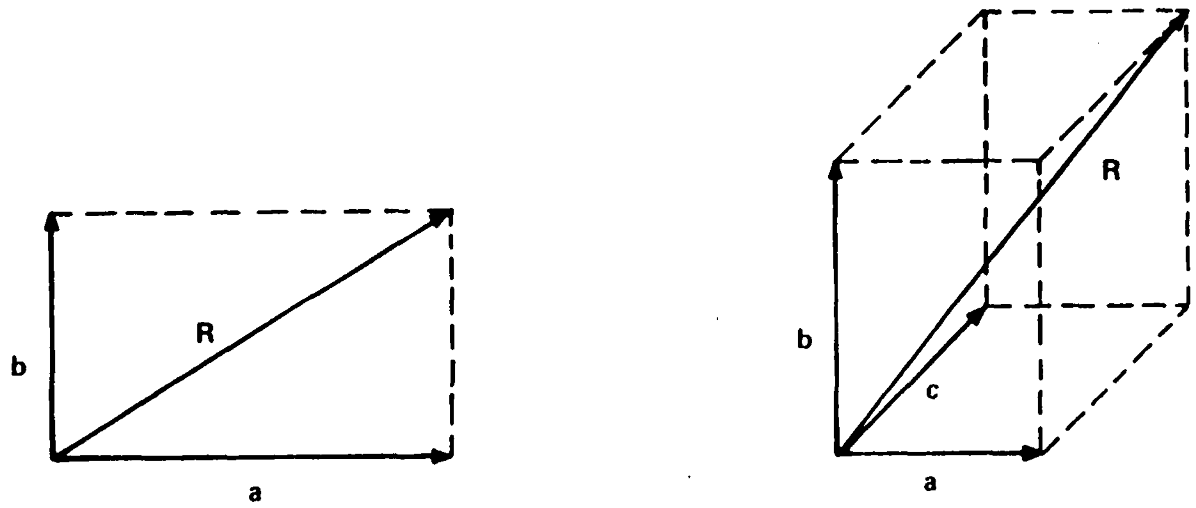
In 1985, the WTF was upgraded to a fully operational system with the installation of new transmitters early in the year. The transmitters required testing in mid-year, which allowed only limited manipulation of antenna conditions. This was followed by full-time transmitting during the fourth quarter, which did not allow any control over antenna conditions. The WTF antenna has continued transmitting full-time since then.

IITRI required control of the WTF antenna for the measurement protocol used prior to 1985; the loss of antenna control required that a new protocol be adopted. The following subsections describe the pre-1985 protocol and the protocol used from 1985 onward.

3.3.2.1 Protocol, Pre-1985

Prior to June 1985, the EM measurement protocol in Wisconsin consisted of making orthogonal sets of measurements of the transverse electric field, longitudinal electric field, and magnetic flux density at each measurement point as follows:

60297/189



$$R = \sqrt{a^2 + b^2} \qquad R = \sqrt{a^2 + b^2 + c^2}$$

FIGURE 8. GEOMETRIC PRESENTATION OF THE VECTOR SUM OF ORTHOGONAL MEASUREMENT COMPONENTS.

(1) measurement of the ambient 60 Hz EM fields with both antenna elements off

(2) measurement of unmodulated 76 Hz EM fields from the NS antenna element with the EW antenna element off

(3) measurement of unmodulated 76 Hz EM fields from the EW antenna element with the NS antenna element off

All measurements were made using a narrow bandwidth meter setting to discriminate the frequency of interest. When necessary, the 76 Hz EM fields at the WTF measured at lower currents were extrapolated to 300 amperes (full power). Each set of orthogonal components was used to compute a vector sum, or EM field magnitude. The 76 Hz EM field magnitudes from the NS and EW antenna elements were then added algebraically to compute the worst-case or highest EM field level that could be produced by both antennas operating simultaneously at any phase angle. These worst-case values were presented in pre-1985 reports.

3.3.2.2 Protocol, 1985-1988

In 1985, the WTF measurement protocol was modified so that measurements could be made during continuous, phased operation of the two antenna elements. The new protocol, adopted in 1985 and used since then, is outlined below:

(1) The EM fields generated by the ELF Communications System, which are normally modulated with a center frequency of 76 Hz, are measured with a meter bandwidth setting of 30 Hz to accommodate the wider frequency spectrum of the modulated signal.

(2) At control and/or other sites where the 60 Hz ambient EM fields are comparable to the ELF fields, an IITRI-fabricated active notch filter instrument is used to eliminate the 60 Hz signal from the field measurement.

(3) At each site, the orthogonal components of the magnetic flux density and transverse and longitudinal electric fields are measured, and a vector sum magnitude is computed for each EM field. The antenna current phase angle is recorded (normally -75° for Wisconsin).

(4) For the six sites where phasing data have been obtained, the longitudinal electric field magnitudes obtained in Step 3 are multiplied by the correction factor from Appendix I to obtain the actual EM field magnitude.

(5) The 60 Hz ambient EM fields are unmeasurable unless the ELF transmitter can be turned off (unlikely during fleet transmission), or unless the ambient 60 Hz levels are higher than the ELF-signal-generated "noise" at the same frequency. This latter scenario is likely only at certain control sites. When 60 Hz EM fields are measured, a narrow bandwidth meter setting is used.

This protocol allows for direct comparisons between pre- and post-1985 data for all but six sites. These six sites--8A2, 8M3, 8M4, 10T6-2, 10T8-4, and 10T10-1--are near enough to both WTF antennas that their EM fields vary with the phasing of the antennas. Appendix I contains tables of conversion factors for these sites that allow comparisons of EM field measurements made in any year at any antenna phasing.

3.3.3 Michigan Measurement Protocols

Construction of the MTF began in 1984 and continued through 1985. During this period the MTF was not capable of generating ELF EM fields. Construction of the MTF was completed in early 1986, and intermittent operation began at low power levels of 4-10 ampere antenna current. Only one antenna element--i.e., NS, NEW, or SEW--was operated at any one time during 1986.

The MTF operated intermittently at a 15 ampere antenna current in 1987 and at 15 and 75 ampere antenna currents in 1988, but under an antenna configuration that was slightly different from the one used in 1986. In 1987 and 1988, the NS antenna element was operated alone as in 1986; the NEW and SEW antenna elements, however, were operated simultaneously and in phase with each other in 1987 and 1988 rather than individually as in 1986. The NEW and SEW antenna elements will continue to be operated in parallel during testing and in the final operating configuration. These two elements configured in this parallel fashion are collectively referred to as the EW element.

All measurements in 1986, 1987, and 1988 were taken using a 3 Hz bandwidth meter setting to discriminate the frequency of interest. Each set of orthogonal measurements was used to compute a vector sum, or field magnitude, corresponding to that measurement condition. The 76 Hz magnitudes were also linearly extrapolated to full antenna power (150 amperes). The extrapolated magnitudes contributed by the individual antenna elements were then algebraically summed to give the worst-case, or highest, field level that could be produced by all antenna elements operating simultaneously at any phase angle.

3.3.3.1 Protocol, 1986

In 1986, the EM measurement protocol in Michigan consisted of making orthogonal sets of measurements of the transverse electric field, longitudinal electric field, and magnetic flux density at each measurement point as follows:

(1) measurement of the ambient 60 Hz EM fields with all three antenna elements (NS, NEW, and SEW) off

(2) measurement of the unmodulated 76 Hz EM fields from the NS antenna element with both EW antenna elements off

(3) measurement of the unmodulated 76 Hz EM fields from the NEW antenna element with the other antenna elements off

(4) measurement of the unmodulated 76 Hz EM fields from the SEW antenna element with the other antenna elements off

3.3.3.2 Protocol, 1987, 1988

In 1987 and 1988, the EM measurement protocol for Michigan changed only slightly from the 1986 protocol to account for the new operating configuration. It consisted of making orthogonal sets of measurements of the transverse electric field, longitudinal electric field, and magnetic flux density as follows:

(1) measurement of the ambient 60 Hz EM fields with all three antenna elements (NS, NEW, and SEW) off

(2) measurement of the unmodulated 76 Hz EM fields from the NS antenna element with both EW antenna elements off

(3) measurement of the unmodulated 76 Hz EM fields from the NEW and SEW antenna elements operated in parallel with the NS antenna element off

3.4 1988 Measurements and Data Summary

The annual EM field measurements in Wisconsin were conducted by IITRI field crews during the week of 15 to 19 August 1988. Measurements in Michigan were conducted during the period from 19 September to 7 October 1988. All active sites were measured during these periods.

Table 1 presents a summary of the number of sites and measurement points examined during 1988. As shown, a total of 193 measurement points were needed to characterize 60 sites. The number of measurement locations per site was determined by plot size, the presence of known or anticipated EM field gradients, and the information needed by the study investigators for statistical analysis.

TABLE 1. SUMMARY OF 1988 ELECTROMAGNETIC FIELD MEASUREMENTS

	Number of Measurement Sites			Number of Measurement Points		
Study	Pre-Existing, Still in Use	New, 1988	Total	Pre-Existing, Still in Use	New, 1988	Total
Small Mammals and Nesting Birds	13	1	14	59	5	64
Native Bees	4	1	5	15	3	18
Soil Arthropods and Earthworms	2	0	2	8	0	8
Upland Flora and Soil Microflora	6	0	6	30	0	30
Aquatic Ecosystems	10	0	10	17	1	18
Soil Amoeba	3	0	3	9	0	9
Bird Species and Communities						
Michigan	10	0	10	24	0	24
Wisconsin	10	0	10	22	0	22
Total	58	2	60	184	9	193

3.4.1 Wisconsin Measurements

The data taken during the 1988 annual EM measurements in Wisconsin appear in Appendix G, and consist of EM field magnitudes measured during simultaneous operation of both antennas at an antenna current phase angle of -75°. Measurements were made during periods of modulated signal transmission with a center frequency of 76 Hz and a current of 300 amperes.

In Appendix G, 76 Hz data for years prior to 1985 are presented individually for each antenna element (NS and EW). These data are readily compared to data from the new protocol by calculating the algebraic sum of the fields produced during individual operation of the NS and EW antenna elements, and comparing them with the EM fields measured in later years during the simultaneous operation of both antenna elements. The 1985-1988 76 Hz data are presented in columns labeled "Both, -75°," indicating that both antenna elements were operating at a current phase angle of -75°. For some sites, 1985 data are also given in the "NS" and "EW" columns. These data were taken early that year during site selection/relocation activities, during the phasing measurements, or when only one antenna element was operational at the time of the measurement.

No 60 Hz data were taken in 1986, 1987, or 1988, because 60 Hz EM fields were masked by the 76 Hz EM fields from the antenna.

3.4.2 Michigan Measurements

Construction of the MTF antenna was completed in 1986, and 76 Hz EM field measurements have been made in 1986, 1987, and 1988. Since 1986, the antenna has operated at current levels lower than the anticipated full operating current of 150 amperes. In 1986 the primary antenna operating currents were 4 amperes for the NS element, 6 amperes for the NEW element, and 6 and 10 amperes for the SEW element; measurements were made at 4, 6, and 6 ampere antenna element currents for the NS, NEW, and SEW elements, respectively. In 1987, the NS and EW elements were operated at 15 amperes; measurements were made at this current for both elements. In 1988 antenna elements operated at 15 and 75 amperes; measurements were made at 75 ampere antenna currents. 60 Hz measurements have been made each year since in 1983.

The data taken during the 1988 annual EM measurements in Michigan appear in Appendixes A through G. Each appendix contains nine data tables. There are a measured 60 Hz data table, a measured 76 Hz data table, and an extrapolated 76 Hz data table for each of the three fields characterized (transverse electric field, longitudinal electric field, and magnetic flux density). These tables are described below.

The tables of 60 Hz data appear first in each appendix. Each table contains separate columns for data from 1983 through 1988. Footnotes for each column describe the physical status of the ELF antenna during the 60 Hz measurements for that year. The physical status of the ELF antenna has a significant impact on the 60 Hz EM fields measured at test sites because it affects the degree of coupling to the antenna of 60 Hz EM fields generated by nearby power lines. This phenomenon is explained in Section 3.4.2.2.

Following the 60 Hz data tables are tables containing 76 Hz EM field intensities measured in 1986, 1987, and 1988. An extrapolated data column is included under 1986 exposures for the SEW antenna element operating at a 10 ampere current; this was a significant operating condition for which measurements were not performed. The same is true of 15 ampere antenna operation in 1988. Although extrapolated data are not included in the tables for 15 ampere operation, estimates of the EM fields can be determined by dividing the reported 75 ampere measurements by five. Data in this second group of tables represent actual field measurements of study biota EM exposure.

In the third group of tables, low-power measurement data are linearly extrapolated to a 150 ampere (full-power) current for each antenna element. Extrapolated data are presented for 1986 through 1988. Extrapolations were not performed when EM field values were below the sensitivity of the measurement instruments. The 1988 extrapolations are more accurate than previous predictions of the EM field levels at full operating antenna current, since half-power EM field measurements are more accurate than those made at lower antenna currents. The 1988 extrapolations also reflect the operational antenna configuration and tuning of the antenna elements with the new power amplifiers. The worst-case, or maximum, EM field levels that can occur during simultaneous operation of both antennas at any antenna phasing can be calculated as the algebraic sum of the levels from the individual antenna extrapolations. Similarly, minimums can be calculated as the algebraic difference.

3.4.2.1 Selection of Measurement Points

Measurement points at study sites were selected to define the spatial variation of the 76 Hz EM fields over each site. This was done on the basis of the size and shape of a site and its location relative to the antenna elements, as described below.

Control sites, all of which are several miles from the nearest antenna element, are expected to have minimal EM field gradients. At small control sites, a single measurement point was deemed sufficient to characterize the EM fields. Intermediate-size control sites were measured at the points nearest to and farthest from the antenna grid. Large control sites were measured at several more points in order to accurately define the EM field gradients across them.

EM field gradients across test sites are large for all but the smallest of sites. It was generally necessary to make multiple measurements at all test sites. The selection of measurement points for the test sites was based on one of four strategies dictated by the nature of the site. For sites comprised of long, narrow transects parallel to the antenna (e.g., the bird species and communities studies), measurements typically were taken at the ends of the transect and often at intermediate points along the transect. For sites of very restricted area (e.g., the aquatic ecosystems studies), only one measurement was made at each experiment location. The final two measurement strategies were applied at test sites covering a large area. For those sites arranged with well defined, grid-like borders, measurements were made at the borders or corners of the plots such that the measurements encompassed the study area. For those sites without distinct borders, measurements were made along a transect perpendicular to the antenna, typically at 25-m intervals.

This measurement point selection technique allows the investigators to estimate the EM field intensity at any point of interest within a study plot. Such estimates can be made based on the fact that the EM fields vary greatly with distance from the antenna but show little variation along a path parallel to it. Therefore, given the distance of a point of interest from the antenna, the EM fields can be estimated by interpolation between measured values at greater and lesser distances from the antenna. Because the EM fields vary little along a path parallel to the antenna, the point of interest and measured points do not need to be at the same lateral position along the length of the antenna. The EM field can be estimated by linear interpolation between the two measured points. The accuracy of the interpolation can be improved by plotting the EM field gradients as a function of distance from the antenna, as was done for all transects at the nesting birds study sites. These plots appear in Appendix A.

3.4.2.2 Coupling of 60 Hz Fields

The 60 Hz data in Appendixes A through G for Michigan studies show that there were significant yearly fluctuations of the 60 Hz EM fields from 1983 through 1988. The primary factors in these fluctuations were:

- completion of antenna installations in 1986
- parallel connection of the two EW antenna elements in 1987
- differences in antenna-power amplifier connections between 1986 and 1987
- changes in power line loads
- changes in earth conductivity

The first three factors apply only to test sites; the last two apply to both test and control sites.

The 60 Hz EM fields at the test sites are strongly influenced by the presence of the ELF antenna elements. This is because EM fields generated by 60 Hz power lines couple to the conducting loop formed by the ELF antenna, its ground terminals, and the earth. This coupling results in a 60 Hz current flow on the antenna wires that in turn sets up new 60 Hz EM fields in nearby areas. The 60 Hz EM fields generated by the two sources (power lines and antenna) may interact at test measurement sites and elsewhere. The general observation has been that the longitudinal electric fields sourced by the power lines and antenna partially cancel each other. The relative magnitude of the resulting EM field is dependent on the intensities of the EM fields generated by the two sources. The magnetic fields from power lines fall off more rapidly than the longitudinal electric fields, and they do not appear to significantly interact with the 60 Hz magnetic fields from the antenna. The result is that 60 Hz magnetic fields near the antenna are greater in magnitude than those measured prior to antenna construction.

The coupling of ambient 60 Hz fields to the ELF antenna was first observed in 1986, coincident with the completion of antenna construction in Michigan. This phenomenon will continue as long as the ELF antenna and power lines are present. Year-to-year differences in the test site 60 Hz EM fields are likely due to changes in coupling to the antenna elements resulting from changes in antenna configuration and to changes in 60 Hz power line loads. The antenna configuration changes were the connection of the two EW antenna elements in parallel beginning in 1987 and differences in the antenna connections to the power amplifiers between 1986 and 1987 in the antenna "off" mode, the antenna condition when 60 Hz measurements are made.

In 1988, 60 Hz coupling to the NS antenna appeared to have increased substantially. This correlates with large load increases on a transmission line that parallels the NS antenna element about four miles to the west. The purchase of the Presque Isle power plant by Wisconsin Electric Power Company in January 1988 and its subsequent operation as a major producer of electrical energy in the region suggests that this line will remain heavily loaded.

Variations in the 60 Hz EM fields at control sites are not related to the location of the ELF antenna or its configuration. 60 Hz variations here are most likely the result of varying power line currents and temporal changes in earth conductivity. These same factors also influence the 60 Hz EM fields at test sites, but not necessarily to the same extent.

3.4.2.3 76 Hz Electromagnetic Fields (Measured)

Measurements of the 76 Hz EM fields were made in 1986, 1987, and 1988 under different MTF operating conditions, as summarized in Table 2.

TABLE 2. ANTENNA OPERATING CONDITIONS DURING 76 Hz EM FIELD MEASUREMENTS

Antenna Condition	1986	1987	1988
Antenna Elements Measured	NS NEW SEW	NS EW (NEW and SEW in parallel)	NS EW (NEW and SEW in parallel)
Antenna Currents	NS --4 amperes NEW--6 amperes SEW--6 amperes	NS--15 amperes EW--15 amperes	NS--75 amperes EW--75 amperes
Connection of Non-Driven Antenna element(s) at Power Amplifiers	Grounded	Not grounded	Not grounded

76 Hz EM field exposures at all study sites, where measurable, generally increased from year to year in proportion to the increase in antenna currents. The EM field exposures at most test sites were dominated by the fields of the nearest antenna element versus those of the remote antenna element by a ratio of 10:1 or greater.

3.4.2.4 76 Hz Electromagnetic Fields (Extrapolated to Full Operating Current)

The 1988 low-power (75 ampere) EM field measurement magnitudes for each antenna element were linearly extrapolated to the planned operating antenna current of 150 amperes, and are presented in Appendixes A through G. These appendixes also present extrapolations of the 1986 and 1987 measurements.

Extrapolations were not performed when EM field values were below the sensitivity of the measurement instruments.

The 1988 extrapolations are more complete and accurate than previous estimates of a fully operational MTF because:

- low current estimates were not extrapolated when EM field values were below the detection limits of measurement equipment
- the MTF configuration in 1988 more closely resembled the planned operational configuration than it did in previous years
- measurements were made at higher antenna currents than in previous years

The EM field extrapolations are provided as an engineering estimate of the level of EM field exposures that will be present at study sites when the ELF antennas become fully operational. EM exposure ratios have not been recalculated for 1987 and 1988, since their primary function was to serve as guidelines for site selection. The EM field extrapolations, however, should be reviewed for each study by the investigators to determine whether there is a significant difference in the exposure levels between test and control sites.

4. ENGINEERING SUPPORT ACTIVITIES

4.1 Support for Soil Amoebae Studies

The soil amoebae studies use buried culture cells that isolate the study organisms from the surrounding soil. This *in vitro* procedure allows close monitoring of biotic end points without contamination from other soil organisms and bacteria.

Culture cells are buried in the earth at shallow depths at test and control sites, thus exposing the cultures of soil amoebae to the earth's ambient temperature. It is also desirable to expose the amoebae to the same EM environment that they would encounter if living in the soil. Ideally, this would be accomplished simply by connecting electrodes in the culture cell directly to the earth, so that the electric voltages and currents present in the earth could be applied to and flow through the culture medium in the cell. However, the electric field exposure in the culture cells is complicated by a mismatch between the conductivity of the soil and that of the culture medium. Therefore, external control circuitry must be used to regulate the drive voltages obtained from a set of collector electrodes in the earth before they are applied to the culture cell electrodes.

Two basic culture cell drive control circuits were developed: one for matching electric field exposure in the culture cell to that of the earth, and the other for matching current density exposure. Drive control circuits and protocols explaining their use are detailed in Appendix J. Magnetic flux is not perturbed by the culture cells.

In 1987 and 1988, culture cells and control apparatus were installed at the soil amoebae study sites. Control voltages V_{CL} and V_R and open circuit voltage V_{OC} were measured according to the protocol outlined in Appendix J. Culture cell electric field (E_{CL}) and current density (J_{CL}) are calculated from exposure control measurements as follows:

$$E_{CL} = \frac{V_{CL}\ \text{(volts)}}{0.113\ m} \qquad \text{(V/m)} \qquad (5)$$

$$J_{CL} = \frac{V_R\ \text{(volts)}}{R\ \text{(ohms)}\ 1.42\ x^{-4}\ m^2} \qquad (A/m^2) \qquad (6)$$

where 0.113 m is the measured distance between culture cell electrodes and 1.42×10^{-4} m^2 is the cross-sectional area of the culture cell growth medium. The area used assumes that the cell is half full of growth medium.

IITRI designed and installed microprocessor controlled data loggers at all amoebae study sites in 1988. Figure 9 shows a data logger beside a portable personal computer that is used to initiate operation of the data logger and to offload data from it at the end of each measurement period. These data loggers measure the voltage and current of the culture cells, the temperatures within the partially buried data logger enclosure, and the longitudinal electric field at each site. Samples of the data logger measurements at the antenna and ground study sites are plotted in Figures 10 and 11.

Figure 10 shows calculations of culture cell electric fields for matched E-field cells based on hourly measurements at the antenna and ground study sites. These values were calculated using Equation 5 and data logger measurements of V_{CL}. The data presented in Figure 10 were measured while the NS antenna element was on. Gaps in the data sequence correspond to periods when the NS antenna element was not operated. The differences in electric field intensity between the two sites are expected because of the differences in the electric field coupling at antenna and ground sites. The ground site electric fields are much more sensitive to changes in soil conductivity due to moisture and temperature.

The data presented in Figure 11 are calculated current densities for matched current density cells based on hourly measurements at the antenna and ground study sites. These values were calculated using Equation 6 and data logger measurements of V_R. The measurements were made while the NS antenna element was on and correspond in time to the electric field intensities shown in Figure 10. All data collected by the data loggers at the soil amoebae sites should be considered preliminary at this time.

4.2 Support for Upland Flora and Soil Microflora Studies

In 1987, study investigators asked IITRI to assist in analyzing their established ambient monitoring systems at the upland flora and soil microflora study sites to determine the susceptibility of the systems to ELF interference, and to help design lightning protection for the monitoring equipment. Specific areas of concern were:

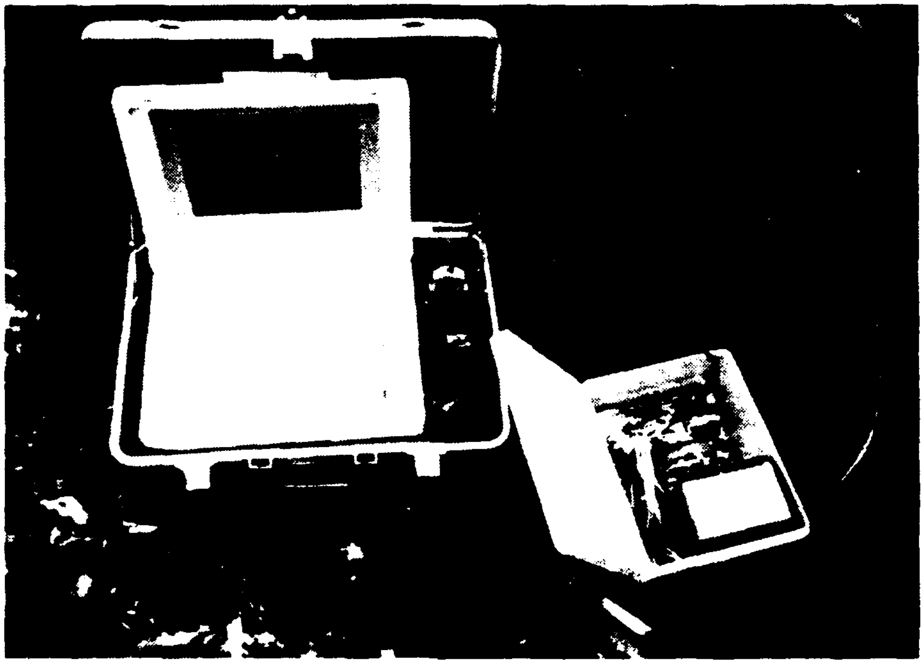


FIGURE 9. MICROPROCESSOR-CONTROLLED FIELD DATA LOGGER (RIGHT) WITH A PORTABLE PERSONAL COMPUTER.

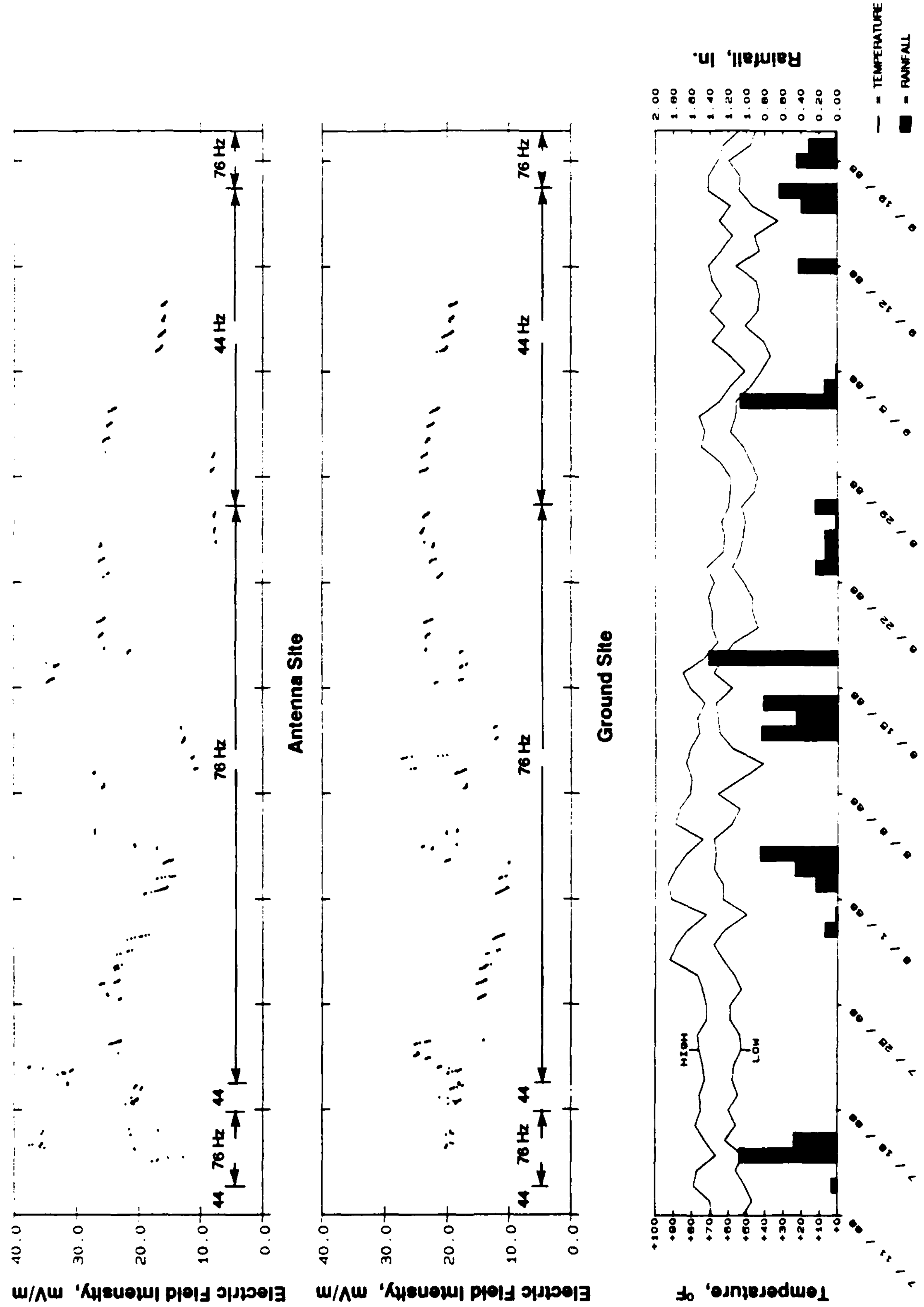


FIGURE 10. HOURLY CULTURE CELL ELECTRIC FIELD MEASUREMENTS FOR MATCHED ELECTRIC FIELD CELLS AT SOIL AMOEBAE ANTENNA AND GROUND STUDY SITES.

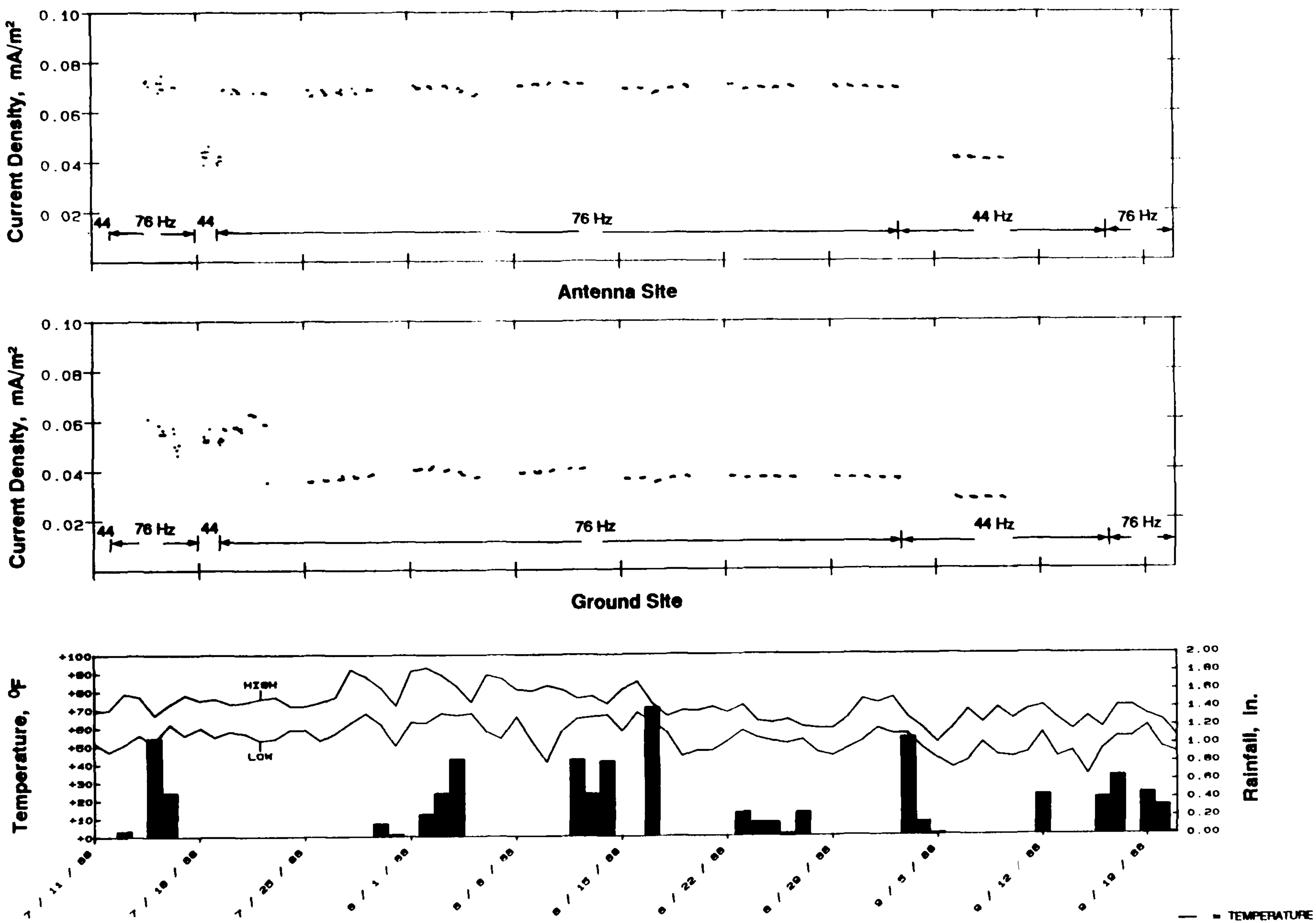


FIGURE 11. HOURLY CULTURE CELL CURRENT DENSITY MEASUREMENTS FOR MATCHED CURRENT DENSITY CELLS AT SOIL AMOEBAE ANTENNA AND GROUND STUDY SITES.

- The magnitude of ELF voltages accessible to the public on metallic sensor housings and cables (touch voltage).
- The magnitude of ELF voltages accessible to study investigators on wires and terminals inside sensor housings and junction boxes (craftsman safety).
- The possibility of ELF interference to sensor signals.
- The design of lightning protection for the remote sensors and the Handar 540 monitoring platform.

Measurements made with the MTF antenna operating at 15 amperes indicated that safety voltages and ELF coupling would become a problem when the antenna was operated at full power. Analysis of the monitoring systems and design of ELF mitigation schemes began in late 1987 and continued during early 1988. A lightning protection design was formulated based on the layout of the monitoring system site and on circuitry information from the manufacturer of the monitoring system. This design included recommendations for reconfiguring sensor and cable sheath grounding and specified terminal protection devices to be installed at sensor outputs and monitoring system inputs.

A second analysis of the monitoring system was conducted to take the grounding changes into account. This analysis indicated that ELF touch voltages on all metallic equipment associated with the monitoring system would be below the safety threshold* at full power antenna operation following implementation of the lightning protection recommendations. However, 18 soil moisture sensors at the test sites were still susceptible to ELF interference and would require appropriate mitigation. In addition, two solar radiation sensors, which were extremely susceptible to lightning damage, could not be protected as wired. An additional buffer circuit was specified to isolate these sensors for lightning protection. ELF signal interference mitigation for the soil moisture sensors was accomplished by specifying ac bypass capacitors to be installed across the sensor output terminals.

Study investigators acquired the hardware and parts needed to implement the lightning protection and ELF mitigation designs based on materials lists

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*Navy standards limit the sum of 60 Hz and ELF voltages on any conductor that is accessible to the general public to 6 V_{rms}. They also limit the sum of 60 Hz and ELF voltages that are accessible to telephone craftsmen to 50 V_{rms}.

provided to them by IITRI. IITRI personnel assisted the study investigators in the installation and wiring of the mitigation and protection hardware and in the reconfiguration of the system grounding. Following the installation, IITRI conducted safety and interference voltage measurements at the test sites. The measurements indicated that safety (touch voltage) problems would still remain at the antenna site for full power antenna operation. Additional ground rods were installed at this site in an effort to reduce the touch potentials to acceptable levels, but five ground rings were needed as well in order to successfully eliminate the remaining touch potential problems.

Ground rod impedance measurements made at all study sites indicated high ground rod impedances because of the sandy nature of the soil. Most ground rod impedances were unacceptably large to provide good lightning protection using the terminal block protectors. Discussions with the manufacturer of the terminal block protectors indicated that deep ground rods would have unacceptably high self-inductance for good lightning protection, and suggested chemically treating the existing ground rods with magnesium sulfate as an effective alternative. Study investigators were contacted regarding this procedure and had no objection provided the salts were deposited 1 to 2 ft below the soil surface.

IITRI personnel treated four ground rods at the antenna site on 13 and 14 July. Ground rod impedances were improved by a factor of five (average) after treatment, and remained stable over the first week after installation. Based on these tests and the procedures established, plans were made to treat the ground rods at the control site, considered to have the highest risk of lightning damage.

During the first week of August, IITRI personnel treated 24 ground rods at the control site. Significant improvements in impedances were obtained at all ground rods. Measurements made at the previously treated rods at the antenna site indicated that these impedance values had remained stable over the first month after installation. IITRI personnel revisited the control site the week of 8 to 12 August and remeasured the impedances of the treated rods. All impedances remained stable or showed slight improvements over the one-week period. Due to the labor-intensive nature of the ground rod treatment methodology, no plans were made tc salt the remaining untreated ground rods at the antenna and ground sites.

4.3 Support for Small Mammals and Nesting Birds Studies

Study investigators for the small mammals and nesting birds studies conducted tests in 1986 and 1987 in which tree swallows were captured and removed from their nest sites, displaced about 18 miles, and then released. The time that the swallows took to return to their nest sites was measured. Study investigators did not find significant differences in return times between test and control swallows for 1986, nor between test swallows from 1986 to 1987. However, control swallows took significantly longer to return in 1987 than did control swallows in 1986.

Study investigators are examining gender and age as possible biological factors, but they are also concerned about EM anomalies that could be disorienting birds attempting to home to control nest sites. IITRI has responded to these concerns by:

- measuring EM field intensities at nest (capture) sites and release points
- plotting return transects relative to power system distribution systems
- acquiring information on the operation and power outputs of the nearby electric power generating plant during the periods of the 1986 and 1987 experiments
- flying the return path to control sites in a small plane in an attempt to identify additional power distribution lines or other sources of EM fields along the birds' flight path
- providing copies and sources for geomagnetic maps

The Way Dam and Hemlock Falls electric power generating plants are situated along the flight path for the control displacement test, as illustrated in Figure 12. These generating plants, an interconnecting 69 kV transmission line from the Crystal Falls substation, and associated distribution lines as shown in Figure 13 represent the predominant source of EM fields in the study area. Operating and load data from these sources have been obtained from Wisconsin Electric Power Company, transformed to line currents, and provided to the study investigators. The aerial survey of the study area revealed no sources of EM fields along the control return transect other than the transmission line running from Crystal Falls to Way and Hemlock Dams and their associated distribution lines.

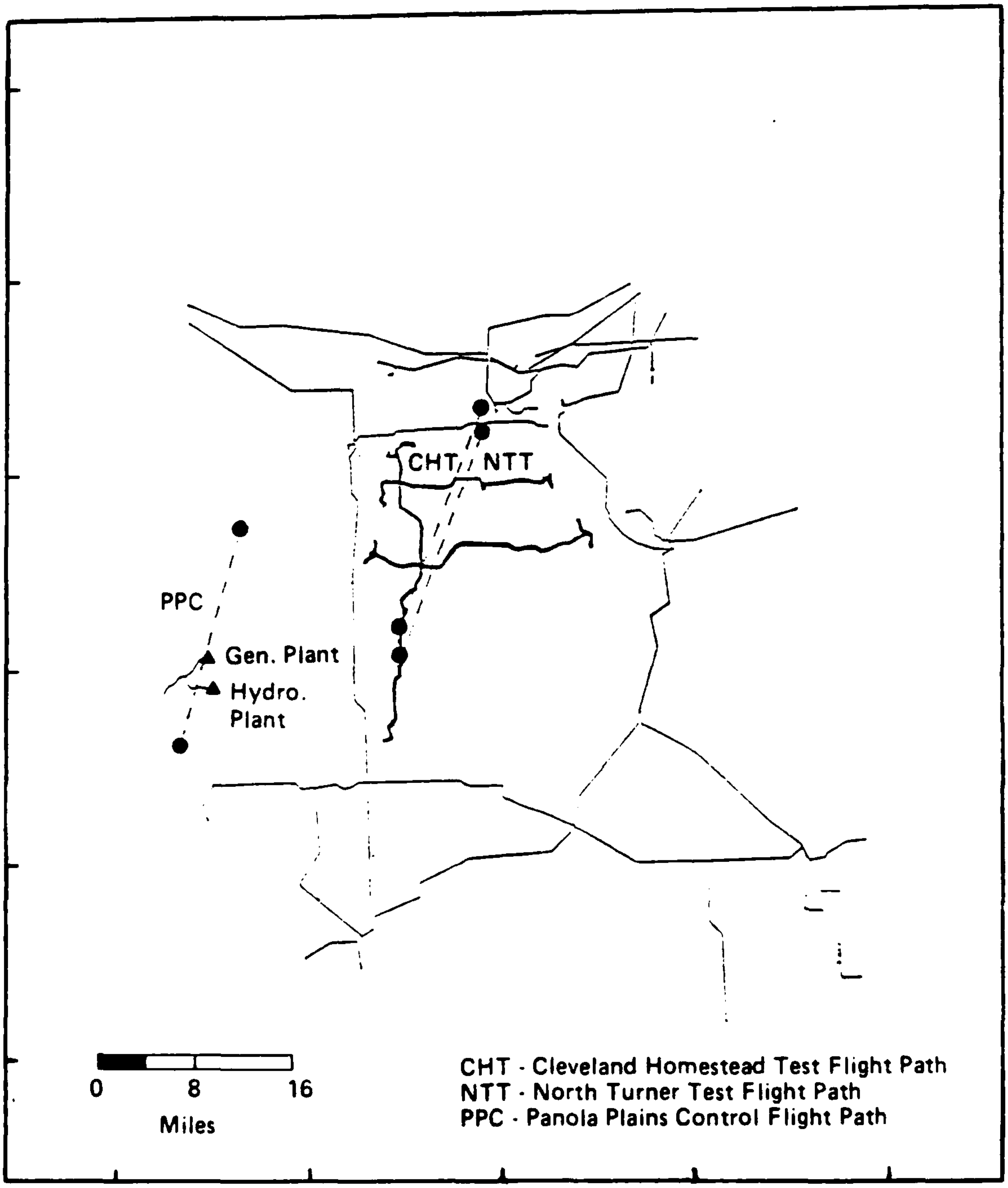

FIGURE 12. BIRD DISPLACEMENT FLIGHT PATH LOCATIONS RELATIVE TO HIGH VOLTAGE 60 Hz TRANSMISSION LINES.

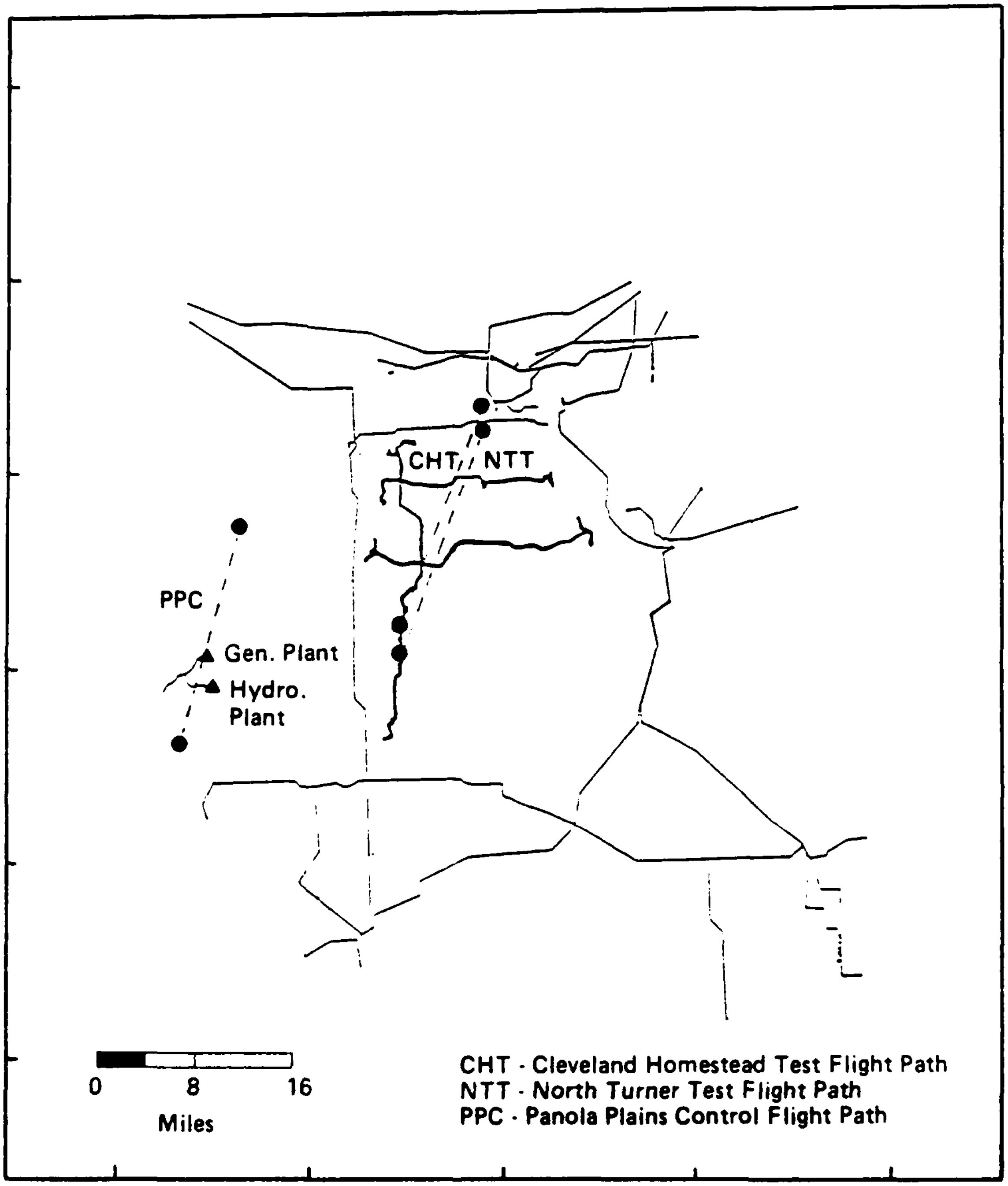

FIGURE 13. BIRD DISPLACEMENT FLIGHT PATH LOCATIONS RELATIVE TO 60 Hz POWER DISTRIBUTION LINES.

4.4 Support for Bird Species and Communities Studies

The bird species and communities studies monitor migrating bird population using a census technique involving 200 m (600 ft) wide by 4.5 km (2.7 mile) long study transects. Ten transects are located in the WTF system area and 10 near the MTF. Each transect is subdivided into eight segments. The study involves monitoring the total population of migrating birds in an area both as a whole and as individual species. The electric and magnetic fields in the air are considered the most important EM factors influencing migrating birds; however, the electric field in the earth may also have an influence.

Early in 1988 the study investigators requested information regarding the EM field gradients across study transects as well as the variability of the EM fields along the centerline of the transects. IITRI responded by taking several special sets of EM measurements at WTF study sites during the annual EM measurement survey.

Measurements were made at regular intervals on a line perpendicular to both the WTF NS antenna and study transect 10T8. The measurement data are reported in Appendix G, Table G-6. These measurements define typical gradients of 76 Hz longitudinal electric field intensity and magnetic flux density across the width of the study transect. A graph of the magnetic field data is presented in Figure 14. The magnetic field curve closely matches calculated values and can be used to predict the magnetic flux density at other locations near a WTF antenna element. Similarly, if the magnetic flux density at a location is known, the distance to the antenna can be interpolated from the same curve.

The longitudinal electric field gradient is plotted in Figure 15, and illustrates the changes in intensity of the longitudinal electric field with respect to changes in soil conductivity. This curve, because it is site-specific, cannot be used for estimating electric field intensities or the distances from other sites to the antenna.

Measurement data for electric and magnetic fields along control (10C7) and treatment (10T8) transects are reported in Appendix G, Table G-7. Measurements were taken at the beginning and end of each transect, as well as between transect segments at the "X" flag. Graphs of the EM field intensities along transects 10C7 and 10T8 are presented in Figures 16 and 17, respectively.

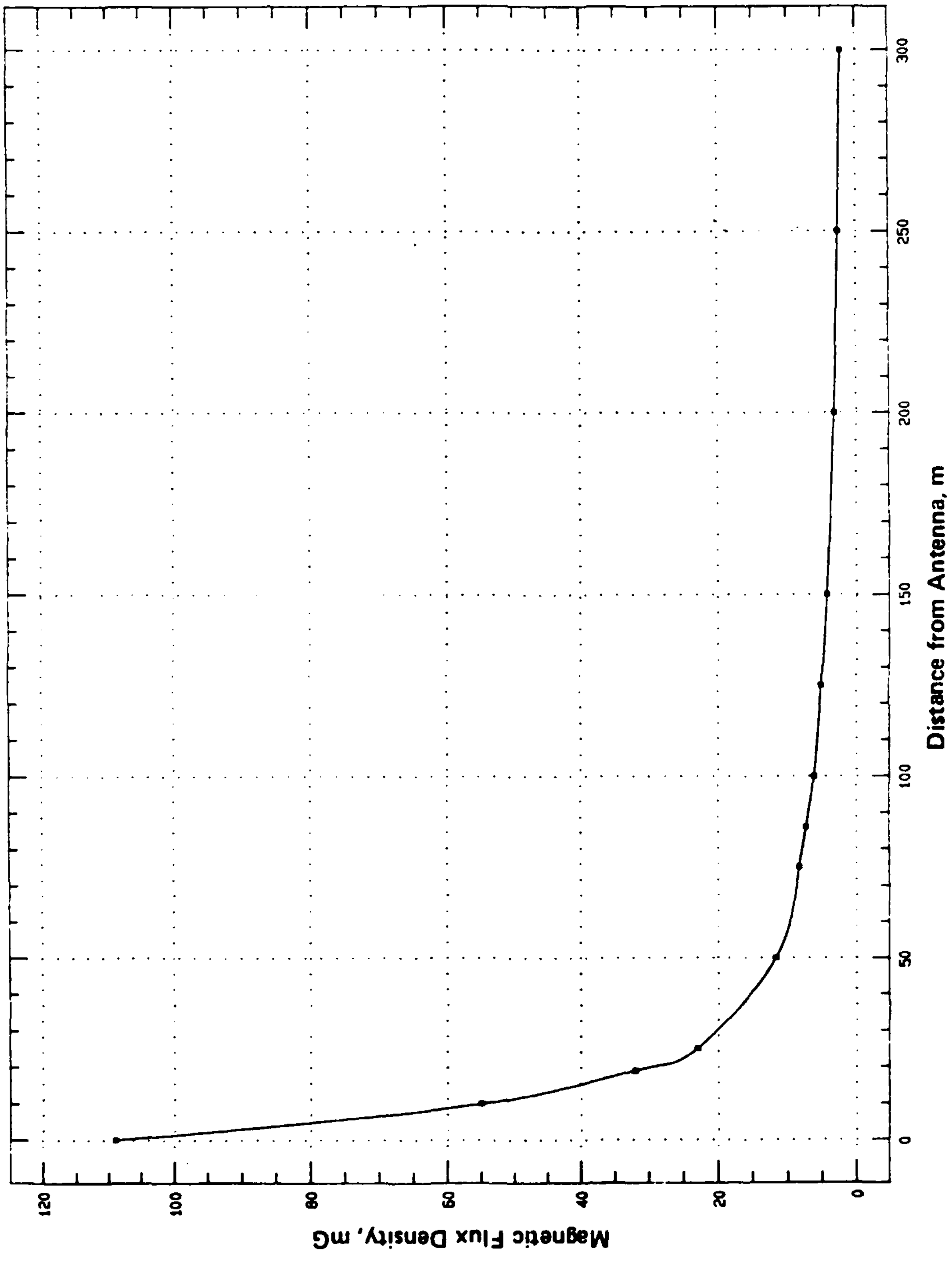

FIGURE 14. MAGNETIC FIELD GRADIENT PERPENDICULAR TO THE WTF ANTENNA.

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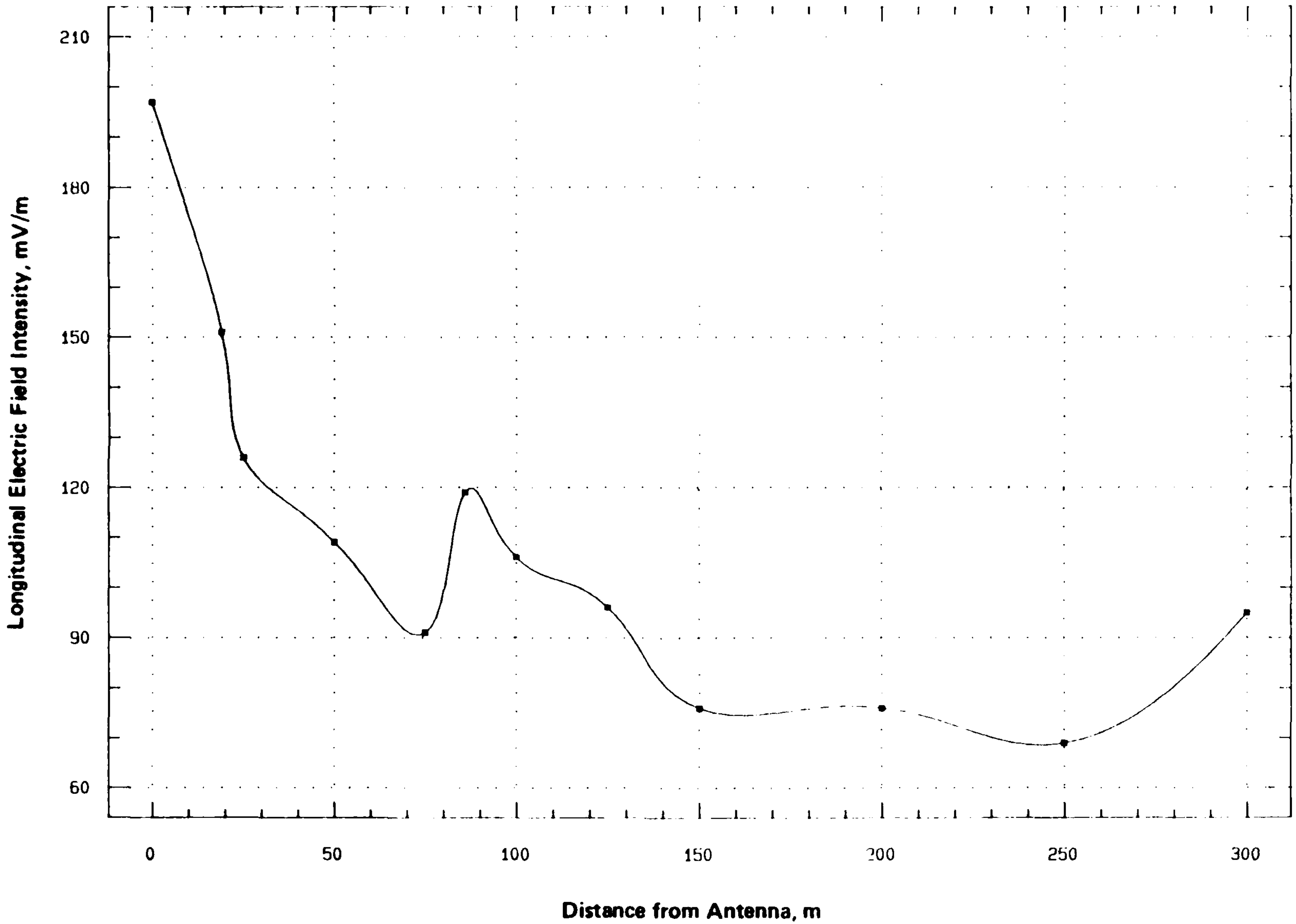

FIGURE 15. LONGITUDINAL ELECTRIC FIELD GRADIENT PERPENDICULAR TO THE WTF ANTENNA.

Figure 16 shows that the 76 Hz magnetic flux density along control transect 10C7 (Mineral Lake) is quite uniform, with only a slight and gradual increase from the beginning to the end of the transect. This is the expected behavior of the magnetic field at a great distance from the antenna. The earth electric field intensity along this transect is more variable than the magnetic field, again illustrating the effect of changes in soil conductivity on the longitudinal electric field.

The magnetic flux density along test transect 10T8 (Little Clam Lake) is much more variable than that along the control transect (see Figure 17). This is because the test transect is much closer to the antenna, and differences in the distance of each transect segment from the antenna will have a greater relative effect than at control transects. The earth electric field along the test transect is also highly variable, as expected.

The magnetic field data for 10T8 were used in conjunction with the magnetic field gradient curve of Figure 14 to estimate the distance to the antenna wire from each transect segment. These estimates are plotted in Figure 18. As indicated, the distance varies from a minimum of about 50 m to a maximum of about 200 m.

4.5 Study of Temporal Variations in Electromagnetic Fields

Annual field measurements generally have been made in late summer and early fall. Since most study biota remain on the study sites throughout the year, the subject of EM field variations over the course of a year is important and is addressed below.

It is anticipated that the magnetic fields at study sites will show little or no seasonal variation, since they are dependent primarily on fixed factors such as antenna current and wire height and are not affected by the conductivity of surrounding vegetation and soil. The magnetic field, B, at the earth's surface near an ELF antenna element can be approximated as:

$$B = \frac{\mu_0 I}{2\pi\sqrt{x^2 + h^2}} \tag{7}$$

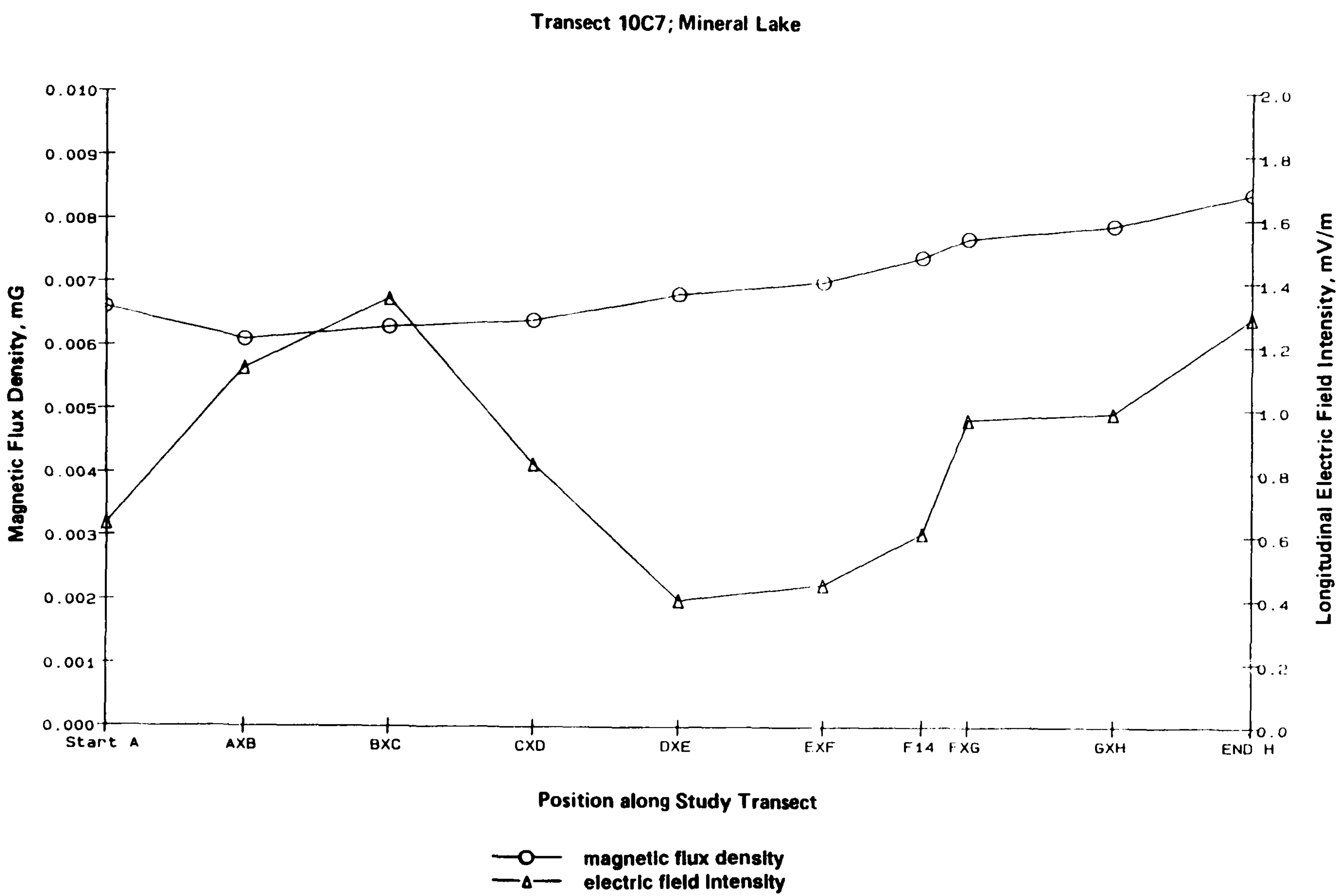

FIGURE 16. EM FIELD VARIATIONS ALONG STUDY TRANSECT 10C7.

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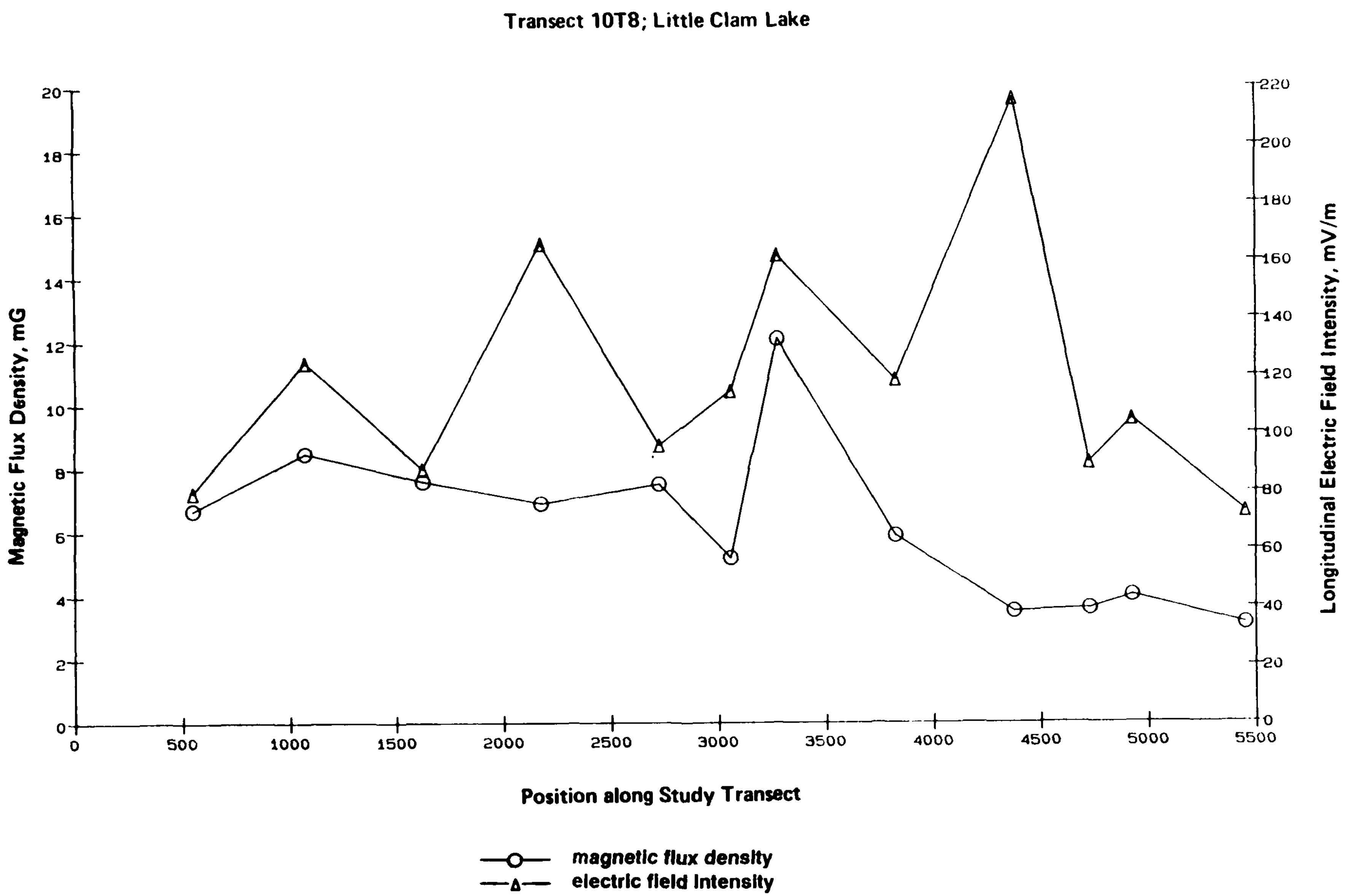

FIGURE 17. EM FIELD VARIATIONS ALONG STUDY TRANSECT 10T8.

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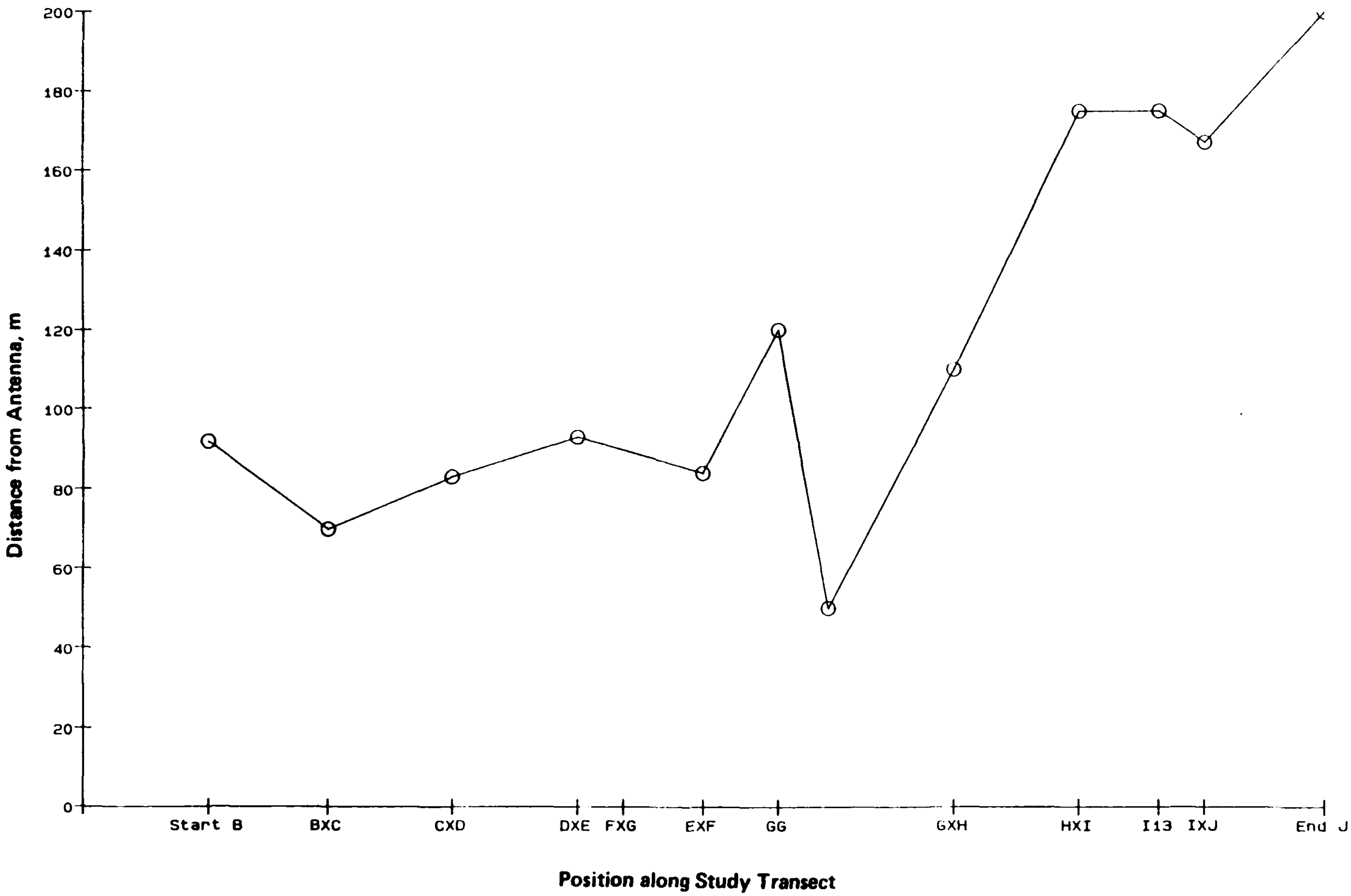

FIGURE 18. ESTIMATED DISTANCE FROM TRANSECT 10T8 TO THE ANTENNA WIRE.

where B = magnetic flux density

I = antenna current

μ_0 = magnetic permeability in free space

h = height of antenna wire

x = horizontal distance to antenna wire

The transverse electric field in an ROW or a clearing near the antenna is essentially dependent on the antenna voltage, distance to the overhead wire, and wire height, and is not expected to show significant variation throughout the year. The transverse electric field intensity at the earth's surface can be approximated as:

$$E = \frac{2V}{h \ln\left(\frac{2h}{a}\right)} \bullet \frac{1}{1 + \left(\frac{x}{h}\right)^2} \qquad (8)$$

where E = transverse electric field intensity

V = voltage on antenna wire

h = height of antenna wire

a = radius of antenna wire

x = horizontal distance to antenna wire

However, at other locations where the transverse electric field is shielded by vegetation and trees or generated as a by-product of the longitudinal electric field, more seasonal variation is expected as plants enter dormancy and leaves fall or as the longitudinal electric field varies. Such variations in the transverse (air) electric field would be difficult to document because the transverse electric field probe is not suitable for long-term unattended operation.

Longitudinal electric fields are induced by the magnetic field as well as being generated by current from antenna ground terminals. In both cases, the field intensities are dependent on soil conductivity, which varies in response to changes in soil moisture and temperature. The relationship of electric fields to soil conductivity for the two field sources is discussed below.

The longitudinal electric field along an ELF horizontal ground terminal is generated primarily by current flowing off the ground wire to the earth, and may be approximated as:

$$E \approx \frac{I}{\pi l \sigma_S} \cdot \frac{x}{x^2 + d^2} \tag{9}$$

where E = longitudinal electric field

I = antenna current

l = ground length

d = depth of buried ground wire

x = horizontal distance from ground wire

σ_S = surface earth conductivity

The magnetically induced longitudinal electric field near an antenna ROW may be approximated as:

$$E \approx -jfI\mu_0 \ln\left(\frac{1.85}{x\sqrt{2\pi f \mu_0 \sigma_B}}\right) - \frac{\pi f I \mu_0}{4} \tag{10}$$

where E = longitudinal electric field

$j = \sqrt{-1}$

f = frequency

I = antenna current

μ_0 = magnetic permeability in free space

x = horizontal distance from antenna

σ_B = bulk earth conductivity

Equations 9 and 10 illustrate differences in the variation of the longitudinal electric field near ground terminals and antenna ROWs, respectively, as a function of soil conductivity. In both equations, earth conductivity is the only variable expected to show a seasonal variation. The two conductivity terms (bulk and surface) are not equivalent and have different functional relationships within the corresponding electric field equations. The longitudinal electric field near ground terminals is dependent primarily on surface earth conductivity, while bulk earth conductivity determines the electric field near antenna ROWs. The bulk earth conductivity is a weighted average of the surface and deep earth conductivities. Because the deep earth conductivity remains stable throughout the year, the bulk earth conductivity shows less seasonal variation than does the surface earth conductivity. In addition to these differences in conductivity, the longitudinal electric field near ground terminals is inversely proportional to conductivity, while the longitudinal electric field along antenna ROWs is proportional to the natural logarithm of the inverse of the square root of conductivity. Thus, the longitudinal electric field is almost twice as sensitive to changes in conductivity near ground terminals as it is to changes in conductivity along antenna ROWs. This fact, in conjunction with the expected higher variation in surface conductivity, indicates that the greatest seasonal variations in longitudinal electric fields will occur along ground terminal ROWs.

Data loggers at the soil amoebae study sites are being kept on site all year in order to monitor variations in the longitudinal electric field. Preliminary 1988 electric field data from two study sites, one adjacent to an antenna ROW and the other adjacent to a ground ROW, are presented in Figures 19 and 20, respectively. These figures plot hourly measurements of the longitudinal electric field, using a pair of fixed electrodes, during operation of the NS antenna element. The figures also present minimum and maximum temperature and precipitation data from the upland flora test site approximately 20 miles to the northwest.

The data in both figures are highly variable for the first week because the MTF antenna was undergoing extensive testing and tuning during this period for 75 ampere operation, and many transmission frequencies were used each day. Electric field measurements at the ground study site (Figure 20) show a marked and permanent decrease in field levels on 22 July. This decrease correlates exactly in time with a reduction in current being fed to the section of horizontal ground wire adjacent to the study site. Other periodic decreases in electric field levels are evident in both figures. These level shifts are the result of changes in antenna operating frequency from 76 Hz to 44 Hz, usually for a week or more at a time. The shifts are more dramatic at the antenna site because the electric field generated by magnetic induction is directly dependent on frequency (see Equation 10). Thus, 44 Hz antenna operation will produce lower longitudinal electric field intensities at study sites than will 76 Hz operation.

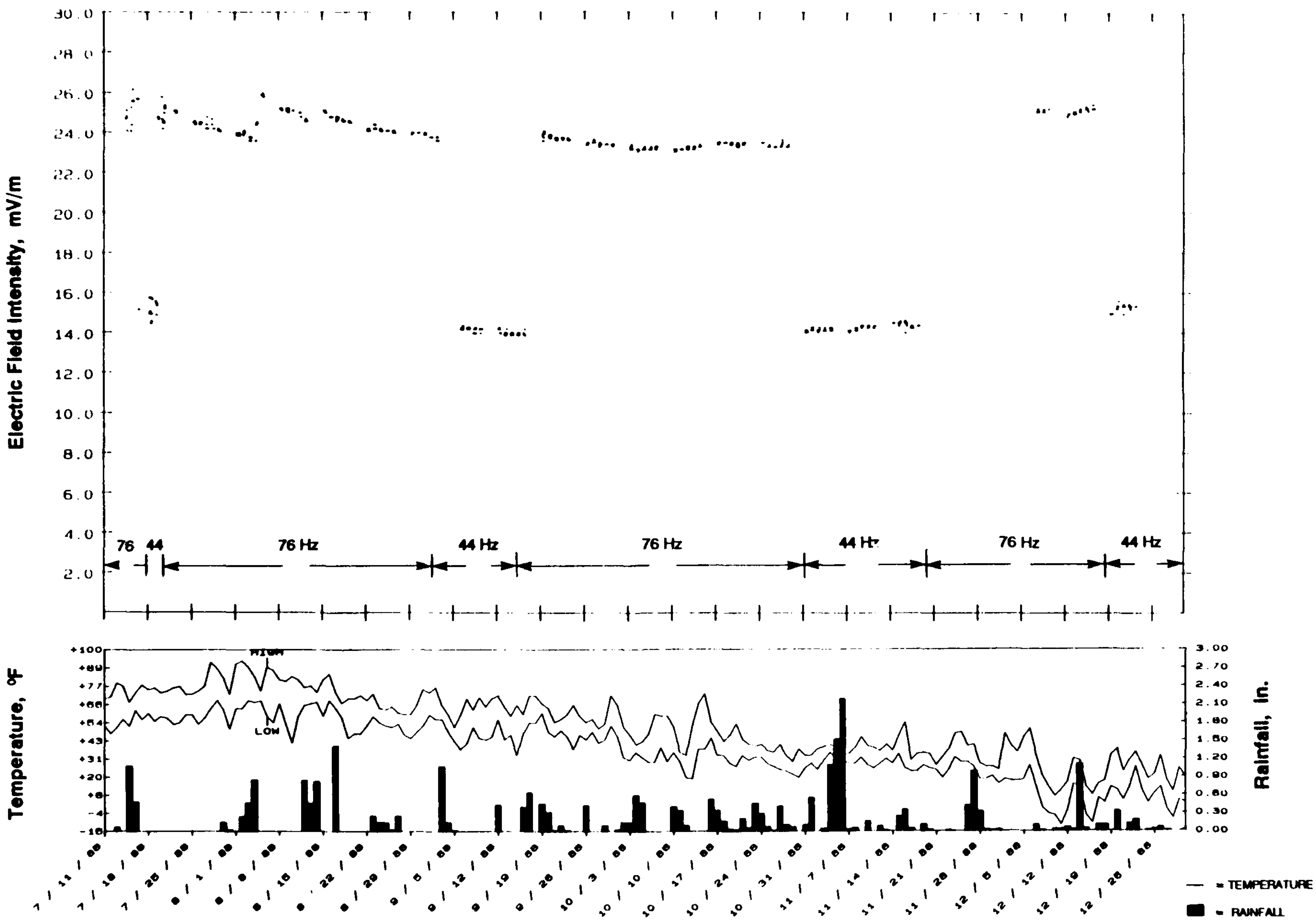

FIGURE 19. HOURLY LONGITUDINAL ELECTRIC FIELD MEASUREMENTS NEAR AN ELF ANTENNA ELEMENT.

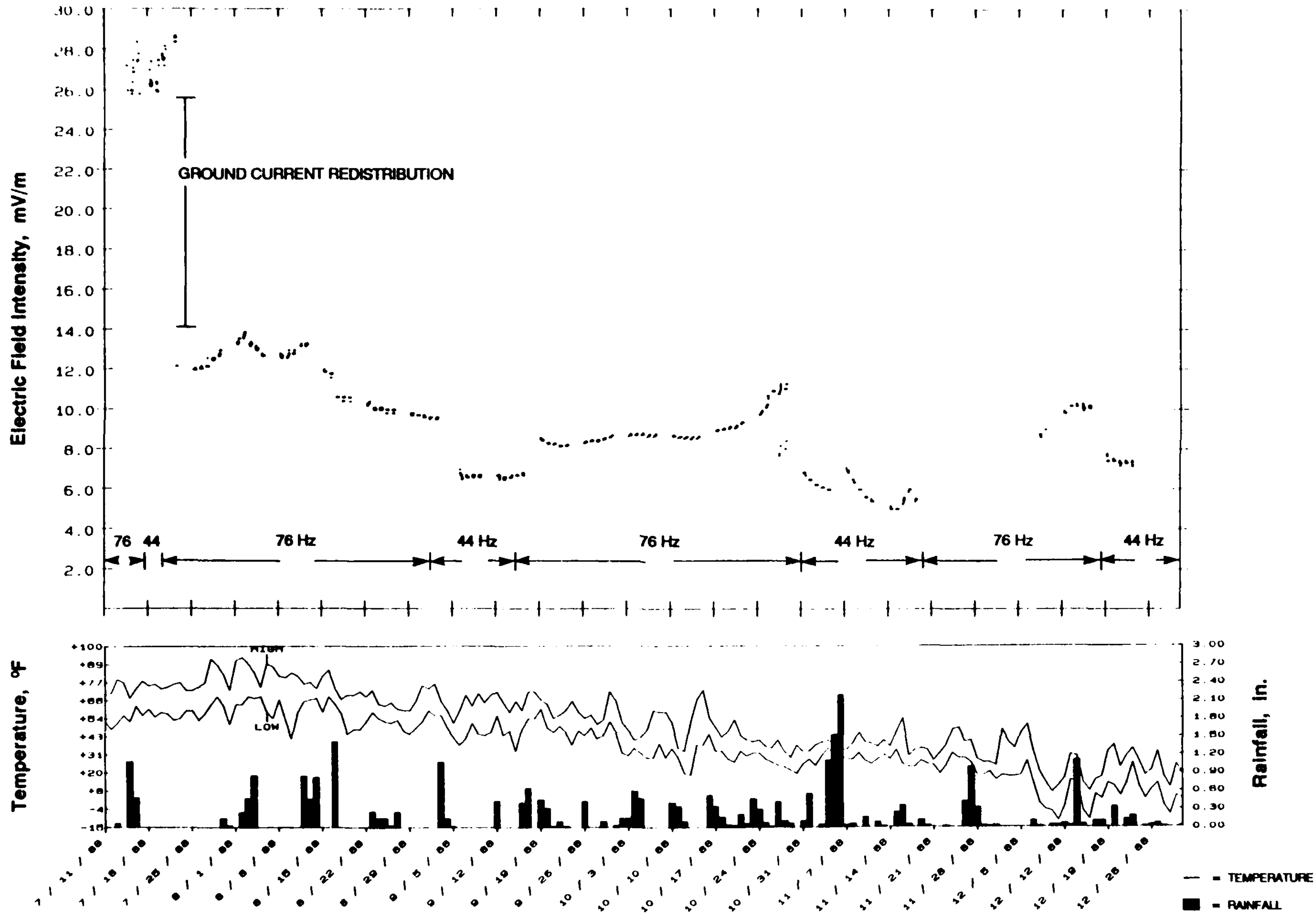

FIGURE 20. HOURLY LONGITUDINAL ELECTRIC FIELD MEASUREMENTS NEAR AN ELF GROUND TERMINAL.

The limited data on electric field versus time suggest that the seasonal field variations near an antenna ROW are on the order of ±5% if periods of antenna tuning are eliminated. As expected, seasonal electric field variations near ground terminal ROWs are somewhat greater, approaching ±20%. Figure 20 shows that the changes in electric field also correlate well with rainfall, which presumably affects upper soil conductivity via moisture content. Thus, as soil moisture content increases, soil conductivity increases, and the electric fields decrease. This is evident in early August as rainfall ended a period of drought. The increase in electric field shown in Figure 20 at the end of October probably reflects a decrease in soil conductivity as winter approached and the soil began to freeze.

Only two study sites in Michigan are actually located in or near ground terminal ROWs. All other test sites are along antenna ROWs and are generally in loamy soil. Seasonal variations in the longitudinal electric field can be expected to have the greatest impact on studies investigating subterranean biota, i.e., the soil arthropods and earthworms studies, the upland flora and soil microflora studies, and the soil amoebae studies. The aquatic ecosystems studies should have the lowest seasonal variation in longitudinal electric field because of the relatively constant bulk conductivity of the Ford River, where these studies are performed.

4.6. Transmitter Operations--Analysis and Data Base

4.6.1 Operating Log Data Base

In order to calculate the EM exposure regimes, study investigators must have both field intensity measurements at the study sites and data on the operating times of the antennas. Field intensity measurements were discussed in Section 3, and data tables are presented in Appendixes A through G. Data on antenna operating conditions are provided to IITRI by the Navy's Submarine Communications Project Office. These data include changes in the operating frequency, modulation, power, and phasing for each antenna element. This information is entered into a computer-based spreadsheet that allows the generation of operating condition summaries in both graphic and tabular form. Graphic summaries for both the WTF and MTF are presented in this section; more detailed tabular summaries appear in Appendix K. IITRI provides the data bases to study investigators on request.

4.6.2 Summary of WTF Operations, 1984-1988

The WTF has gone through three stages of development from an operational standpoint. The first stage began in the late 1960s, when the WTF was constructed as a test system for a Navy ELF communications system. The test procedures required various modulations, frequencies, currents, and separate as well as simultaneous powering (at various antenna current phase angles) of the antenna elements. This stage was marked by sporadic periods of operation.

The second stage began in early 1985 with the installation of the new transmitter equipment. This stage was marked by short powerings interspersed with long periods when the antenna was not powered.

After this initial test period was completed, the third stage began: the WTF began operational testing, operating nearly 24 hours a day at a predetermined current level, frequency, modulation, and antenna phase angle.

The changes from one stage to the next are represented clearly in the WTF monthly operating summary bar graph of Figure 21. This figure shows the hours of operation on a month-by-month basis for the years 1984-1988. Operation of both antenna elements simultaneously was predominant in 1984, with only sporadic operation of the antenna elements individually. There was little operation of the WTF in the first quarter of 1985, followed by intermittent operation in the second and third quarters, and nearly full-time operation in the fourth quarter. This nearly full-time operation continued through 1988.

Figure 22 provides a bar graph of the WTF annual operating summary by mode of operation for 1984-1988. As indicated, the predominant operating condition for all four years was modulated signal transmission at a center frequency of 76 Hz.

The pie charts in Figure 23 provide an annual operating summary by percentage of time per antenna element. As shown, the percentage of time spent in single-antenna operation remained relatively constant during 1984 and 1985 and dropped significantly in 1986, 1987, and 1988. The total "on" time decreased somewhat in 1985 as a result of the transmitter equipment changeover, and then increased dramatically in 1986 through 1988.

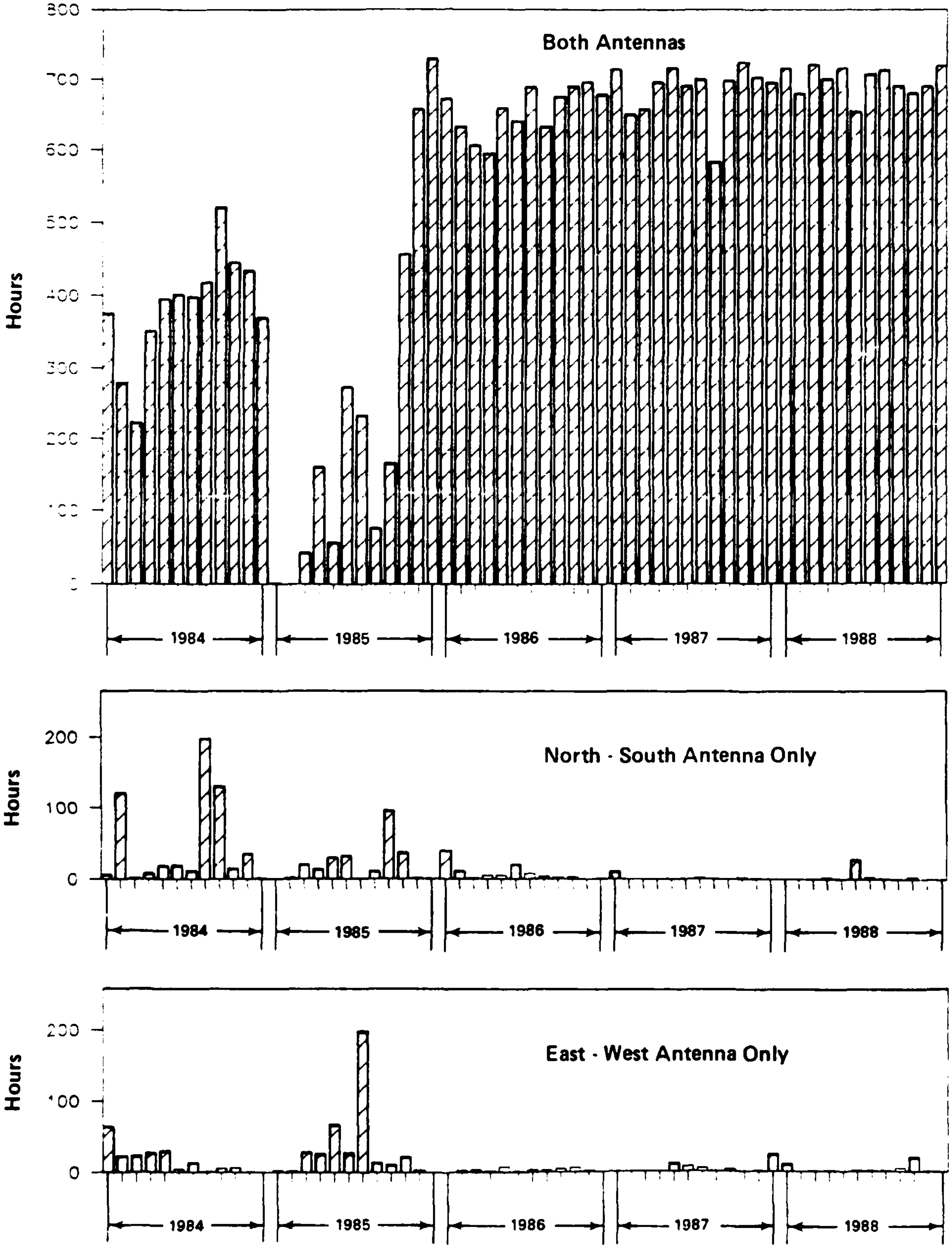

FIGURE 21. WTF MONTHLY OPERATING SUMMARY, 1984-1988.

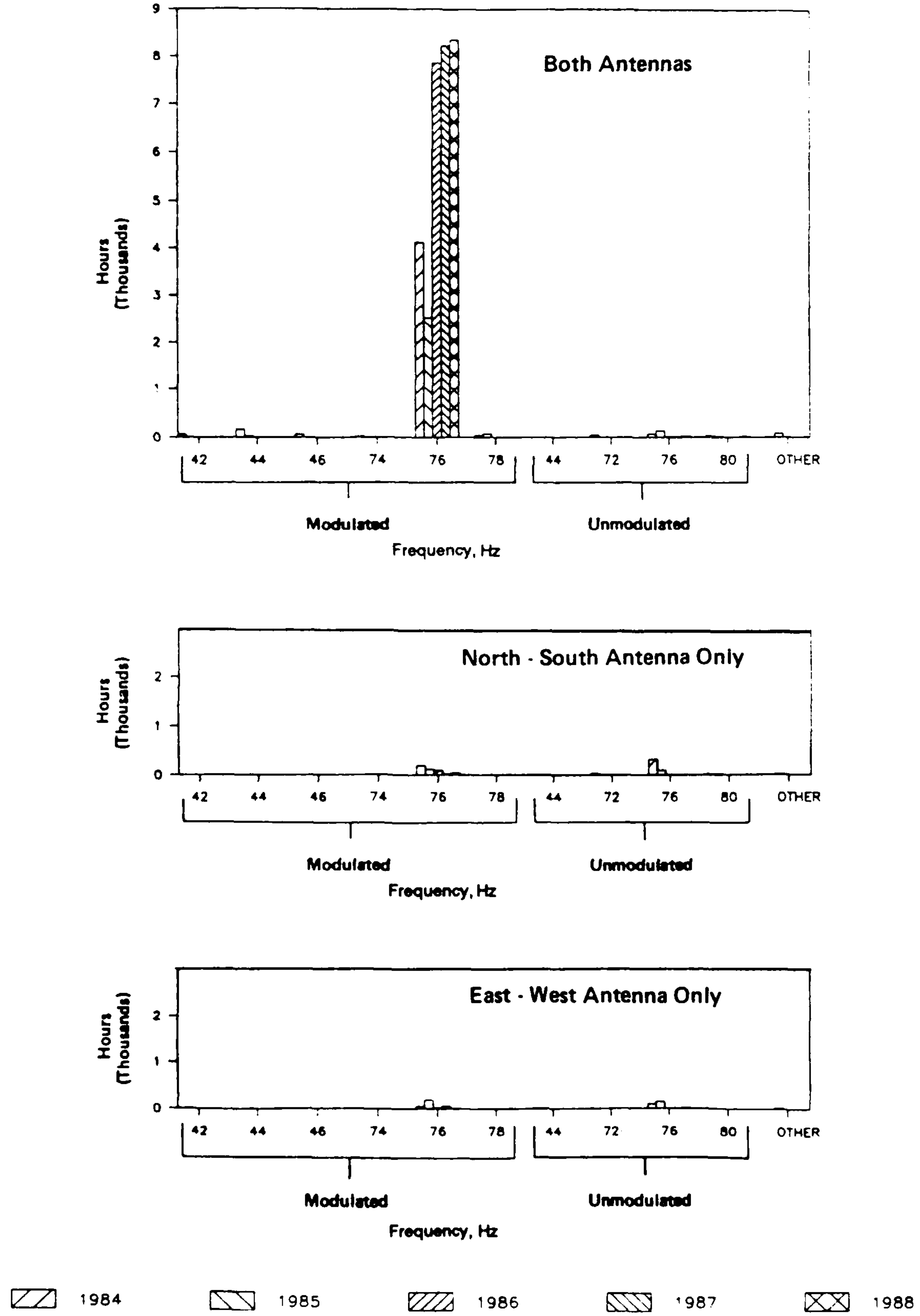

FIGURE 22. WTF OPERATING MODE SUMMARY, 1984-1988.

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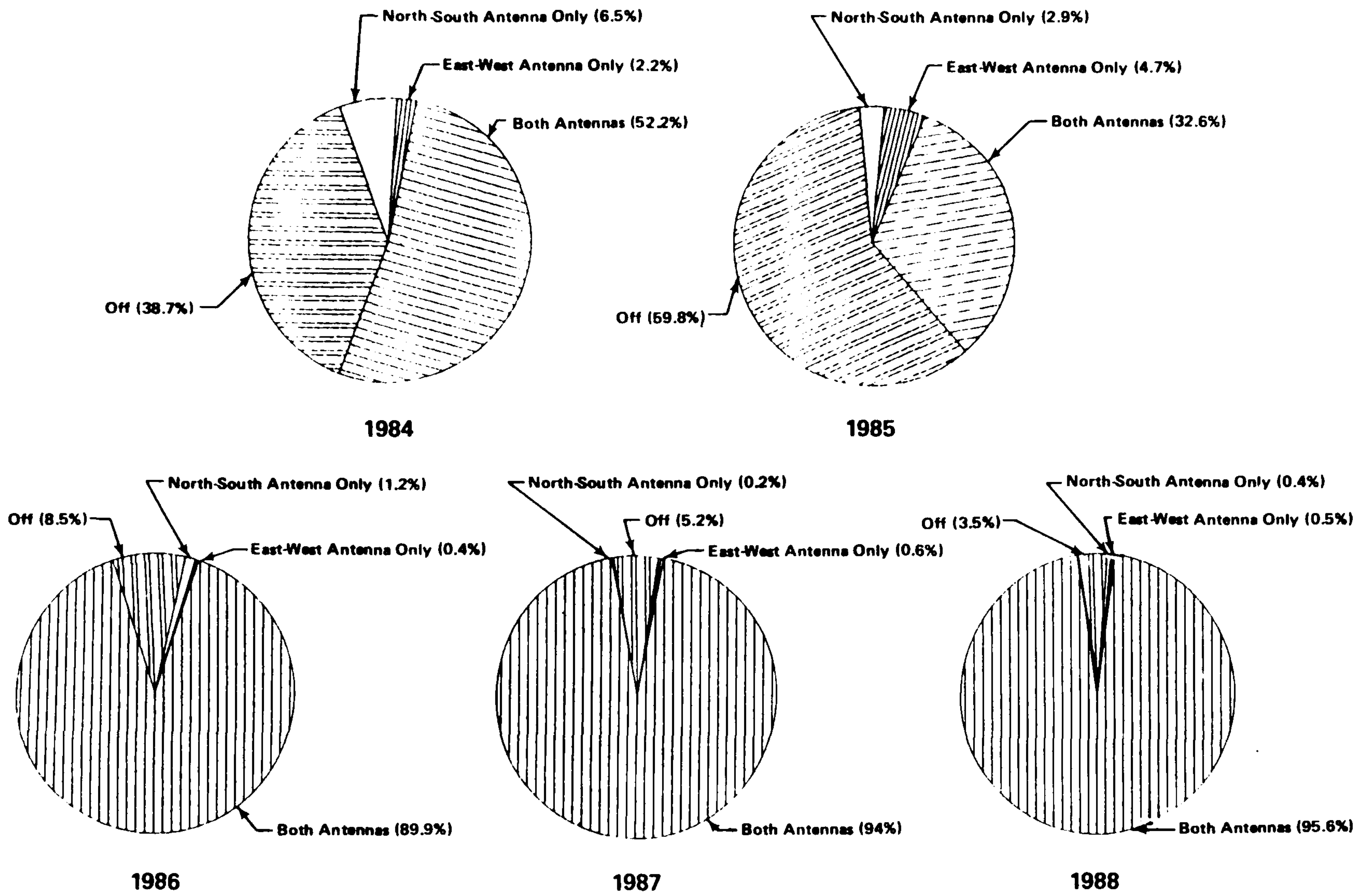


FIGURE 23. WTF OPERATING SUMMARY: PERCENTAGE OF TIME PER ANTENNA ELEMENT, 1984-1988.

WTF operation from 1984 through 1988 can be summarized as follows:

1984

- The WTF was transmitting about 60% of the time (about 5000 hours) (see Figures 21 and 23).
- About 81% of "on" time was with a modulated 76 Hz signal (see Figure 22).
- About 75% of "on" time was accrued in ~12 hour blocks of continuous operation each day.
- The remaining 25% of "on" time was in short, intermittent time periods, and accounted for most of the transmitter changes in operational mode.
- Less than 2.5% of total "on" time for both antenna elements was at a current level less than 290 amperes.

1985

- The WTF was transmitting about 40% of the time (about 3500 hours) (see Figures 21 and 23).
- About 81% of "on" time was with a modulated 76 Hz signal (see Figure 22).
- About 70% of "on" time was accrued in varying-length blocks of continuous operation each day.
- The remaining 30% of "on" time was in short, intermittent time periods and accounted for most of the transmitter changes in operational mode.
- Less than 1.5% of total "on" time for both antenna elements was at a current level less than 290 amperes.

1986

- The WTF was transmitting about 91% of the time (about 8000 hours) (see Figures 21 and 23).
- About 99.8% of "on" time was with a modulated 76 Hz signal (see Figure 22).
- The transmitter was off weekly for a four-hour scheduled maintenance period.
- The transmitter was off intermittently because of equipment failure or unscheduled maintenance.
- Less than 1% of total "on" time for both antenna elements was at a current level less than 290 amperes.

1987

- The WTF was transmitting about 95% of the time (about 8300 hours) (see Figures 21 and 23).

- More than 99.9% of "on" time was with a modulated 76 Hz signal (see Figure 22).
- The transmitter was off weekly for a four-hour scheduled maintenance period.
- The transmitter was off intermittently because of equipment failure or unscheduled maintenance (note maintenance period from 24 to 28 August).
- Less than 1% of total "on" time for both antenna elements was at a current level less than 300 amperes.

1988

- The WTF was transmitting about 96% of the time (about 8500 hours) (see Figures 21 and 23).
- Approximately 99.1% of "on" time was with a modulated 76 Hz signal (see Figure 22).
- The transmitter was off weekly for a four-hour scheduled maintenance period during January through April, and for a six-hour scheduled maintenance during May through December.
- The transmitter was off intermittently because of unscheduled maintenance or testing.
- Less than 1% of total "on" time for both antenna elements was at a current level less than 300 amperes.

4.6.3 Summary of MTF Operations, 1986-1988

The MTF will go through several stages of development, as did the WTF. The antenna elements at the MTF were first operated in March 1986. The signal was a low current unmodulated (continuous wave) signal. The three antenna elements (NS, NEW, and SEW) were operated individually and intermittently through 1986, predominantly at 4, 6, or 10 amperes. In 1987 almost all testing was performed under an unmodulated, 15 ampere test condition. Differences in operation between 1986 and 1987 consisted of the NEW and SEW antenna elements being operated in parallel in 1987 rather than independently as in 1986. These two elements will remain in parallel in the future as well. In 1988, testing was performed with 15 and 75 ampere unmodulated antenna current. Full power (150 ampere) testing is scheduled for 1989.

Figures 24 and 25 show the hours of operation for each antenna element on a month-by-month basis. Figure 24 shows the hours of operation for 1986 only because of a change in the configuration of the NEW and SEW antenna elements. In 1986, the NEW and SEW antenna elements were always operated individually.

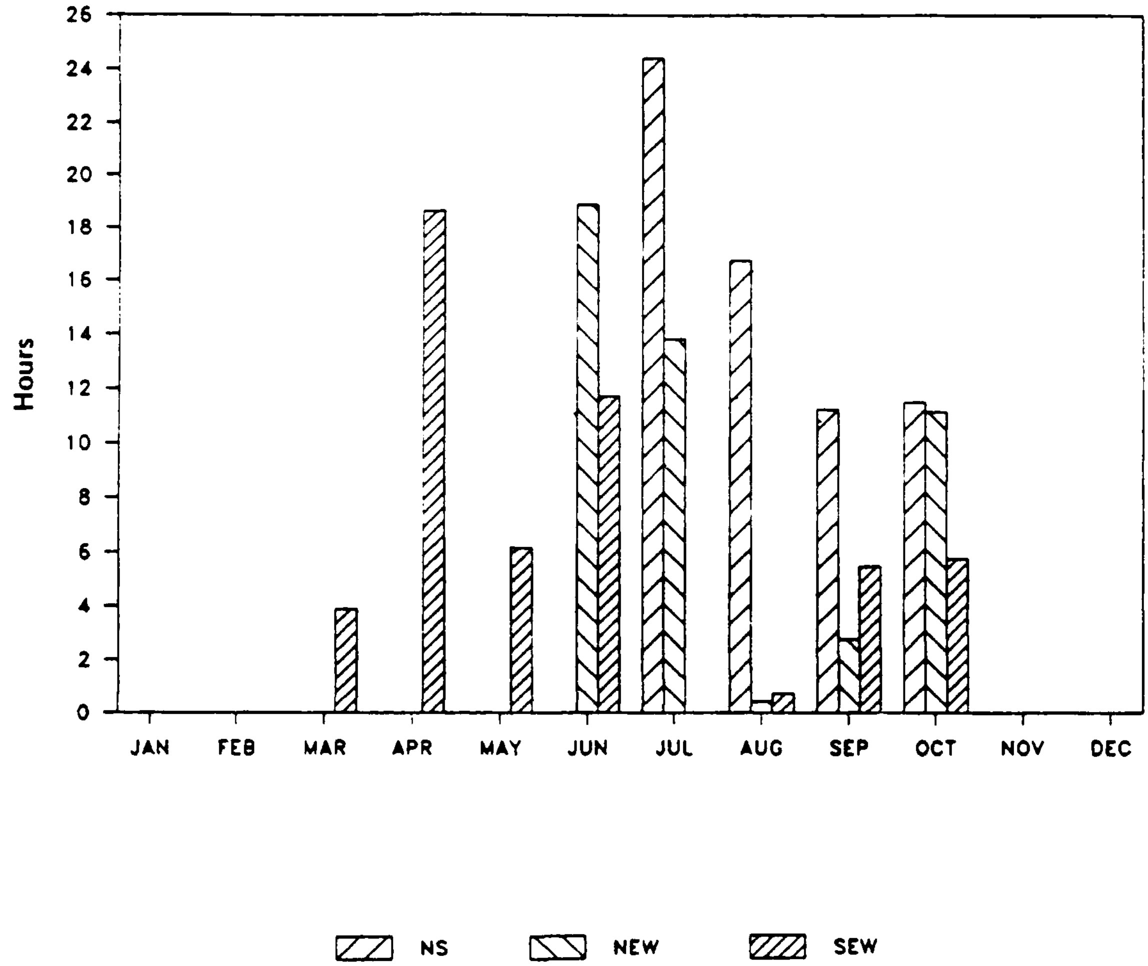


FIGURE 24. MTF MONTHLY OPERATING SUMMARY, 1986.

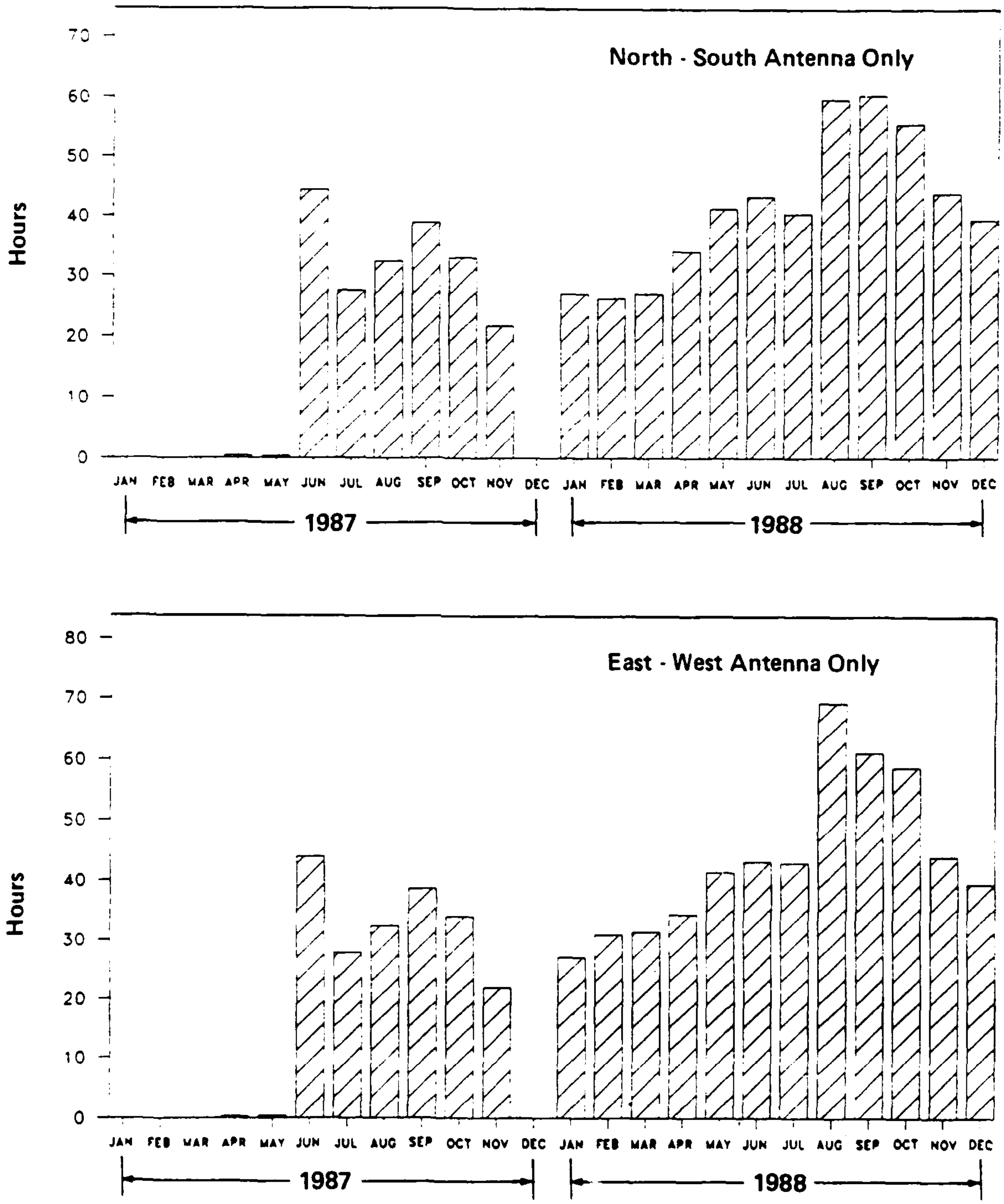


FIGURE 25. MTF MONTHLY OPERATING SUMMARY, 1987-1988.

In 1987, the two antenna elements were configured to operate in parallel. They continued to operate in this parallel fashion through 1987 and 1988, and are collectively referred to as the EW antenna element. As can be seen from these figures, operation began in March 1986 and continued through October of that year, then resumed in April 1987 and continued through November. The MTF did not operate in December 1987, but resumed operation in January 1988 and continued through the end of the year. The operating currents are not shown in these figures. In 1986, the NS antenna element carried a current of 4 amperes for more than 99% of its operating time, the NEW antenna element carried a current of 6 amperes for more than 99% of its operating time, and the SEW antenna element carried both 6 and 10 ampere currents for approximately equal time periods during its operation. In 1987, minimal testing was performed in April and May using 3, 4, and 6 ampere currents. Extensive testing was performed from June through November with 15 ampere currents in each element. In 1988, 15 ampere testing was performed from January through June. In July 1988, the antenna elements were tuned for 75 ampere operation, and 75 ampere testing was performed from July through December. During the 15 and 75 ampere testing periods in 1987 and 1988, virtually all transmitter operations were conducted according to a 15-minute rotational schedule, referenced to quarter hours as follows:

- 5 minutes--both elements off
- 5 minutes--NS element only on
- 5 minutes--EW element pair only on

MTF operational logs supplied to IITRI list specific times at which such cycles begin and end. The actual operating times were estimated by assuming a 33% duty cycle for each element during the testing period.

The pie charts in Figure 26 provide an annual operating summary by percentage of time per antenna element for 1986, 1987, and 1988. In 1986, the total "on" time for all antenna elements was 1.8% of the year; this time was split rather evenly among the NS, NEW, and SEW antenna elements. In 1987, the total "on" time for all antenna elements was 4.5%; this time was split evenly between the NS and EW elements. In 1988, the total "on" time for all antenna elements was 11.7%; this time was split evenly between the NS and EW elements.

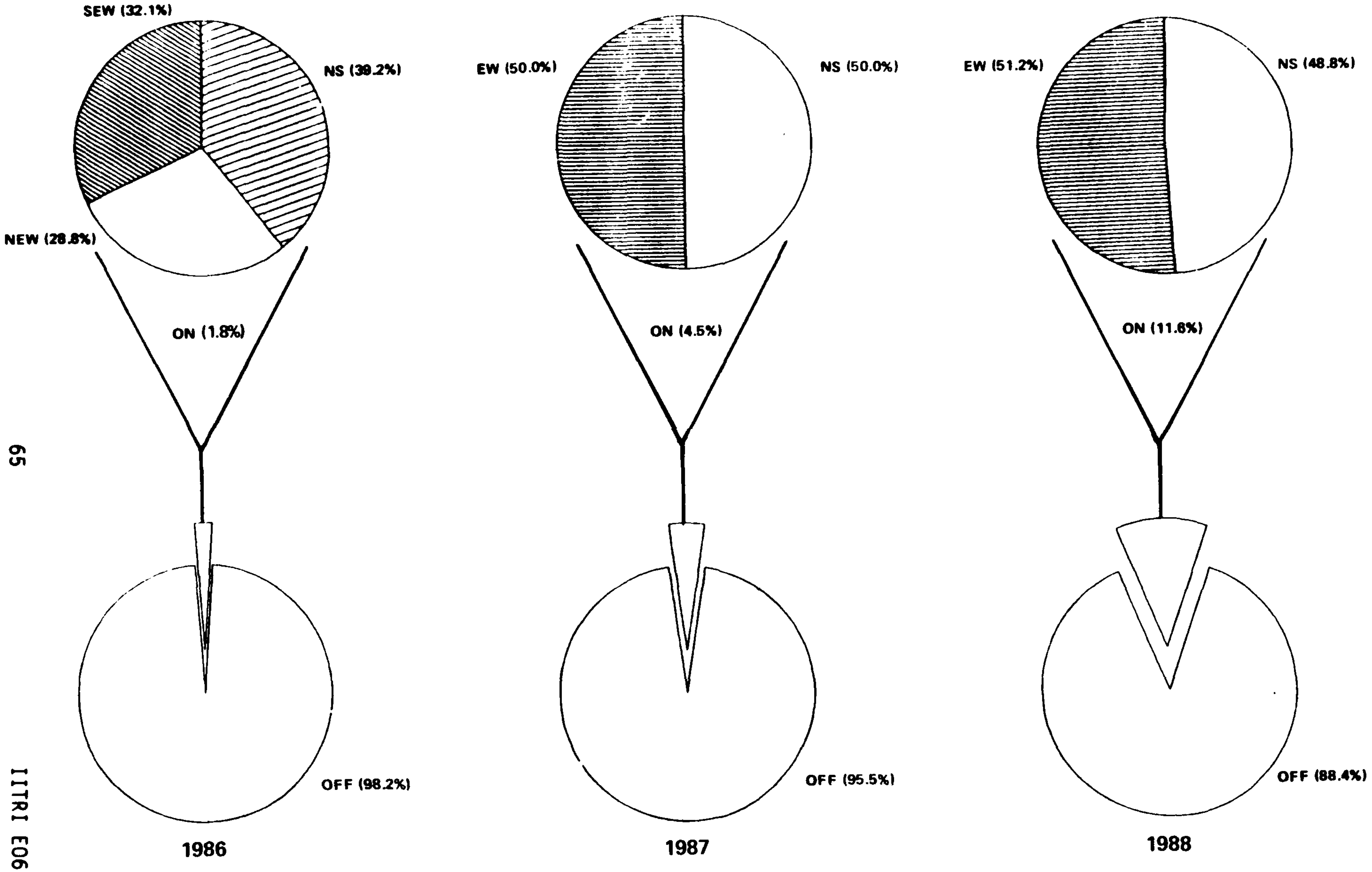


FIGURE 26. MTF OPERATING SUMMARY: PERCENTAGE OF TIME PER ANTENNA ELEMENT, 1986-1988.

MTF operation in 1986, 1987, and 1988 can be summarized as follows:

1986

- The MTF was transmitting about 1.8% of the time (about 160 hours) (see Figures 24, 25, and 26).
- About 98% of "on" time was with a continuous wave 76 Hz signal.
- Antenna elements were operated individually.
- Primary operating currents were 4 and 6 amperes for the NS and NEW antenna elements, respectively, and both 6 and 10 amperes for the SEW antenna element.

1987

- The MTF was transmitting about 4.6% of the time (about 400 hours) (see Figures 24, 25, and 26).
- 100% of "on" time was with a continuous wave 76 Hz signal.
- The NS element and EW element pair were operated individually.
- 99.6% of the operating time in 1987 was with a 15 ampere current.

1988

- The MTF was transmitting about 11.6% of the time (about 1000 hours) (see Figures 24, 25, and 26).
- About 98% of "on" time was with a continuous wave 76 or 44 Hz signal.
- The NS element and EW element pair were operated individually.
- Primary operating currents were 15 and 75 amperes. 40.6% of "on" time was at 15 amperes and 59.2% of "on" time was at 75 amperes.

5. CONCLUSIONS AND DISCUSSION

Annual EM field measurement surveys were performed during August, September, and October of 1988. Measurements were made at a total of 193 points at 60 study sites in both Wisconsin and Michigan, compared with 266 measurement points at 74 sites in 1987. Completion of the Wisconsin-based slime mold and wetlands studies accounted for the greatly reduced number of measurement points. New measurement points in 1988 included four at a mouse enclosure, one at the newly established holding facility for the small mammals and nesting birds studies, three at the Crystal Falls laboratory for the native bees studies, and one at the Ford River downstream control site for the aquatic ecosystems studies. Two measurement points at the upland flora and soil microflora studies were considered redundant and were dropped in 1988.

The measurement protocol used in Wisconsin in 1988 for the bird species and communities studies was the same as that used in 1985 through 1987. All points measured in 1987 were remeasured in 1988. Yearly measurement variations were within expected limits at all sites in Wisconsin.

In 1988, the MTF was operated intermittantly for its third season under conditions that differed from those in 1987 only in the operating antenna current. In 1988, the MTF antenna elements were operated at a 15 ampere current from January through June; in July, power amplifiers were retuned for operation at a 75 ampere current, and the MTF continued operating at a 75 ampere current from July through December. All 1988 EM field measurements were made during 75 ampere operation. A change in ownership of a major transmission line that parallels the NS antenna element resulted in increased 60 Hz EM field intensities at many study sites near the NS antenna element in 1988.

IITRI designed data loggers and installed them at the soil amoebae study sites in Michigan. These data loggers recorded electrical exposure parameters of the culture cells as well as the earth electric fields at the sites. The data were retrieved and used to calculate the electric field and current density within each culture cell. After the biological field study season ended in September, the logger algorithm was changed to measure only the earth electric field. These data will be collected throughout the winter to determine seasonal variability of the longitudinal electric field.

Seasonal variations of the longitudinal electric field are of concern to study investigators whose biota remain on a study site throughout the year. These variations are expected to be greater near ground terminals than near antenna ROWs. The variation is being continuously monitored near both a ground terminal and antenna ROW using the data loggers set up for the soil amoebae studies. Data collection will continue through 1989.

IITRI also performed EM measurements and analyses of the ambient monitoring systems for the upland flora and soil microflora studies to determine coupled ELF safety and interference voltages and to develop lightning protection schemes for the systems. The design implementation and testing of ELF interference mitigation and lightning protection techniques was completed in 1988.

Unexpected findings for tree swallow displacement and return studies led study investigators to request a thorough characterization of 60 Hz EM fields along the control study flight path during periods of experimentation in 1986 and 1987. IITRI responded by supplying electrical loading data for the Way Dam and Hemlock Falls generating plant outputs, a survey of all possible generators of EM fields along the flight path, specific EM field measurements at capture and release points, geomagnetic maps, and maps of power distribution systems relative to the flight path. These materials are being reviewed by the study investigators.

EM field intensities were characterized in considerable detail for the bird species and communities studies in Wisconsin in 1988. Measurements were made to define the field gradient as a function of distance from a WTF antenna element for the longitudinal electric field and magnetic flux density. The variations of these fields along the length of both a test and a control study transect were also characterized by making several measurements along the length of two such transects.

The slime mold and wetlands studies had their final field season in Wisconsin in 1987. The bird species and communities studies, which began later, will continue in Wisconsin through 1989. No significant changes in the mode of operation of the WTF are expected in 1989. Therefore, the 1989 annual field measurements for the bird species and communities studies in Wisconsin are expected to be made using the same protocol as in 1985-1988. Additional measurements under consideration are those of EM field gradients as a function of distance from a WTF antenna element and the variation of EM fields along study transects.

In 1989, the MTF is expected to operate both antenna elements simultaneously with a 150 ampere MSK signal. IITRI plans to remeasure all points measured in 1988, characterize the bird species and communities studies transects in Michigan as was done in Wisconsin, and determine the phase dependency of EM fields at study sites physically close to more than one antenna element. Measurement protocols to be used in 1989 will be determined by the actual antenna status at the time. Data logger monitoring of the soil amoebae study sites will continue in 1989, with control algorithms being modified as dictated by the MTF operating condition and cycling schedules.

APPENDIX A

SMALL MAMMALS AND NESTING BIRDS STUDIES

SMALL MAMMALS AND NESTING BIRDS STUDIES

On 19-22 and 27-28 September, 3-5 October, and 11 November 1988, IITRI field crews made ELF electromagnetic (EM) field measurements at 64 measurement points at a total of five test sites, four control sites, three (bird) displacement sites, the Crystal Falls laboratory site, and the remote holding facility where the study animals are kept prior to being examined in the laboratory. There were the following changes in the measurement regime in 1988: four measurement points (1T1-28, 1T1-29, 1T1-30, 1T1-31) were added at mouse enclosures on the Pirlot Road site, one (1L4-1) was added at the remote holding facility, two (1L2-1, 1L3-1) were dropped at the candidate remote holding facilities, and two (1L1-2, 1L1-3) were dropped at the laboratory holding facility.

The positions of all sites relative to the MTF are shown on the composite map in Figure A-1. The site numbers listed on the map are those used by IITRI. Table A-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are shown in Figures A-2 through A-14.

The small mammals and nesting birds studies monitor parental care, nestling growth and maturation, fecundity, homing, activity patterns, embryological development, and metabolic physiology. The electric and magnetic fields in the air are considered important factors to be examined in orientation and other behavior patterns of birds. The electric and magnetic fields in the earth near the surface are important to the small mammals studies.

EM field measurements for 1988 and previous years are found in Tables A-2 through A-10. Tables A-2, A-3, and A-4 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables A-5, A-6, and A-7 present 76 Hz data for these three fields at 1986, 1987, and 1988 MTF operating currents. Tables A-8, A-9, and A-10 present 76 Hz data extrapolated to a full-power condition of 150 amperes.

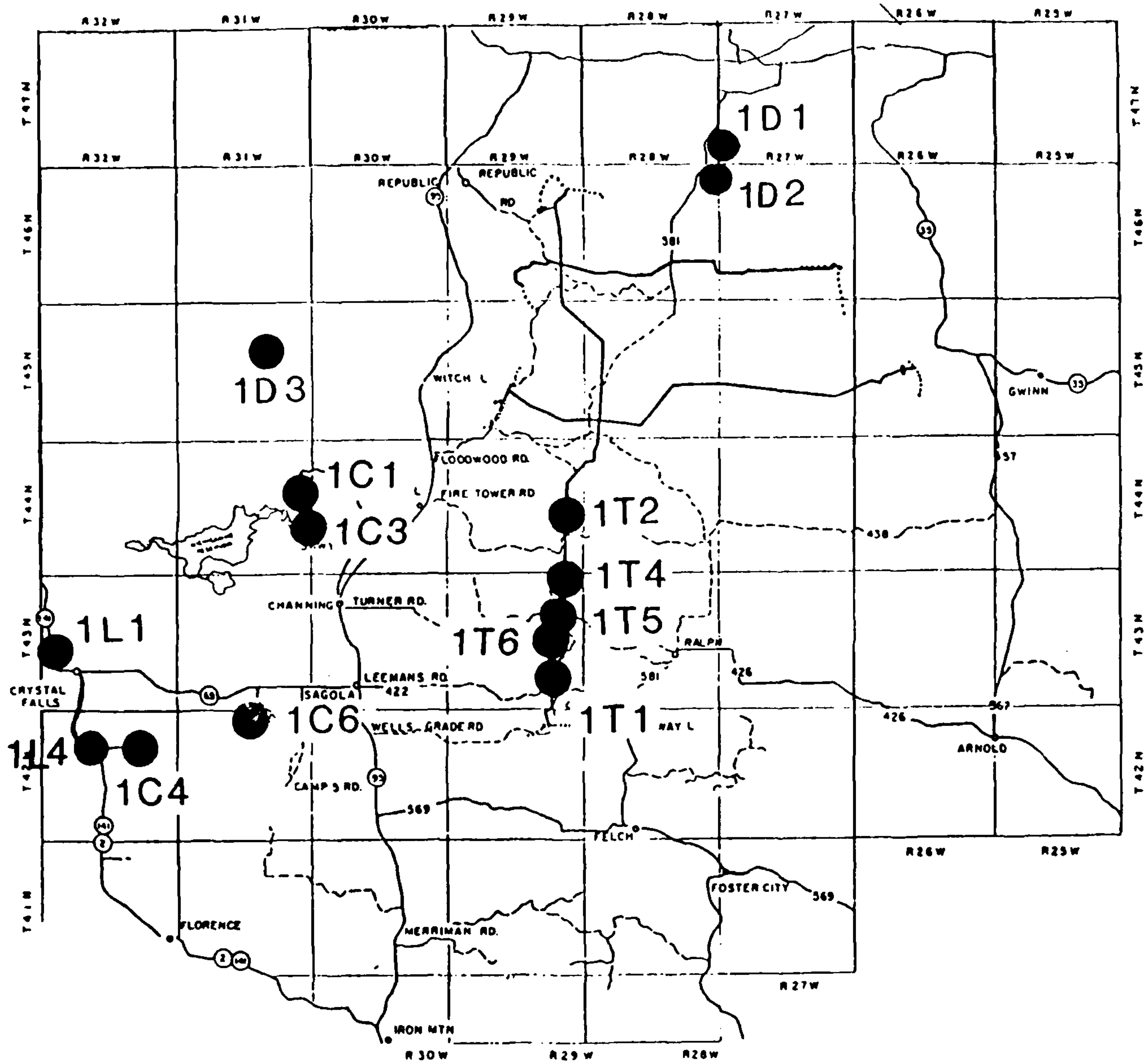


FIGURE A-1. POSITIONS OF SMALL MAMMALS AND NESTING BIRDS STUDY SITES RELATIVE TO MICHIGAN TRANSMITTING FACILITY ANTENNA ELEMENTS.

TABLE A-1. SITE NO. CROSS-REFERENCE
Small Mammals and Nesting Birds Studies

IITRI Site No.	Investigator's Site Name	Location		
		Township	Range	Section(s)
1T1	Pirlot Road	T43N	R29W	23, 26
1T2	Cleveland Homestead	T44N	R29W	25
1T4	North Turner Road	T43N	R29W	1
1T5	Ford River North	T43N	R29W	14
1T6	Ford River South	T43N	R29W	14
1C1	Michigamme North	T44N	R31W	13
1C3	Michigamme South	T44N	R31W	24
1C4	Panola Plains	T42N	R32W	10
1C6	Tachycineta Meadow	T42N	R31W	3
1D1	Cleveland Homestead Displacement	T47N	R28W	36
1D2	North Turner Displacement	T46N	R28W	12
1D3	Panola Plains Displacement	T45N	R31W	14
1L1	Crystal Falls Laboratory	T43N	R32W	29
1L4	Remote Holding Facility	T42N	R32W	9

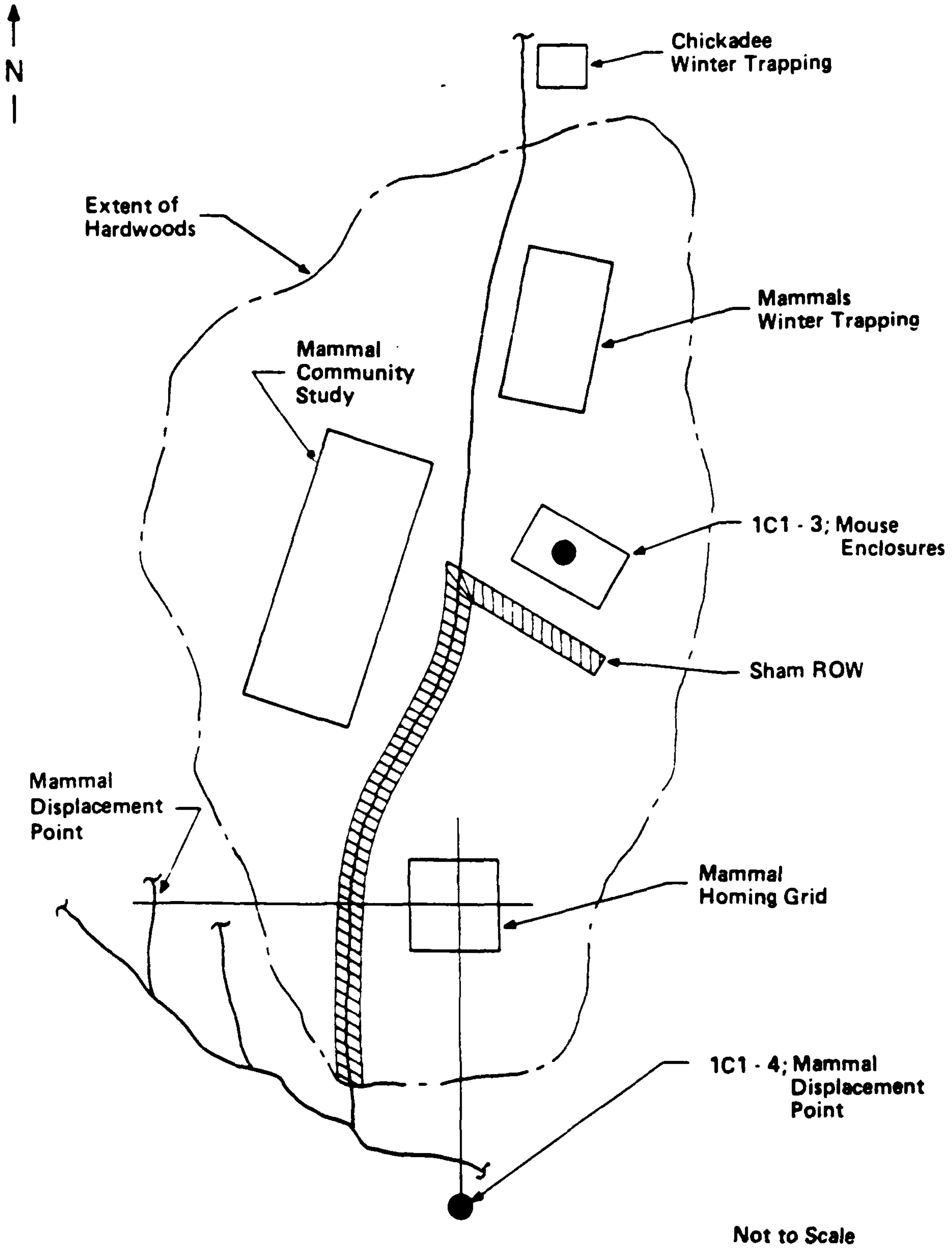


FIGURE A-2. MEASUREMENT POINTS AT MICHIGAMME NORTH; 1C1-3, 4.

60297/189

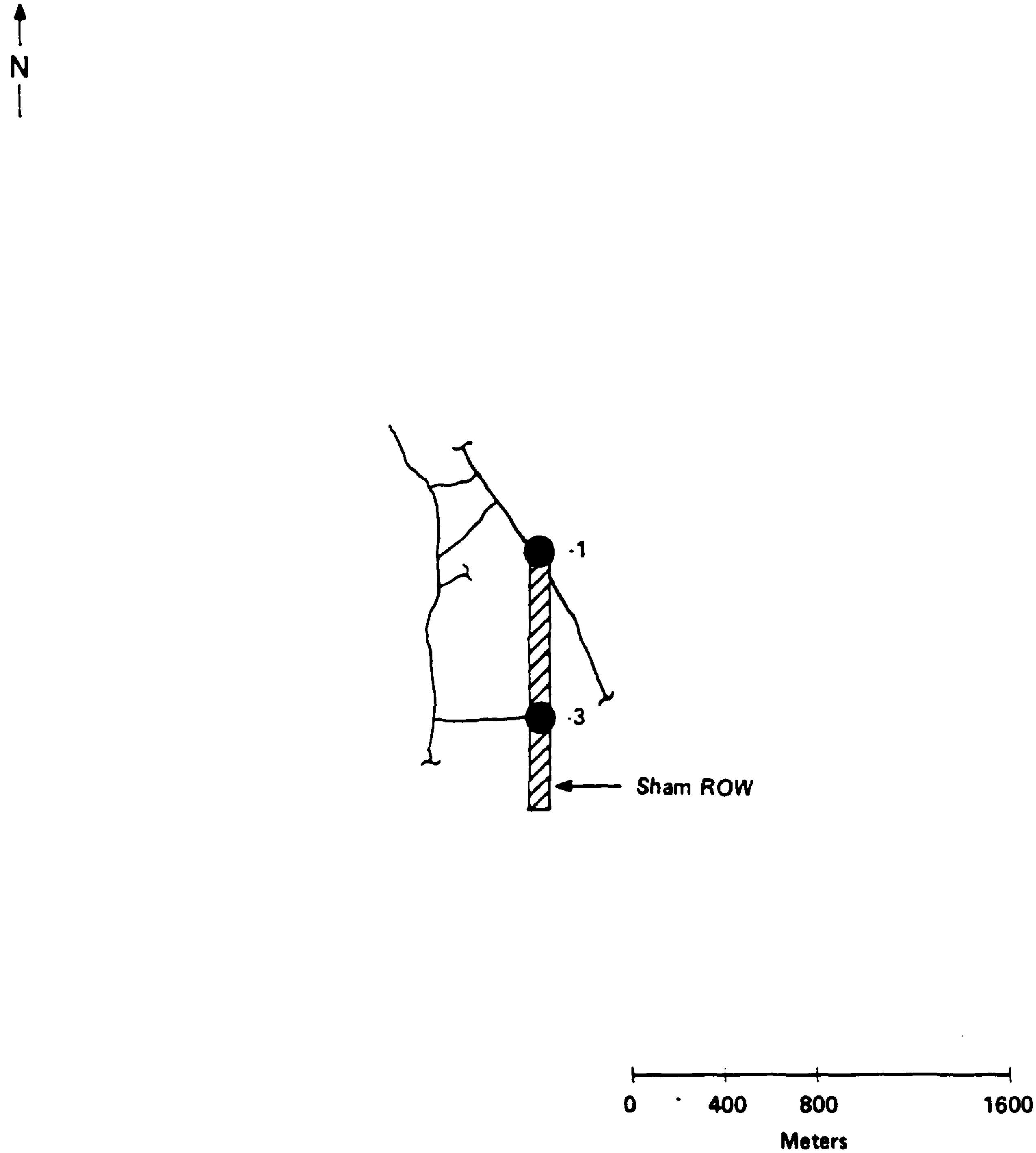


FIGURE A-3. MEASUREMENT POINTS AT MICHIGAMME SOUTH; 1C3-1, 3.

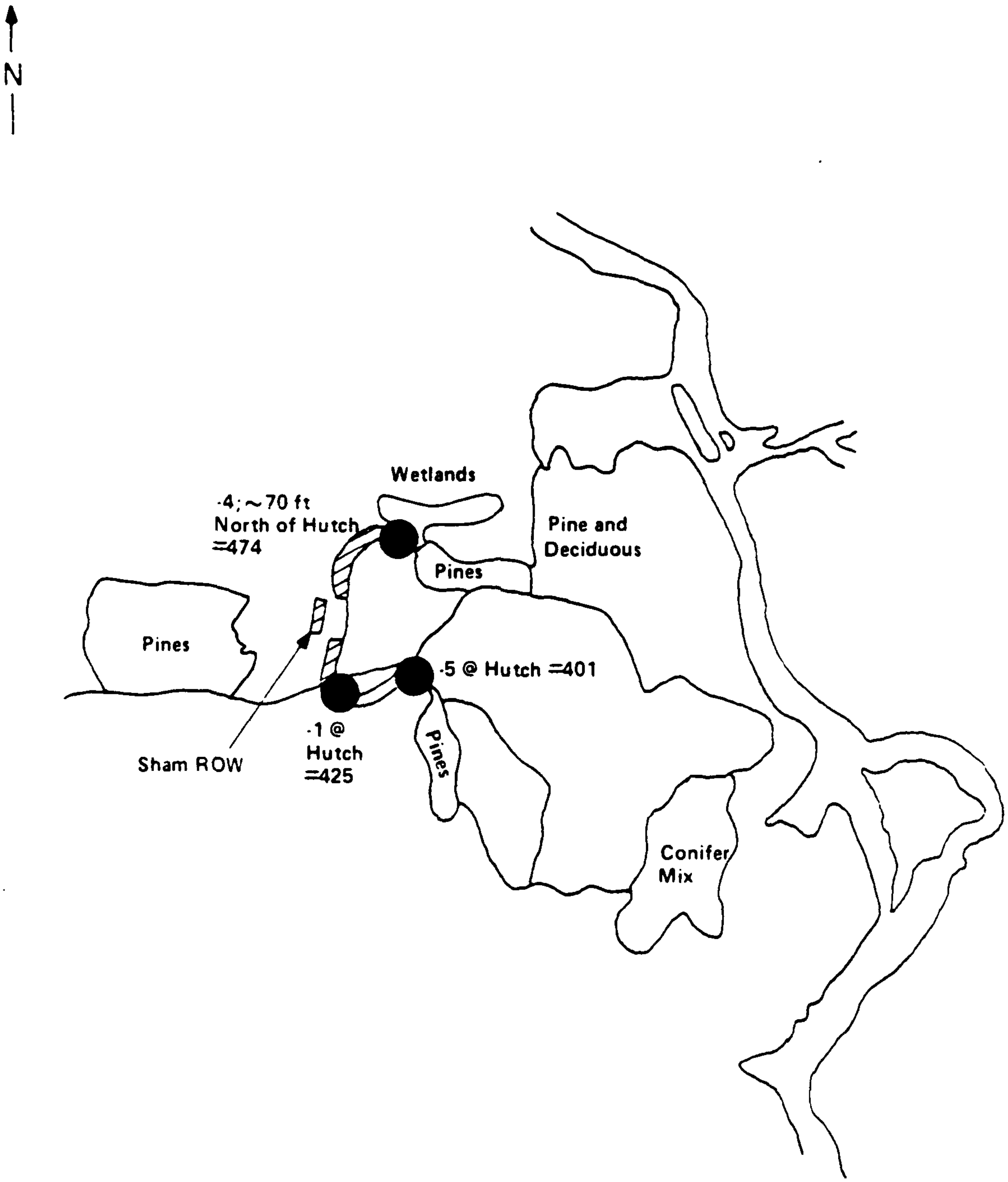


FIGURE A-4. MEASUREMENT POINTS AT PANOLA PLAINS; 1C4-1, 4, 5.

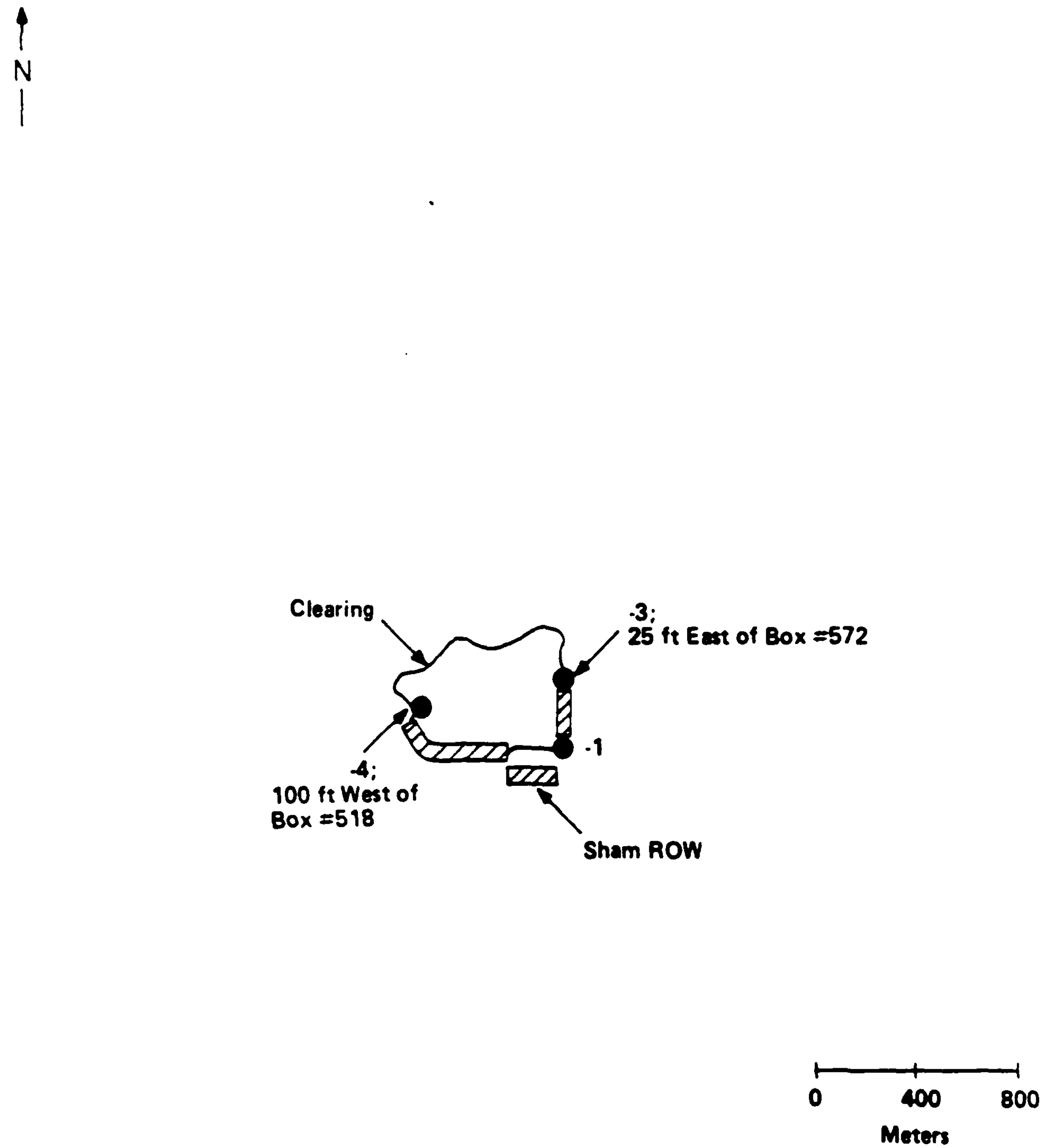


FIGURE A-5. MEASUREMENT POINTS AT TACHYCINETA MEADOW; 1C6-1, 3, 4.

80297/169

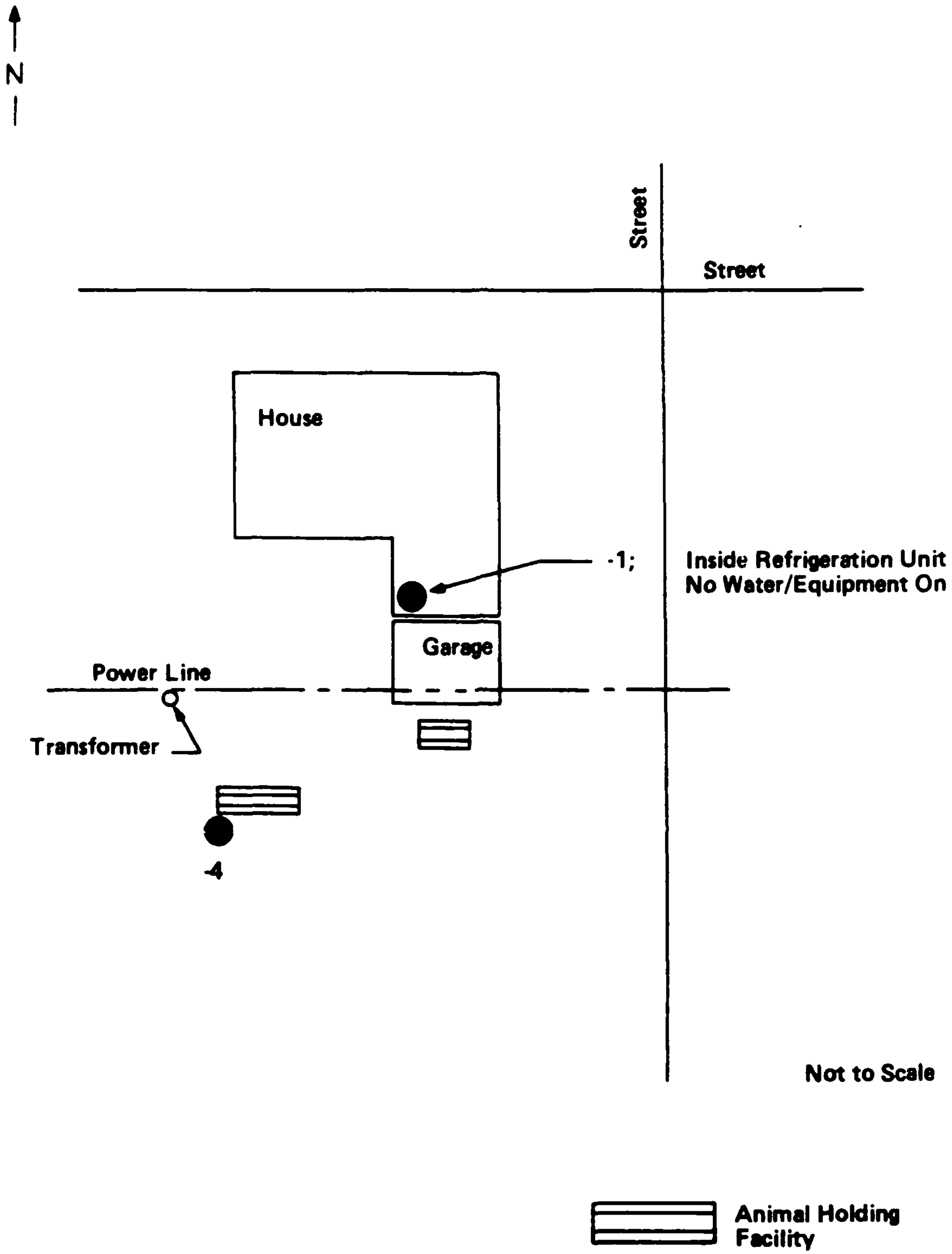


FIGURE A-6. MEASUREMENT POINTS AT MAMMAL LABORATORY; 1L1-1, 4.

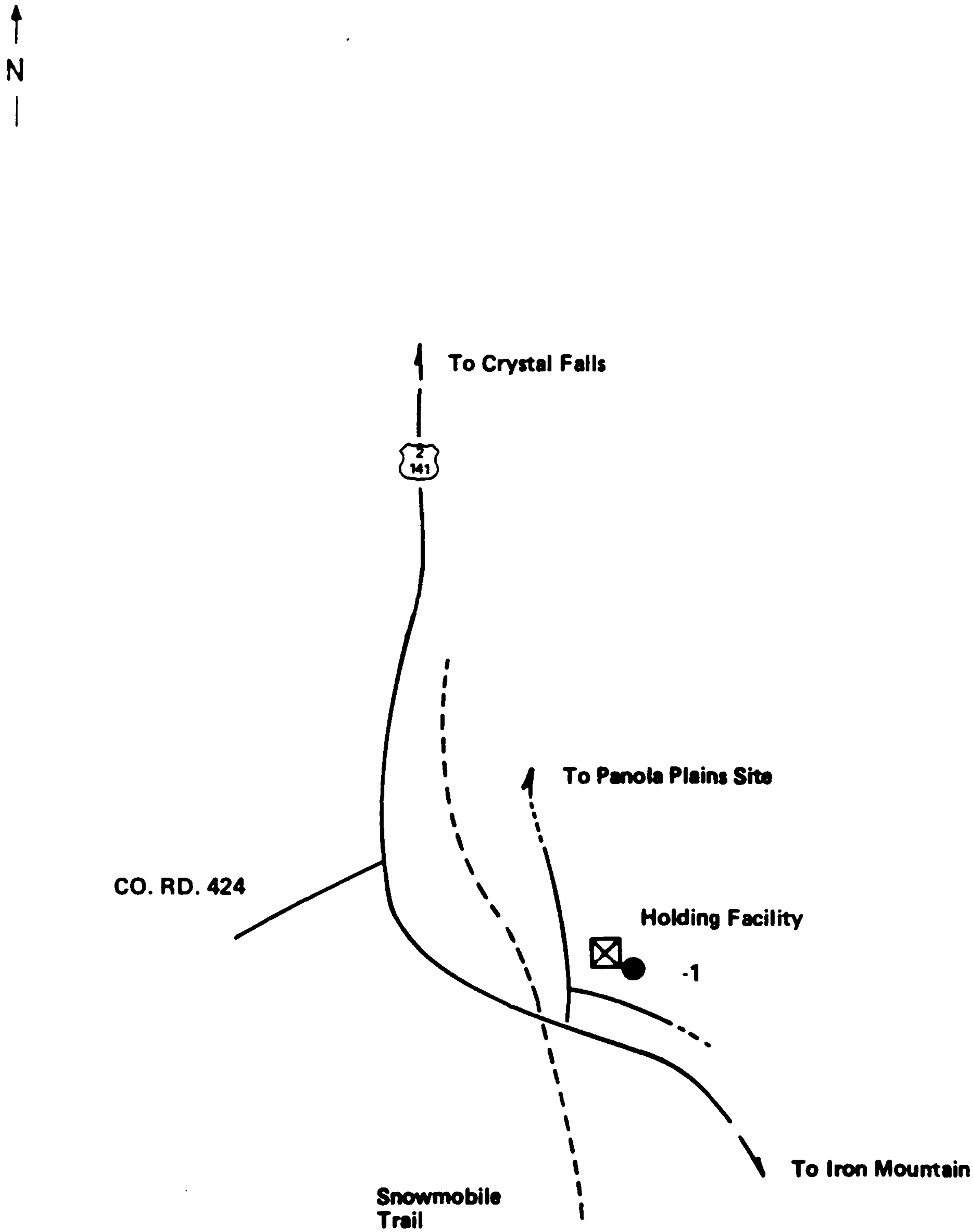


FIGURE A-7. MEASUREMENT POINT AT REMOTE HOLDING FACILITY; 1L4-1.

60297/189

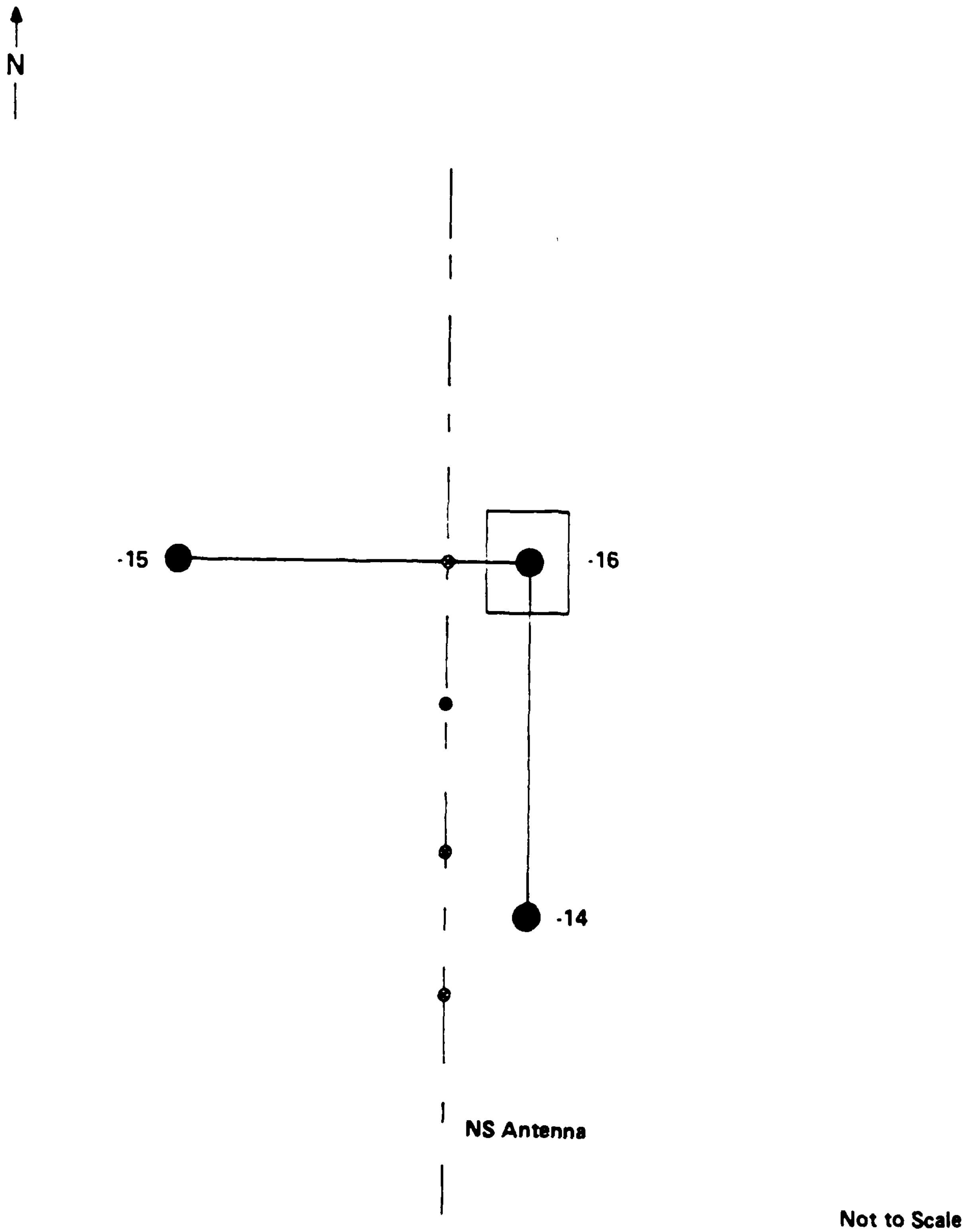


FIGURE A-8. MEASUREMENT POINTS AT PIRLOT ROAD MAMMAL DISPLACEMENT; 1T1-14, 15, 16.

60297/189

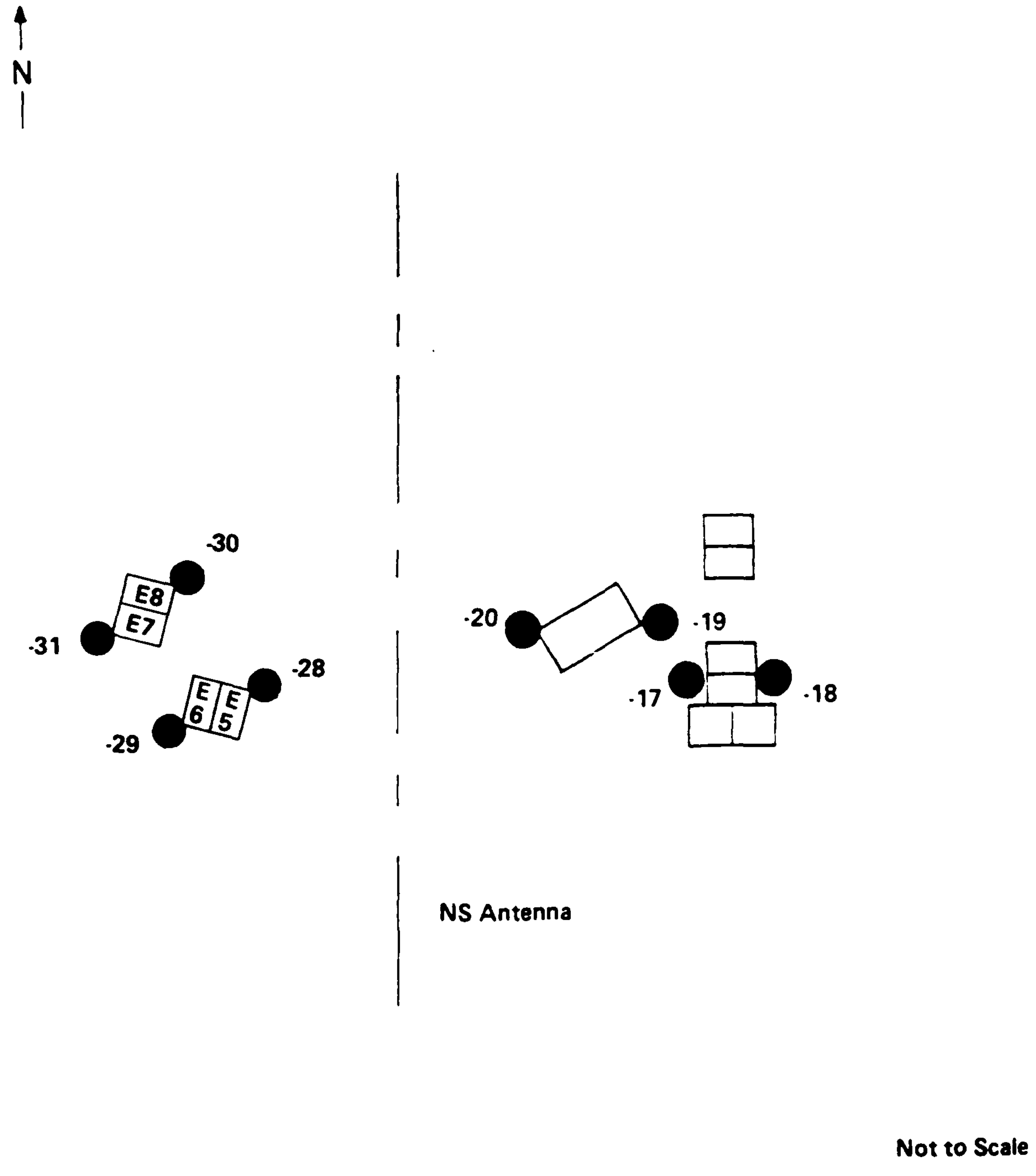


FIGURE A-9. MEASUREMENT POINTS AT PIRLOT ROAD MOUSE ENCLOSURES; 1T1-17 THROUGH 20, 28 THROUGH 31.

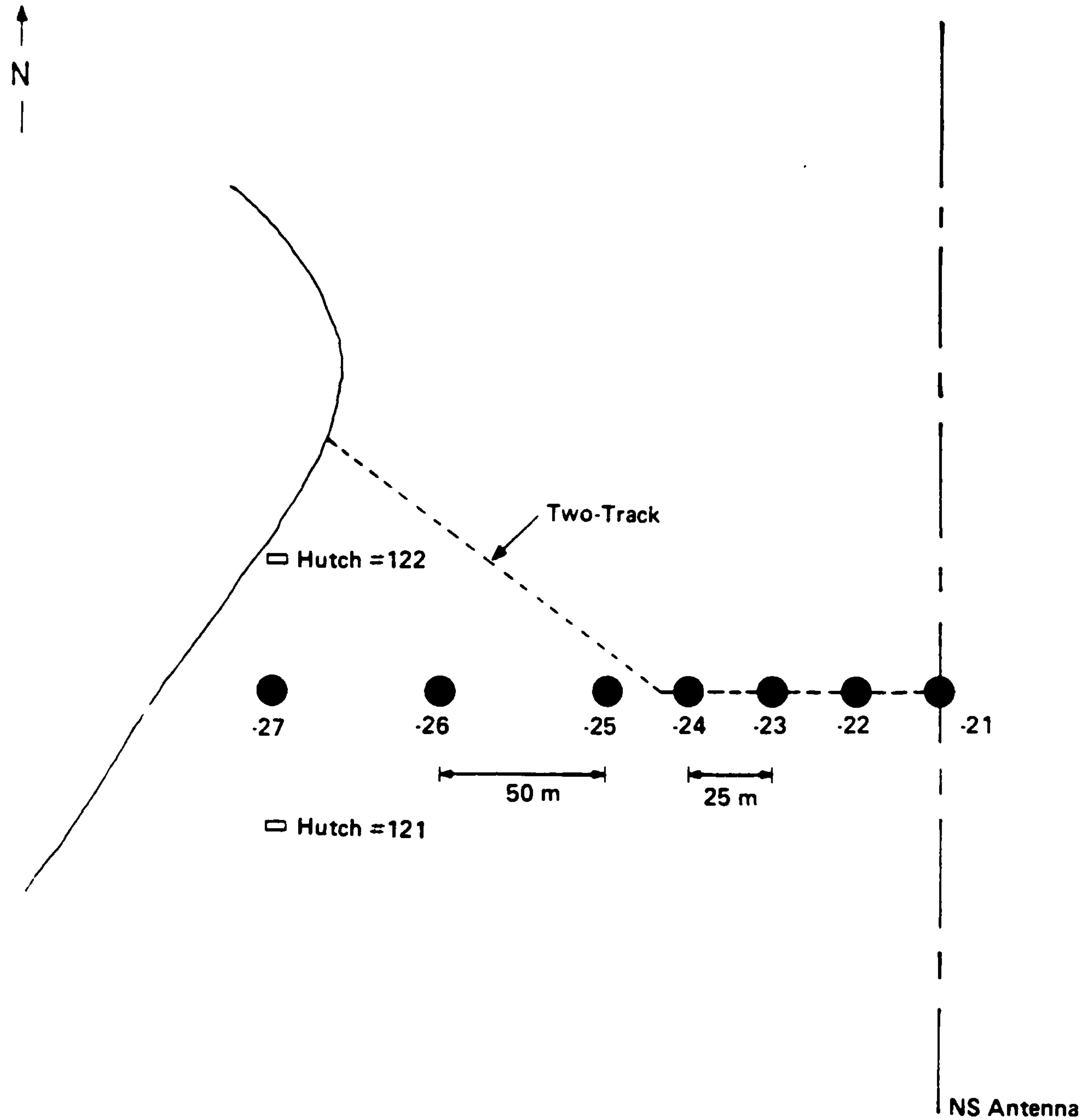


FIGURE A-10. MEASUREMENT POINTS AT PIRLOT ROAD NEST BOXES; 1T1-21 THROUGH 27.

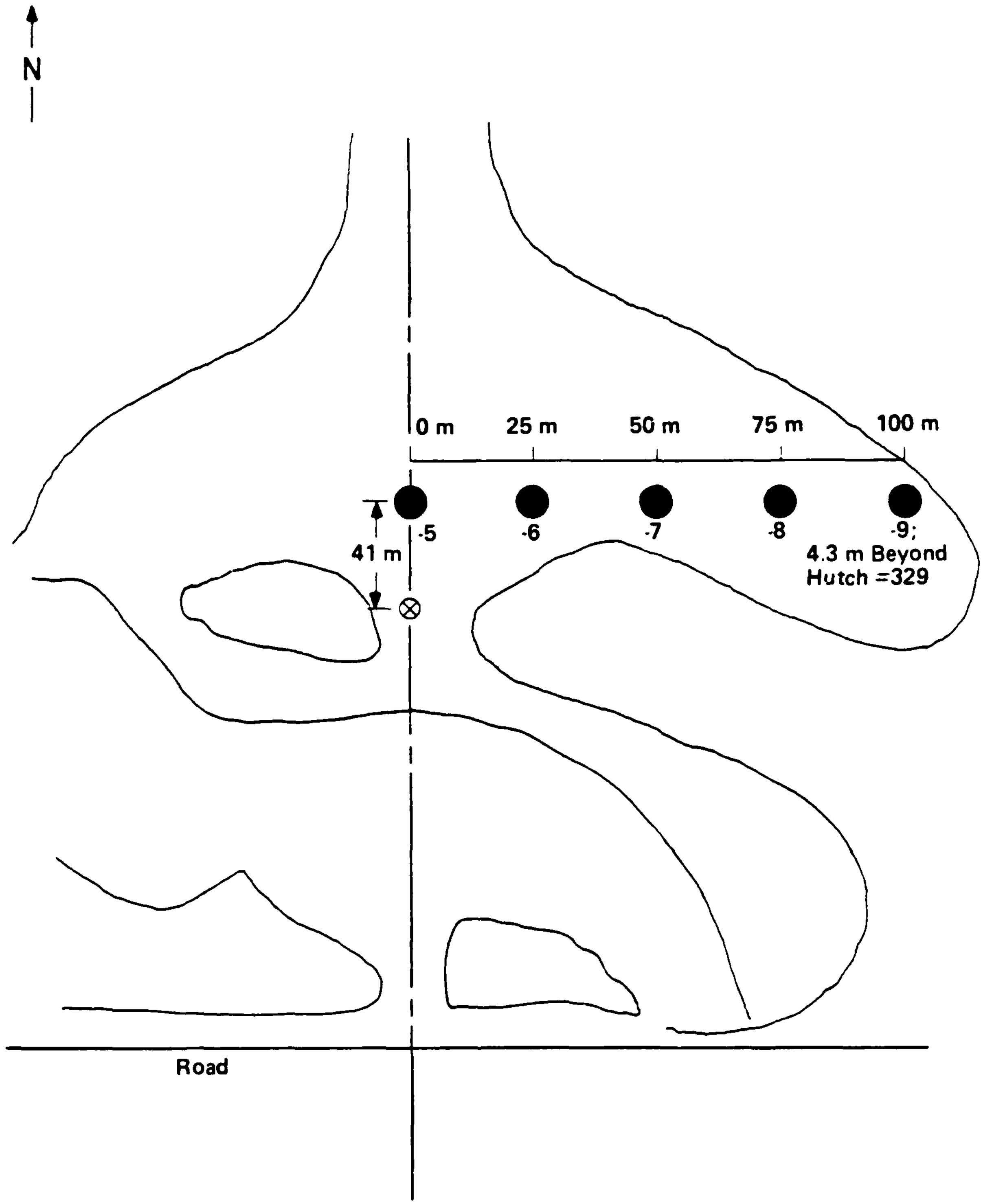


FIGURE A-11. MEASUREMENT POINTS AT CLEVELAND HOMESTEAD; 1T2-5 THROUGH 9.

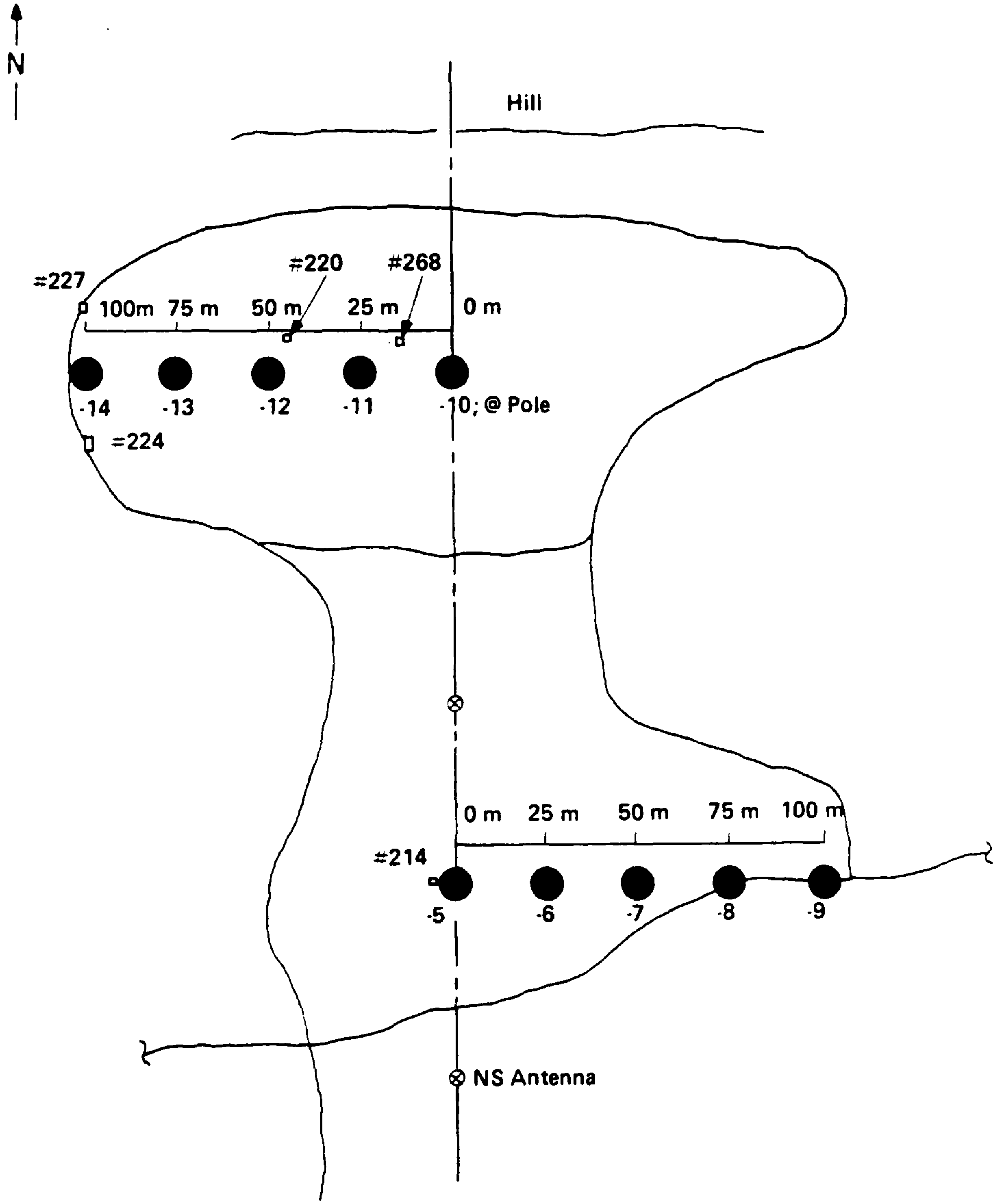


FIGURE A-12. MEASUREMENT POINTS AT NORTH TURNER ROAD; 1T4-5 THROUGH 14.

60297/189

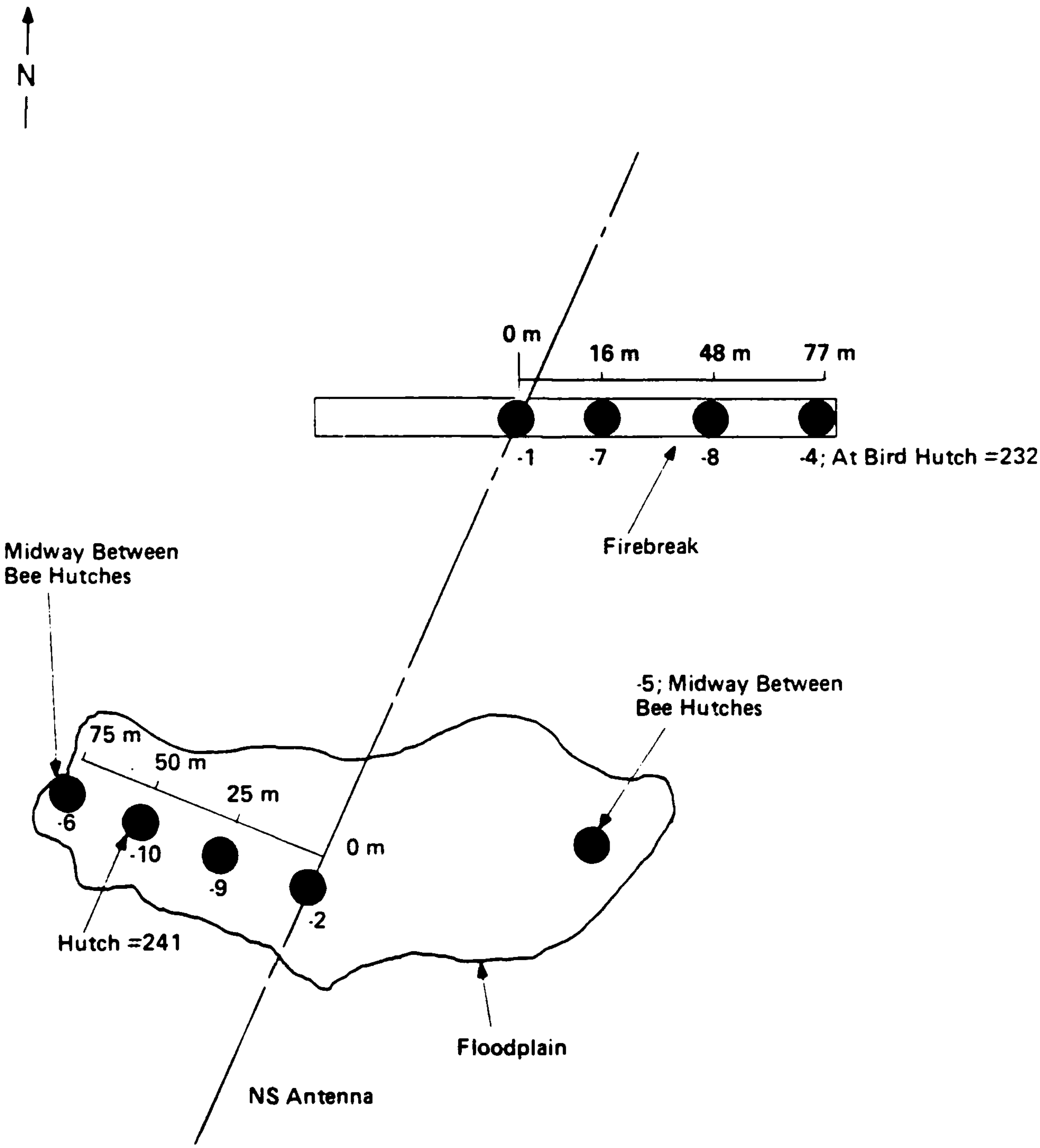


FIGURE A-13. MEASUREMENT POINTS AT FORD RIVER NORTH; 1T5-1, 2, 4, 6, 7, 8, 9, 10.

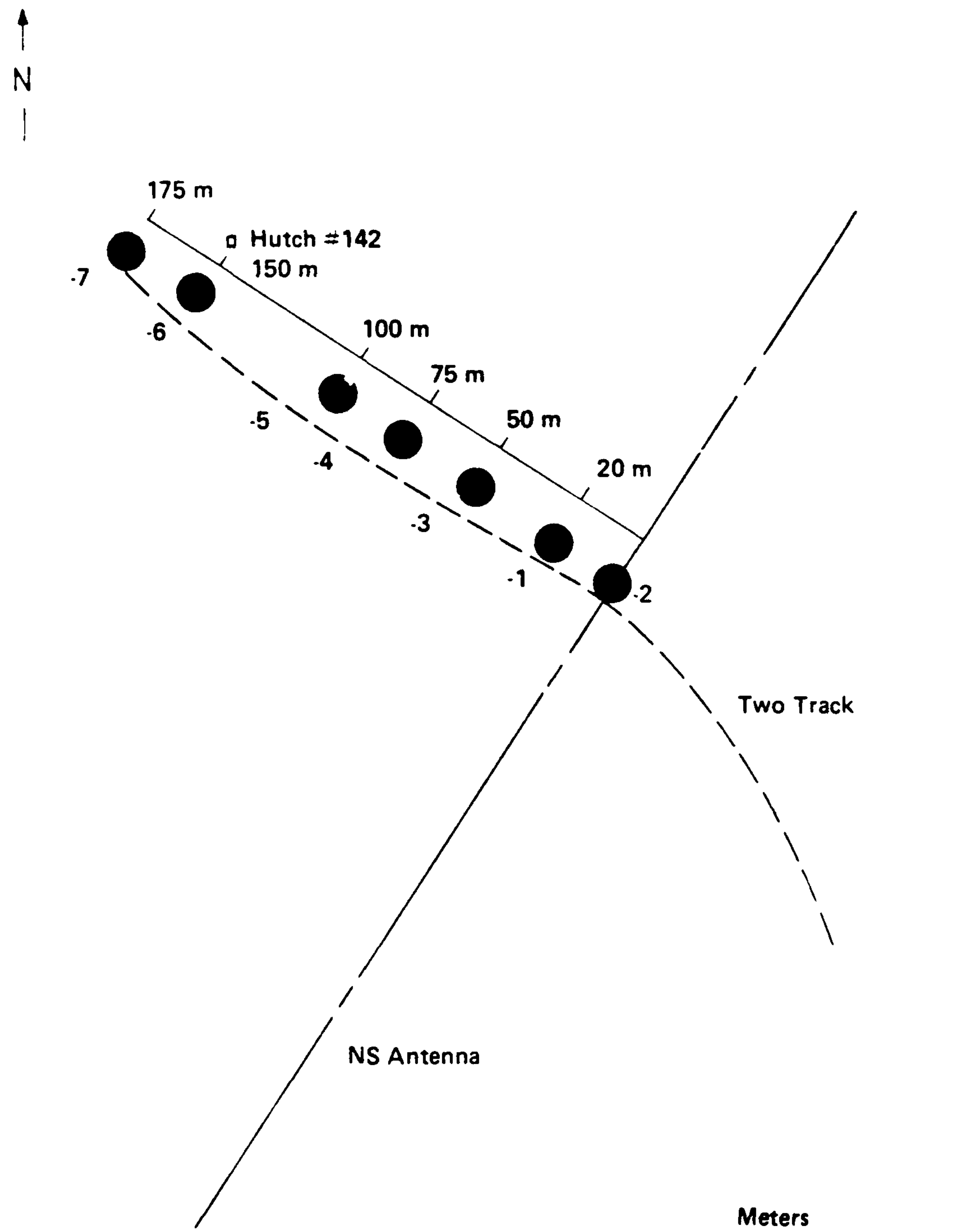


FIGURE A-14. MEASUREMENT POINTS AT FORD RIVER SOUTH NEST BOXES; 1T6-1 THROUGH 7.

60297/189

TABLE A-2. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies (page 1 of 3)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
1C1-2	-	-	-	--	--	--
1C1-3	-	-	-	-	-	-
1C1-4	-	-	-	-	-	-
1C3-1	-	-	-	-	-	-
1C3-2	-	-	--	--	--	--
1C3-3	-	-	-	-	-	-
1C4-1	-	0.001	-	-	-	-
1C4-2	-	<0.001	-	--	--	--
1C4-3	-	<0.001	-	-	--	--
1C4-4	-	-	-	-	-	-
1C4-5	-	-	-	-	-	-
1D3-1	-	-	-	-	-	-
1C6-1	-	0.001	-	-	-	-
1C6-3	-	-	-	-	-	-
1C6-4	-	-	-	-	-	-
1L1-1	-	-	-	/	/	/
1L1-2	-	-	-	0.94	0.96	--
1L1-3	-	-	-	0.79	0.034	--
1L1-4	-	-	-	0.042	0.047	0.062
1L4-1	-	-	-	--	--	-
1T1-1	0.001	-	-	--	--	--
1T1-3	-	-	-	--	--	--
1T1-4	-	-	-	--	--	--
1T1-10	-	-	-	--	--	--
1T1-12	-	-	-	--	--	--
1T1-13	-	-	-	--	--	--
1T1-14	-	-	-	-	-	-
1T1-15	-	-	-	-	-	-
1T1-16	-	-	-	-	-	-
1T1-17	-	-	-	-	-	-
1T1-18	-	-	-	-	-	-
1T1-19	-	-	-	-	-	-
1T1-20	-	-	-	-	-	-
1T1-28	-	-	-	-	-	-
1T1-29	-	-	-	-	-	-
1T1-30	-	-	-	-	-	-
1T1-31	-	-	-	-	-	-

TABLE A-2. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies (page 2 of 3)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
1T1-21	-	-	-	-	0.086	0.49
1T1-22	-	-	-	-	<0.001	-
1T1-23	-	-	-	-	-	-
1T1-24	-	-	-	-	-	-
1T1-25	-	-	-	-	-	-
1T1-26	-	-	-	-	-	-
1T1-27	-	-	-	-	-	-
1T2-1	<0.001	0.001	-	-	--	--
1T2-2	-	-	-	-	--	--
1T2-3	-	-	-	-	--	--
1T2-4	-	-	-	-	--	--
1T2-5	-	-	-	-	0.198	0.053
1T2-6	-	-	-	-	0.024	0.007
1T2-7	-	-	-	-	0.005	-
1T2-8	-	-	-	-	0.002	-
1T2-9	-	-	-	-	<0.001	-
1D1-1	-	-	-	2.5	2.0	9.2
1T4-1	-	<0.001	-	--	--	--
1T4-3	-	-	-	--	--	--
1T4-4	-	-	-	--	--	--
1T4-5	-	-	-	-	0.094	0.066
1T4-6	-	-	-	-	0.014	0.014
1T4-7	-	-	-	-	0.004	0.002
1T4-8	-	-	-	-	<0.001	<0.001
1T4-9	-	-	-	-	-	-
1T4-10	-	-	-	-	0.062	0.041
1T4-11	-	-	-	-	0.014	0.006
1T4-12	-	-	-	-	0.004	0.003
1T4-13	-	-	-	-	0.002	0.002
1T4-14	-	-	-	-	0.001	0.001
1D2-1	-	-	-	-	-	-
1T5-1	-	<0.001	-	-	0.118	0.157
1T5-7	-	-	-	-	0.019	0.019
1T5-8	-	-	-	-	<0.001	-
1T5-4	-	-	-	-	-	-
1T5-2	<0.001	<0.001	-	-	0.074	0.130
1T5-9	-	-	-	-	0.014	0.017
1T5-10	-	-	-	-	0.002	0.004
1T5-6	-	-	-	-	<0.001	-

TABLE A-2. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies (page 3 of 3)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
1T5-3	-	-	-	-	--	--
1T5-5	-	-	-	-	<0.001	0.001
1T6-2	-	-	-	-	0.162	0.46
1T6-1	<0.001	<0.001, 0.001	-	-	0.024	0.079
1T6-3	-	-	-	-	0.003	0.003
1T6-4	-	-	-	-	0.001	0.003
1T6-5	-	-	-	-	0.001	0.002
1T6-6	-	-	-	-	0.001	<0.001
1T6-7	-	-	-	-	<0.001	<0.001

a = prior to antenna construction.
b = antenna elements grounded at transmitter (condition 2).
c = antenna elements connected to transmitter, transmitter off (condition 9).
\- = site measurement point not established.
-- = site measurement point dropped.
\- = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.
/ = data not taken.

TABLE A-3. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies (page 1 of 3)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
1C1-2	0.041	0.146	0.056	--	--	--
1C1-3	-	-	0.128	0.082	0.114	0.59
1C1-4	-	-	-	0.117	0.114	0.085
1C3-1	0.106	0.26	0.133	0.086	0.118	0.085
1C3-2	0.125	0.191	/	--	--	--
1C3-3	-	-	-	0.074	0.178	0.148
1C4-1	-	0.028, 0.030	0.045	0.065	0.093	0.087
1C4-2	-	0.019, 0.023	0.015	--	--	--
1C4-3	-	0.036, 0.065	0.103	0.118	--	--
1C4-4	-	-	0.009, 0.017	0.011	0.011	0.011
1C4-5	-	-	-	-	0.037	0.046
1D3-1	-	-	-	0.052	0.156	0.053
1C6-1	-	0.072	0.095	0.088	0.106	0.057
1C6-3	-	-	0.123	0.109	0.141	0.053
1C6-4	-	-	0.038	0.007	0.020	0.013
1L1-1	-	-	-	/	/	/
1L1-2	-	-	-	25	23	--
1L1-3	-	-	-	10.7	1.32	--
1L1-4	-	-	-	3.9	8.9	5.9
1L4-1	-	-	-	-	-	0.019
1T1-1	0.090	0.091	0.131	--	--	--
1T1-3	-	0.21	0.179	--	--	--
1T1-4	-	0.174	0.171	--	--	--
1T1-10	-	0.097	0.147	--	--	--
1T1-12	-	-	0.033	--	--	--
1T1-13	-	-	0.034	--	--	--
1T1-14	-	-	-	0.102	0.058	0.29
1T1-15	-	-	-	0.040	0.029	0.064
1T1-16	-	-	-	0.115	0.102	0.40
1T1-17	-	-	-	0.118	0.128	0.37
1T1-18	-	-	-	0.100	0.104	0.46
1T1-19	-	-	-	0.112	0.132	0.43
1T1-20	-	-	-	0.118	0.123	0.43
1T1-28	-	-	-	-	-	0.018
1T1-29	-	-	-	-	-	0.014
1T1-30	-	-	-	-	-	0.019
1T1-31	-	-	-	-	-	0.022

TABLE A-3. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies (page 2 of 3)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
1T1-21	-	-	-	0.082	0.082	0.53
1T1-22	-	-	-	0.050	0.047	0.40
1T1-23	-	-	-	0.037	0.037	0.31
1T1-24	-	-	-	0.042	0.058	0.23
1T1-25	-	-	-	0.033	0.035	0.26
1T1-26	-	-	-	0.022	0.025	0.20
1T1-27	-	-	-	0.014	0.021	0.094
1T2-1	0.170	0.22	0.197	0.122	--	--
1T2-2	-	-	-	0.047	--	--
1T2-3	-	-	-	0.083	--	--
1T2-4	-	-	-	0.044	--	--
1T2-5	-	-	-	-	0.074	0.074
1T2-6	-	-	-	-	0.069	0.087
1T2-7	-	-	-	-	0.047	0.062
1T2-8	-	-	-	-	0.051	0.067
1T2-9	-	-	-	-	0.055	0.087
1D1-1	-	-	-	9.6	2.4	1.15
1T4-1	-	0.178, 0.184	0.150	--	--	--
1T4-3	-	-	0.22	--	--	--
1T4-4	-	-	0.131	--	--	--
1T4-5	-	-	-	0.052	0.081	0.135
1T4-6	-	-	-	0.104	0.066	0.128
1T4-7	-	-	-	0.102	0.090	0.128
1T4-8	-	-	-	0.082	0.078	0.096
1T4-9	-	-	-	0.088	0.063	0.098
1T4-10	-	-	-	-	0.135	0.124
1T4-11	-	-	-	-	0.071	0.089
1T4-12	-	-	-	-	0.071	0.100
1T4-13	-	-	-	-	0.063	0.083
1T4-14	-	-	-	-	0.068	0.121
1D2-1	-	-	-	0.47	0.160	0.28
1T5-1	-	0.24, 0.42	0.25	0.115	0.128	0.34
1T5-7	-	-	-	-	0.107	0.33
1T5-8	-	-	-	-	0.099	0.23
1T5-4	-	-	-	0.061	0.073	0.166
1T5-2	0.23	0.26	0.22	0.042	0.092	0.108
1T5-9	-	-	-	-	0.080	0.089
1T5-10	-	-	-	-	0.036	0.056
1T5-6	-	-	-	0.051	0.034	0.053

TABLE A-3. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies (page 3 of 3)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
1T5-3	-	-	-	0.125	--	--
1T5-5	-	-	-	0.077	0.051	0.059
1T6-2	-	-	-	-	0.48	1.52
1T6-1	0.071	0.65-0.88	0.86, 0.88	0.23	0.54	1.49
1T6-3	-	-	-	-	0.32	1.54
1T6-4	-	-	-	-	0.25	1.32
1T6-5	-	-	-	-	0.21	1.19
1T6-6	-	-	-	-	0.178	0.90
1T6-7	-	-	-	-	0.100	1.31

[a] = prior to antenna construction.
[b] = antenna elements grounded at transmitter (condition 2).
[c] = antenna elements connected to transmitter, transmitter off (condition 9).
- = site measurement point not established.
-- = site measurement point dropped.
/ = data not taken.

TABLE A-4. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies (page 1 of 3)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
1C1-2	<0.001	0.001	0.001	--	--	--
1C1-3	-	-	0.001	0.001	0.001	0.001
1C1-4	-	-	-	0.001	0.001	0.001
1C3-1	<0.001	0.002	0.002	0.001	0.001	0.001
1C3-2	0.001	0.003	/	--	--	--
1C3-3	-	-	-	0.001	0.001	0.001
1C4-1	-	<0.001, 0.001	0.001	0.001	0.002	0.001
1C4-2	-	0.002	0.002	--	--	--
1C4-3	-	<0.001, 0.002	<0.001	0.001	--	--
1C4-4	-	-	0.003	0.002	0.002	0.001
1C4-5	-	-	-	-	0.001	0.002
1D3-1	-	-	-	0.003	0.002	0.002
1C6-1	-	0.003	0.003	0.002	<0.001	0.002
1C6-3	-	-	0.003	0.003	0.003	0.002
1C6-4	-	-	0.003	0.003	0.004	0.003
1L1-1	-	-	-	9.13	/	/
1L1-2	-	-	-	0.179	0.156	--
1L1-3	-	-	-	0.080	0.143	--
1L1-4	-	-	-	0.114	0.118	0.080
1L4-1	-	-	-	-	-	0.003
1T1-1	0.002	0.002	0.002	--	--	--
1T1-3	-	0.002	0.002	--	--	--
1T1-4	-	0.002	0.002	--	--	--
1T1-10	-	0.004	0.003	--	--	--
1T1-12	-	-	0.004	--	--	--
1T1-13	-	-	0.005	--	--	--
1T1-14	-	-	-	0.004	0.003	0.014
1T1-15	-	-	-	0.004	0.004	0.009
1T1-16	-	-	-	0.009	0.006	0.22
1T1-17	-	-	-	0.007	0.009	0.031
1T1-18	-	-	-	0.006	0.008	0.028
1T1-19	-	-	-	0.001	0.009	0.032
1T1-20	-	-	-	0.008	0.011	0.034
1T1-28	-	-	-	-	-	0.001
1T1-29	-	-	-	-	-	0.001
1T1-30	-	-	-	-	-	0.001
1T1-31	-	-	-	-	-	0.001

TABLE A-4. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies (page 2 of 3)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
1T1-21	-	-	-	0.055	0.042	0.29
1T1-22	-	-	-	0.012	0.018	0.108
1T1-23	-	-	-	0.008	0.011	0.060
1T1-24	-	-	-	0.005	0.008	0.041
1T1-25	-	-	-	0.005	0.005	0.030
1T1-26	-	-	-	0.003	0.004	0.021
1T1-27	-	-	-	0.002	0.003	0.014
1T2-1	<0.001	0.001	0.001	0.077	--	--
1T2-2	-	-	-	0.009	--	--
1T2-3	-	-	-	0.006	--	--
1T2-4	-	-	-	0.006	--	--
1T2-5	-	-	-	-	0.050	0.023
1T2-6	-	-	-	-	0.018	0.011
1T2-7	-	-	-	-	0.009	0.007
1T2-8	-	-	-	-	0.006	0.005
1T2-9	-	-	-	-	0.005	0.006
1D1-1	-	-	-	0.109	0.154	0.040
1T4-1	-	0.001	0.001	--	--	--
1T4-3	-	-	0.001	--	--	--
1T4-4	-	-	0.001	--	--	--
1T4-5	-	-	-	0.021	0.060	0.061
1T4-6	-	-	-	0.019	0.024	0.017
1T4-7	-	-	-	0.011	0.013	0.010
1T4-8	-	-	-	0.006	0.008	0.005
1T4-9	-	-	-	0.004	0.006	0.004
1T4-10	-	-	-	-	0.051	0.041
1T4-11	-	-	-	-	0.023	0.013
1T4-12	-	-	-	-	0.013	0.010
1T4-13	-	-	-	-	0.009	0.007
1T4-14	-	-	-	-	0.007	0.007
1D2-1	-	-	-	0.004	0.006	0.005
1T5-1	-	0.001, 0.002	0.001	0.051	0.071	0.159
1T5-7	-	-	-	-	0.039	0.077
1T5-8	-	-	-	-	0.016	0.025
1T5-4	-	-	-	0.006	0.008	0.016
1T5-2	0.001	0.002	0.001	0.038	0.042	0.075
1T5-9	-	-	-	-	0.019	0.028
1T5-10	-	-	-	-	0.011	0.017
1T5-6	-	-	-	0.004	0.008	0.012

TABLE A-4. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies (page 3 of 3)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
1T5-3	-	-	-	0.007	--	--
1T5-5	-	-	-	0.005	0.019	0.018
1T6-2	-	-	-	-	0.111	0.34
1T6-1	0.002	0.001	0.001	0.020	0.058	0.134
1T6-3	-	-	-	-	0.020	0.061
1T6-4	-	-	-	-	0.014	0.044
1T6-5	-	-	-	-	0.011	0.033
1T6-6	-	-	-	-	0.008	0.023
1T6-7	-	-	-	-	0.008	0.022

[a] = prior to antenna construction.
[b] = antenna elements grounded at transmitter (condition 2).
[c] = antenna elements connected to transmitter, transmitter off (condition 9).
- = site measurement point not established.
-- = site measurement point dropped.
/ = data not taken.

TABLE A-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
Measured (M) and Extrapolated (Ex) Data (page 1 of 4)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps) NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	1987 Exposures; Antenna Element, Current (Amps) NS(15) M	EW(15) M	1988 Exposures; Antenna Element, Current (Amps) NS(75) M	EW(75) M
1C1-3	-	-	-	--	-	-	-	-
1C1-4	-	-	-	--	-	-	-	-
1C3-1	-	-	-	--	-	-	-	-
1C3-3	-	-	-	--	-	-	-	-
1C4-1	-	-	-	--	-	-	-	-
1C4-3	-	-	-	--	--	--	--	--
1C4-4	-	-	-	--	-	-	-	-
1C4-5	-	-	-	-	-	-	-	-
1D3-1	-	-	-	--	-	-	-	-
1C6-1	-	-	-	--	-	-	-	-
1C6-3	-	-	-	--	-	-	-	-
1C6-4	-	-	-	--	-	-	-	-
1L1-1	/	/	/	/	/	/	/	/
1L1-2	/	/	/	/	/	/	--	--
1L1-3	/	/	/	/	/	/	--	--
1L1-4	/	/	/	/	/	/	/	/
1L4-1	-	-	-	-	--	--	-	-
1T1-14	-	-	-	--	0.004	-	0.017	-
1T1-15	-	-	-	--	0.001	-	0.007	-
1T1-16	-	-	-	--	0.004	-	0.012	-
1T1-17	0.002	-	-	--	0.004	-	0.023	-

TABLE A-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
Measured (M) and Extrapolated (Ex) Data (page 2 of 4)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps) NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	1987 Exposures; Antenna Element, Current (Amps) NS(15) M	EW(15) M	1988 Exposures; Antenna Element, Current (Amps) NS(75) M	EW(75) M
1T1-18	0.001	-	-	--	0.004	-	0.023	-
1T1-19	0.002	-	-	--	0.005	-	0.032	-
1T1-20	0.002	-	-	--	0.004	-	0.025	-
1T1-28	-	-	-	-	-	-	0.016	-
1T1-29	-	-	-	-	-	-	0.013	-
1T1-30	-	-	-	-	-	-	0.017	-
1T1-31	-	-	-	-	-	-	0.016	-
1T1-21	1.08	-	-	--	3.6	0.005	15.7	0.054
1T1-22	0.002	-	-	--	0.005	<0.001	0.024	-
1T1-23	-	-	-	--	0.008	-	0.033	-
1T1-24	-	-	-	--	0.013	-	0.045	-
1T1-25	-	-	-	--	0.019	-	0.059	-
1T1-26	-	-	-	--	0.012	-	0.044	-
1T1-27	-	-	-	--	0.008	-	0.032	-
1T2-1	0.33	-	-	--	--	--	--	--
1T2-2	0.003	-	-	--	--	--	--	--
1T2-3	0.002	-	-	--	--	--	--	--
1T2-4	-	-	-	--	--	--	--	--
1T2-5	-	-	-	-	1.28	0.014	7.3	0.100
1T2-6	-	-	-	-	0.169	0.002	0.84	0.013
1T2-7	-	-	-	-	0.034	<0.001	0.29	0.004
1T2-8	-	-	-	-	0.014	-	0.084	0.004
1T2-9	-	-	-	-	0.008	-	0.035	0.004
1D1-1	-	-	-	--	-	-	-	-

TABLE A-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
Measured (M) and Extrapolated (Ex) Data (page 3 of 4)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps) NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	1987 Exposures; Antenna Element, Current (Amps) NS(15) M	EW(15) M	1988 Exposures; Antenna Element, Current (Amps) NS(75) M	EW(75) M
1T4-5	0.58	-	-	--	2.1	0.003	8.7	0.044
1T4-6	0.091	-	-	--	0.31	<0.001	1.76	0.009
1T4-7	0.022	-	-	--	0.089	-	0.35	0.003
1T4-8	0.005	-	-	--	0.014	-	0.054	0.002
1T4-9	0.002	-	-	--	0.008	-	0.045	0.002
1T4-10	-	-	-	-	1.30	0.001	6.4	0.033
1T4-11	-	-	-	-	0.30	<0.001	1.48	0.008
1T4-12	-	-	-	-	0.090	<0.001	0.39	0.003
1T4-13	-	-	-	-	0.033	<0.001	0.115	0.002
1T4-14	-	-	-	-	0.015	<0.001	0.066	0.002
1D2-1	-	-	-	--	-	0.003	0.001	0.001
1T5-1	0.81	-	-	--	3.1	0.005	12.4	0.040
1T5-7	-	-	-	-	0.54	0.001	1.78	0.005
1T5-8	-	-	-	-	0.008	<0.001	0.039	-
1T5-4	0.002	-	-	--	0.007	-	0.039	-
1T5-2	0.59	-	-	--	2.9	0.003	15.8	0.056
1T5-9	-	-	-	-	0.44	<0.001	1.95	0.007
1T5-10	-	-	-	-	0.076	-	0.29	0.001
1T5-6	0.009	-	-	--	0.022	-	0.135	-
1T5-3	0.004	-	-	--	--	--	--	--
1T5-5	0.005	-	-	--	0.019	-	0.095	0.001

TABLE A-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
Measured (M) and Extrapolated (Ex) Data (page 4 of 4)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps) NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	1987 Exposures; Antenna Element, Current (Amps) NS(15) M	EW(15) M	1988 Exposures; Antenna Element, Current (Amps) NS(75) M	EW(75) M
1T6-2	-	-	-	-	3.2	0.005	14.3	0.054
1T6-1	0.182	-	-	~~	0.48	-	2.4	0.010
1T6-3	-	-	-	-	0.042	<0.001	0.121	<0.001
1T6-4	-	-	-	-	0.029	<0.001	0.122	<0.011
1T6-5	-	-	-	-	0.021	<0.001	0.107	<0.001
1T6-6	-	-	-	-	0.019	<0.001	0.075	<0.001
1T6-7	-	-	-	-	0.015	<0.001	0.079	0.001

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
- = site measurement point not established.
-- = site measurement point dropped.
- = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.
~~ = data cannot be extrapolated.
/ = data not taken.

TABLE A-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies
Measured (M) and Extrapolated (Ex) Data (page 1 of 4)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)		1988 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M	NS(75) M	EW(75) M
1C1-3	0.021	0.003	0.010	0.017	0.082	0.028	0.44	0.139
1C1-4	/	/	/	/	0.087	0.033	0.42	0.185
1C3-1	/	/	/	/	0.050	0.025	0.26	0.119
1C3-3	0.022	0.004	0.012	0.020	0.086	0.032	0.41	0.157
1C4-1	/	/	/	/	0.005	0.004	0.023	0.019
1C4-3	/	/	/	/	--	--	--	--
1C4-4	<0.001	<0.001	<0.001	--	0.002	0.002	0.005	0.005
1C4-5	-	-	-	-	0.003	0.002	0.012	0.008
1D3-1	0.008	0.004	0.005	0.008	0.053	0.019	0.21	0.065
1C6-1	/	/	/	/	0.004	0.003	0.017	0.017
1C6-3	0.001	<0.001	0.001	0.002	0.008	0.004	0.026	0.016
1C6-4	/	/	/	/	0.003	0.002	0.017	0.009
1L1-1	/	/	/	/	/	/	/	/
1L1-2	/	/	/	/	/	/	--	--
1L1-3	/	/	/	/	/	/	--	--
1L1-4	/	/	/	/	/	/	/	/
1L4-1	-	-	-	-	-	-	0.006	0.002
1T1-14	0.86	0.026	0.021	0.035	3.1	0.069	18.1	0.21
1T1-15	0.43	0.013	0.015	0.025	1.60	0.051	9.2	0.21
1T1-16	1.11	0.035	0.035	0.058	4.6	0.133	24	0.61
1T1-17	1.55	0.049	0.053	0.088	6.2	0.139	23	0.57

**TABLE A-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies
Measured (M) and Extrapolated (Ex) Data (page 2 of 4)**

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps) NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	1987 Exposures; Antenna Element, Current (Amps) NS(15) M	EW(15) M	1988 Exposures; Antenna Element, Current (Amps) NS(75) M	EW(75) M
1T1-18	1.44	0.042	0.050	0.083	5.6	0.166	26	0.71
1T1-19	1.54	0.050	0.053	0.088	6.4	0.142	28	0.69
1T1-20	1.45	0.046	0.043	0.072	6.0	0.142	28	0.77
1T1-28	-	-	-	-	-	-	25	0.74
1T1-29	-	-	-	-	-	-	16.1	0.58
1T1-30	-	-	-	-	-	-	17.2	0.63
1T1-31	-	-	-	-	-	-	20	0.71
1T1-21	1.45	0.044	0.009	0.015	7.4	0.026	31	0.133
1T1-22	1.50	0.042	0.009	0.015	4.2	0.021	25	0.62
1T1-23	0.96	0.030	0.003	0.005	2.9	0.017	18.7	0.109
1T1-24	1.15	0.036	0.010	0.017	4.7	0.020	14.8	0.117
1T1-25	0.87	0.027	0.062	0.103	2.9	0.019	15.6	0.079
1T1-26	0.56	0.017	0.004	0.007	2.0	0.014	12.3	0.082
1T1-27	0.38	0.012	0.004	0.007	1.82	0.015	6.2	0.057
1T2-1	2.6	0.083	0.21	0.35	--	--	--	--
1T2-2	1.27	0.045	0.144	0.24	--	--	--	--
1T2-3	1.91	0.073	0.27	0.45	--	--	--	--
1T2-4	1.04	0.043	0.155	0.26	--	--	--	--
1T2-5	-	-	-	-	8.7	0.77	39	3.1
1T2-6	-	-	-	-	8.5	0.86	41	4.6
1T2-7	-	-	-	-	7.0	0.56	31	2.7
1T2-8	-	-	-	-	7.1	0.66	31	3.6
1T2-9	-	-	-	-	6.2	0.79	31	3.6
1D1-1	0.042	0.28	0.066	0.110	0.23	0.67	1.15	3.4

TABLE A-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies
Measured (M) and Extrapolated (Ex) Data (page 3 of 4)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)		1988 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M	NS(75) M	EW(75) M
1T4-5	2.1	0.062	0.054	0.090	6.4	0.191	34	0.76
1T4-6	2.5	0.076	0.103	0.172	6.3	0.29	45	1.35
1T4-7	2.2	0.067	0.092	0.153	8.7	0.30	37	1.40
1T4-8	1.91	0.061	0.123	0.21	7.7	0.31	32	1.59
1T4-9	2.1	0.062	0.126	0.21	6.2	0.34	35	1.74
1T4-10	-	-	-	-	12.4	0.29	47	1.30
1T4-11	-	-	-	-	6.4	0.27	34	1.26
1T4-12	-	-	-	-	7.4	0.38	39	1.31
1T4-13	-	-	-	-	5.7	0.33	29	1.60
1T4-14	-	-	-	-	6.7	0.33	31	1.56
1O2-1	0.094	0.44	0.113	0.188	0.41	1.36	1.58	4.8
1T5-1	2.6	0.079	0.074	0.123	9.7	0.21	47	0.94
1T5-7	-	-	-	-	8.4	0.21	48	1.01
1T5-8	-	-	-	-	8.2	0.20	38	0.87
1T5-4	1.39	0.042	0.061	0.102	5.8	0.21	29	0.98
1T5-2	1.97	0.064	0.108	0.180	8.2	0.23	24	0.77
1T5-9	-	-	-	-	7.2	0.29	19.5	0.84
1T5-10	-	-	-	-	3.4	0.170	14.4	1.00
1T5-6	1.08	0.037	0.070	0.117	3.3	0.21	13.1	0.98
1T5-3	3.4	0.099	0.077	0.128	--	--	--	--
1T5-5	1.31	0.051	0.101	0.168	5.2	0.33	23	1.40

TABLE A-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies
Measured (M) and Extrapolated (Ex) Data (page 4 of 4)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)		1988 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M	NS(75) M	EW(75) M
1T6-2	-	-	-	-	27	0.24	71	0.79
1T6-1	5.4	0.159	0.086	0.143	32	0.25	102	1.03
1T6-3	-	-	-	-	21	0.144	97	0.67
1T6-4	-	-	-	-	16.3	0.122	87	0.61
1T6-5	-	-	-	-	15.3	0.22	80	1.27
1T6-6	-	-	-	-	11.6	0.132	63	0.66
1T6-7	-	-	-	-	6.0	0.178	87	1.41

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
- = site measurement point not established.
-- = site measurement point dropped.
-- = data cannot be extrapolated.
/ = data not taken.

TABLE A-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
Measured (M) and Extrapolated (Ex) Data (page 1 of 4)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps) NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	1987 Exposures; Antenna Element, Current (Amps) NS(15) M	EW(15) M	1988 Exposures; Antenna Element, Current (Amps) NS(75) M	EW(75) M
1C1-3	<0.001	<0.001	<0.001	--	0.001	<0.001	0.003	0.001
1C1-4	/	/	/	/	0.001	<0.001	0.003	0.001
1C3-1	/	/	/	/	0.001	<0.001	0.003	0.001
1C3-3	<0.001	<0.001	<0.001	--	0.001	<0.001	0.003	0.001
1C4-1	/	/	/	/	<0.001	<0.001	0.001	<0.001
1C4-3	/	/	/	/	--	--	--	--
1C4-4	<0.001	<0.001	<0.001	--	<0.001	<0.001	0.001	<0.001
1C4-5	-	-	-	-	<0.001	<0.001	0.001	<0.001
1D3-1	<0.001	<0.001	<0.001	--	<0.001	<0.001	0.002	0.002
1C6-1	/	/	/	/	<0.001	<0.001	0.001	0.001
1C6-3	<0.001	<0.001	<0.001	--	<0.001	<0.001	0.001	0.001
1C6-4	/	/	/	/	<0.001	<0.001	0.002	0.001
1L1-1	/	/	/	/	/	/	/	/
1L1-2	/	/	/	/	/	/	--	--
1L1-3	/	/	/	/	/	/	--	--
1L1-4	/	/	/	/	/	/	/	/
1L4-1	-	-	-	-	-	-	<0.001	<0.001
1T1-14	0.032	0.001	0.001	0.002	0.115	0.003	0.65	0.014
1T1-15	0.027	0.001	0.001	0.002	0.097	0.003	0.47	0.012
1T1-16	0.069	0.002	0.001	0.002	0.22	0.002	1.05	0.013
1T1-17	0.076	0.003	0.001	0.002	0.23	0.001	1.49	0.012

TABLE A-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
Measured (M) and Extrapolated (Ex) Data (page 2 of 4)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps) NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	1987 Exposures; Antenna Element, Current (Amps) NS(15) M	EW(15) M	1988 Exposures; Antenna Element, Current (Amps) NS(75) M	EW(75) M
1T1-18	0.071	0.002	0.001	0.002	0.27	0.002	1.28	0.012
1T1-19	0.081	0.003	0.001	0.002	0.32	0.002	1.51	0.013
1T1-20	0.089	0.003	0.001	0.002	0.36	0.002	1.68	0.013
1T1-28	-	-	-	-	-	-	1.25	0.015
1T1-29	-	-	-	-	-	-	1.10	0.015
1T1-30	-	-	-	-	-	-	1.12	0.015
1T1-31	-	-	-	-	-	-	1.00	0.015
1T1-21	0.78	0.024	0.004	0.007	2.9	0.005	13.8	0.043
1T1-22	0.31	0.010	0.002	0.003	1.16	0.016	5.8	0.019
1T1-23	0.169	0.005	0.001	0.002	0.64	0.003	3.0	0.013
1T1-24	0.113	0.004	0.001	0.002	0.43	0.003	2.1	0.011
1T1-25	0.084	0.003	0.007	0.012	0.32	0.003	1.52	0.011
1T1-26	0.055	0.002	0.001	0.002	0.21	0.002	1.00	0.010
1T1-27	0.040	0.012	0.001	0.002	0.149	0.002	0.69	0.009
1T2-1	0.95	0.029	0.006	0.010	--	--	--	--
1T2-2	0.105	<0.001	<0.001	--	--	--	--	--
1T2-3	0.075	0.002	0.001	0.002	--	--	--	--
1T2-4	0.073	0.002	0.001	0.002	--	--	--	--
1T2-5	-	-	-	-	3.2	0.005	15.1	0.053
1T2-6	-	-	-	-	1.23	0.003	5.8	0.031
1T2-7	-	-	-	-	0.64	0.002	3.1	0.023
1T2-8	-	-	-	-	0.43	0.003	2.1	0.020
1T2-9	-	-	-	-	0.32	0.003	1.59	0.019
1D1-1	<0.001	0.003	0.001	0.002	0.001	0.011	0.004	0.053

TABLE A-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
Measured (M) and Extrapolated (Ex) Data (page 3 of 4)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps) NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	1987 Exposures; Antenna Element, Current (Amps) NS(15) M	EW(15) M	1988 Exposures; Antenna Element, Current (Amps) NS(75) M	EW(75) M
1T4-5	0.70	0.022	0.004	0.007	2.9	0.004	13.4	0.047
1T4-6	0.32	0.010	0.002	0.003	1.21	0.002	5.7	0.025
1T4-7	0.171	0.005	0.001	0.002	0.66	0.001	3.1	0.017
1T4-8	0.116	0.003	0.001	0.002	0.43	0.002	2.1	0.014
1T4-9	0.085	0.003	0.001	0.002	0.34	0.002	1.55	0.012
1T4-10	-	-	-	-	2.7	0.004	16.5	0.042
1T4-11	-	-	-	-	0.87	0.003	5.3	0.015
1T4-12	-	-	-	-	0.64	0.002	2.9	0.008
1T4-13	-	-	-	-	0.43	0.002	2.0	0.007
1T4-14	-	-	-	-	0.32	0.002	1.55	0.006
1D2-1	<0.001	0.003	0.001	0.002	0.002	0.008	0.009	0.043
1T5-1	0.89	0.029	0.005	0.008	3.6	0.005	17.0	0.059
1T5-7	-	-	-	-	1.93	0.002	8.9	0.035
1T5-8	-	-	-	-	0.75	0.001	3.5	0.017
1T5-4	0.124	0.004	0.001	0.002	0.46	0.001	2.2	0.013
1T5-2	0.77	0.024	0.004	0.007	3.1	0.004	14.4	0.052
1T5-9	-	-	-	-	1.18	0.003	5.6	0.017
1T5-10	-	-	-	-	0.67	0.002	3.2	0.009
1T5-6	0.125	0.004	<0.001	--	0.46	0.002	2.1	0.007
1T5-3	0.20	0.006	0.001	0.002	--	--	--	--
1T5-5	0.131	0.004	0.001	0.002	0.53	0.001	2.5	0.014

TABLE A-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
Measured (M) and Extrapolated (Ex) Data (page 4 of 4)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)		1988 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M	NS(75) M	EW(75) M
1T6-2	-	-	-	-	3.9	0.006	17.8	0.061
1T6-1	0.40	0.013	0.002	0.003	1.51	0.004	7.2	0.021
1T6-3	-	-	-	-	0.65	0.002	3.2	0.008
1T6-4	-	-	-	-	0.44	0.002	2.1	0.006
1T6-5	-	-	-	-	0.34	0.002	1.70	0.004
1T6-6	-	-	-	-	0.24	0.016	1.17	0.004
1T6-7	-	-	-	-	0.22	0.002	1.05	0.005

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
\- = site measurement point not established.
-- = site measurement point dropped.
-- = data cannot be extrapolated.
/ = data not taken.

TABLE A-8. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
Data Extrapolated to 150 Ampere Current (page 1 of 2)

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations		1988 Extrapolations	
	NS	NEW	SEW	NS	EW	NS	EW
1C1-3	--	--	--	--	--	--	--
1C1-4	--	--	--	--	--	--	--
1C3-1	--	--	--	--	--	--	--
1C3-3	--	--	--	--	--	--	--
1C4-1	--	--	--	--	--	--	--
1C4-3	--	--	--	--	--	--	--
1C4-4	--	--	--	--	--	--	--
1C4-5	-	-	-	--	--	--	--
1D3-1	--	--	--	--	--	--	--
1C6-1	--	--	--	--	--	--	--
1C6-3	--	--	--	--	--	--	--
1C6-4	--	--	--	--	--	--	--
1L1-1	/	/	/	/	/	/	/
1L1-2	/	/	/	/	/	--	--
1L1-3	/	/	/	/	/	--	--
1L1-4	/	/	/	/	/	/	/
1L4-1	-	-	-	--	--	--	--
1T1-14	--	--	--	0.040	--	0.034	--
1T1-15	--	--	--	0.010	--	0.014	--
1T1-16	--	--	--	0.040	--	0.024	--
1T1-17	0.075	--	--	0.040	--	0.046	--
1T1-18	0.038	--	--	0.040	--	0.046	--
1T1-19	0.075	--	--	0.050	--	0.064	--
1T1-20	0.075	--	--	0.040	--	0.050	--
1T1-28	-	-	-	-	-	0.032	--
1T1-29	-	-	-	-	-	0.026	--
1T1-30	-	-	-	-	-	0.034	--
1T1-31	-	-	-	-	-	0.032	--
1T1-21	41	--	--	36	0.050	31	0.108
1T1-22	0.075	--	--	0.050	--	0.048	--
1T1-23	--	--	--	0.080	--	0.066	--
1T1-24	--	--	--	0.130	--	0.090	--
1T1-25	--	--	--	0.190	--	0.118	--
1T1-26	--	--	--	0.120	--	0.088	--
1T1-27	--	--	--	0.080	--	0.064	--
1T2-1	12.4	--	--	--	--	--	--
1T2-2	0.113	--	--	--	--	--	--
1T2-3	0.075	--	--	--	--	--	--
1T2-4	--	--	--	--	--	--	--
1T2-5	-	-	-	12.8	0.140	14.6	0.20

TABLE A-8. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
Data Extrapolated to 150 Ampere Current (page 2 of 2)

Site No., Meas. Pt.	1986 Extrapolations NS	NEW	SEW	1987 Extrapolations NS	EW	1988 Extrapolations NS	EW
1T2-6	-	-	-	1.69	0.020	1.68	0.026
1T2-7	-	-	-	0.34	--	0.58	0.008
1T2-8	-	-	-	0.140	--	0.168	0.008
1T2-9	-	-	-	0.080	--	0.070	0.008
1D1-1	--	--	--	--	--	--	--
1T4-5	22	--	--	21	0.030	17.4	0.088
1T4-6	3.4	--	--	3.1	--	3.5	0.018
1T4-7	0.83	--	--	0.89	--	0.70	0.006
1T4-8	0.188	--	--	0.140	--	0.108	0.004
1T4-9	0.075	--	--	0.080	--	0.090	0.004
1T4-10	-	-	-	13.0	0.010	12.8	0.066
1T4-11	-	-	-	3.0	--	3.0	0.016
1T4-12	-	-	-	0.90	--	0.78	0.006
1T4-13	-	-	-	0.33	--	0.23	0.004
1T4-14	-	-	-	0.150	--	0.132	0.004
1D2-1	--	--	--	--	0.030	0.002	0.002
1T5-1	30	--	--	31	0.050	25	0.080
1T5-7	-	-	-	5.4	0.010	3.6	0.010
1T5-8	-	-	-	0.080	--	0.078	--
1T5-4	0.075	--	--	0.070	--	0.078	--
1T5-2	22	--	--	29	0.030	32	0.112
1T5-9	-	-	-	4.4	--	3.9	0.014
1T5-10	-	-	-	0.76	--	0.58	0.002
1T5-6	0.34	--	--	0.22	--	0.27	--
1T5-3	0.150	--	--	--	--	--	--
1T5-5	0.188	--	--	0.190	--	0.190	0.002
1T6-2	-	-	-	32	0.050	29	0.108
1T6-1	6.8	--	--	4.8	--	4.8	0.020
1T6-3	-	-	-	0.42	--	0.24	--
1T6-4	-	-	-	0.29	--	0.24	--
1T6-5	-	-	-	0.21	--	0.21	--
1T6-6	-	-	-	0.190	--	0.150	--
1T6-7	-	-	-	0.150	--	0.158	0.002

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
\- = site measurement point not established.
-- = site measurement point dropped.
-- = data cannot be extrapolated.
/ = data not taken.

TABLE A-9. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies
Data Extrapolated to 150 Ampere Current (page 1 of 2)

Site No.,	1986 Extrapolations			1987 Extrapolations		1988 Extrapolations	
Meas. Pt.	NS	NEW	SEW	NS	EW	NS	EW
1C1-3	0.79	0.075	0.25	0.82	0.28	0.88	0.28
1C1-4	/	/	/	0.87	0.33	0.84	0.37
1C3-1	/	/	/	0.50	0.25	0.52	0.24
1C3-3	0.83	0.100	0.30	0.86	0.32	0.82	0.31
1C4-1	/	/	/	0.050	0.040	0.046	0.038
1C4-3	/	/	/	--	--	--	--
1C4-4	--	--	--	0.020	0.020	0.010	0.010
1C4-5	-	-	-	0.030	0.020	0.024	0.016
1D3-1	0.30	0.100	0.125	0.53	0.190	0.42	0.130
1C6-1	/	/	/	0.040	0.030	0.034	0.034
1C6-3	0.038	--	0.025	0.080	0.040	0.052	0.032
1C6-4	/	/	/	0.030	0.020	0.034	0.018
1L1-1	/	/	/	/	/	/	/
1L1-2	/	/	/	/	/	--	--
1L1-3	/	/	/	/	/	--	--
1L1-4	/	/	/	/	/	/	/
1L4-1	-	-	-	-	-	0.012	0.004
1T1-14	32	0.65	0.53	31	0.69	36	0.42
1T1-15	16.1	0.33	0.38	16.0	0.51	18.4	0.42
1T1-16	42	0.88	0.88	46	1.33	48	1.22
1T1-17	58	1.23	1.33	62	1.39	46	1.14
1T1-18	54	1.05	1.25	56	1.66	52	1.42
1T1-19	58	1.25	1.33	64	1.42	56	1.38
1T1-20	54	1.15	1.08	60	1.42	56	1.54
1T1-28	-	-	-	-	-	50	1.48
1T1-29	-	-	-	-	-	32	1.16
1T1-30	-	-	-	-	-	34	1.26
1T1-31	-	-	-	-	-	40	1.42
1T1-21	54	1.10	0.23	74	0.26	62	0.27
1T1-22	56	1.05	0.23	42	0.21	50	1.24
1T1-23	36	0.75	0.075	29	0.170	37	0.22
1T1-24	43	0.90	0.25	47	0.20	30	0.23
1T1-25	33	0.68	1.55	29	0.190	31	0.158
1T1-26	21	0.43	0.100	20	0.140	25	0.164
1T1-27	14.3	0.30	0.100	18.2	0.150	12.4	0.114
1T2-1	96	2.1	5.3	--	--	--	--
1T2-2	48	1.13	3.6	--	--	--	--
1T2-3	72	1.83	6.8	--	--	--	--
1T2-4	39	1.08	3.9	--	--	--	--
1T2-5	-	-	-	87	7.7	78	6.2

TABLE A-9. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies
Data Extrapolated to 150 Ampere Current (page 2 of 2)

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations		1988 Extrapolations	
	NS	NEW	SEW	NS	EW	NS	EW
1T2-6	-	-	-	85	8.6	82	9.2
1T2-7	-	-	-	70	5.6	62	5.4
1T2-8	-	-	-	71	6.6	62	7.2
1T2-9	-	-	-	62	7.9	62	7.2
1D1-1	1.58	7.0	1.65	2.3	6.7	2.3	6.8
1T4-5	79	1.55	1.35	64	1.91	68	1.52
1T4-6	94	1.90	2.6	63	2.9	90	2.7
1T4-7	83	1.68	2.3	87	3.0	74	2.8
1T4-8	72	1.53	3.1	77	3.1	64	3.2
1T4-9	79	1.55	3.2	62	3.4	70	3.5
1T4-10	-	-	-	124	2.9	94	2.6
1T4-11	-	-	-	64	2.7	68	2.5
1T4-12	-	-	-	74	3.8	78	2.6
1T4-13	-	-	-	57	3.3	58	3.2
1T4-14	-	-	-	67	3.3	62	3.1
1D2-1	3.5	11.0	2.8	4.1	13.6	3.2	9.6
1T5-1	98	1.98	1.85	97	2.1	94	1.88
1T5-7	-	-	-	84	2.1	96	2.0
1T5-8	-	-	-	82	2.0	76	1.74
1T5-4	52	1.05	1.53	58	2.1	58	1.96
1T5-2	74	1.60	2.7	82	2.3	48	1.54
1T5-9	-	-	-	72	2.9	39	1.68
1T5-10	-	-	-	34	1.70	29	2.0
1T5-6	41	0.93	1.75	33	2.1	26	1.96
1T5-3	128	2.5	1.93	--	--	--	--
1T5-5	49	1.28	2.5	52	3.3	46	2.8
1T6-2	-	-	-	270	2.4	142	1.58
1T6-1	200	4.0	2.2	320	2.5	200	2.1
1T6-3	-	-	-	210	1.44	194	1.34
1T6-4	-	-	-	163	1.22	174	1.22
1T6-5	-	-	-	153	2.2	160	2.5
1T6-6	-	-	-	116	1.32	126	1.32
1T6-7	-	-	-	60	1.78	174	2.8

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
\- = site measurement point not established.
-- = site measurement point dropped.
~~ = data cannot be extrapolated.
/ = data not taken.

TABLE A-10. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
Data Extrapolated to 150 Ampere Current (page 1 of 2)

Site No., Meas. Pt.	1986 Extrapolations NS	1986 Extrapolations NEW	1986 Extrapolations SEW	1987 Extrapolations NS	1987 Extrapolations EW	1988 Extrapolations NS	1988 Extrapolations EW
1C1-3	--	--	--	0.010	--	0.006	0.002
1C1-4	/	/	/	0.010	--	0.006	0.002
1C3-1	/	/	/	0.010	--	0.006	0.002
1C3-3	--	--	--	0.010	--	0.006	0.002
1C4-1	/	/	/	--	--	0.002	--
1C4-3	/	/	/	--	--	--	--
1C4-4	--	--	--	--	--	0.002	--
1C4-5	-	-	-	--	--	0.002	--
1D3-1	--	--	--	--	--	0.004	0.004
1C6-1	/	/	/	--	--	0.002	0.002
1C6-3	--	--	--	--	--	0.002	0.002
1C6-4	/	/	/	--	--	0.004	0.002
1L1-1	/	/	/	/	/	/	/
1L1-2	/	/	/	/	/	--	--
1L1-3	/	/	/	/	/	--	--
1L1-4	/	/	/	/	/	/	/
1L4-1	-	-	-	-	-	--	--
1T1-14	1.20	0.025	0.025	1.15	0.030	1.30	0.028
1T1-15	1.01	0.025	0.025	0.97	0.030	0.94	0.024
1T1-16	2.6	0.050	0.025	2.2	0.020	2.1	0.026
1T1-17	2.9	0.075	0.025	2.3	0.010	3.0	0.024
1T1-18	2.7	0.050	0.025	2.7	0.020	2.6	0.024
1T1-19	3.0	0.075	0.025	3.2	0.020	3.0	0.026
1T1-20	3.3	0.075	0.025	3.6	0.020	3.4	0.026
1T1-28	-	-	-	-	-	2.5	0.030
1T1-29	-	-	-	-	-	2.2	0.030
1T1-30	-	-	-	-	-	2.2	0.030
1T1-31	-	-	-	-	-	2.0	0.030
1T1-21	29	0.60	0.100	29	0.050	28	0.086
1T1-22	11.6	0.25	0.050	11.6	0.160	11.6	0.038
1T1-23	6.3	0.125	0.025	6.4	0.030	6.0	0.026
1T1-24	4.2	0.100	0.025	4.3	0.030	4.2	0.022
1T1-25	3.2	0.075	0.175	3.2	0.030	3.0	0.022
1T1-26	2.1	0.050	0.025	2.1	0.020	2.0	0.020
1T1-27	1.50	0.30	0.025	1.49	0.020	1.38	0.018
1T2-1	36	0.73	0.150	--	--	--	--
1T2-2	3.9	--	--	--	--	--	--
1T2-3	2.8	0.050	0.025	--	--	--	--
1T2-4	2.7	0.050	0.025	--	--	--	--
1T2-5	-	-	-	32	0.050	30	0.106

TABLE A-10. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
Data Extrapolated to 150 Ampere Current (page 2 of 2)

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations		1988 Extrapolations	
	NS	NEW	SEW	NS	EW	NS	EW
1T2-6	-	-	-	12.3	0.030	11.6	0.062
1T2-7	-	-	-	6.4	0.020	6.2	0.046
1T2-8	-	-	-	4.3	0.030	4.2	0.040
1T2-9	-	-	-	3.2	0.030	3.2	0.038
1D1-1	--	0.075	0.025	0.010	0.110	0.008	0.106
1T4-5	26	0.55	0.100	29	0.040	27	0.094
1T4-6	12.0	0.25	0.050	12.1	0.020	11.4	0.050
1T4-7	6.4	0.125	0.025	6.6	0.010	6.2	0.034
1T4-8	4.4	0.075	0.025	4.3	0.020	4.2	0.028
1T4-9	3.2	0.075	0.025	3.4	0.020	3.1	0.024
1T4-10	-	-	-	27	0.040	33	0.084
1T4-11	-	-	-	8.7	0.030	10.6	0.030
1T4-12	-	-	-	6.4	0.020	5.8	0.016
1T4-13	-	-	-	4.3	0.020	4.0	0.014
1T4-14	-	-	-	3.2	0.020	3.1	0.012
1D2-1	--	0.075	0.025	0.020	0.080	0.018	0.086
1T5-1	33	0.73	0.125	36	0.050	34	0.118
1T5-7	-	-	-	19.3	0.020	17.8	0.070
1T5-8	-	-	-	7.5	0.010	7.0	0.034
1T5-4	4.7	0.100	0.025	4.6	0.010	4.4	0.026
1T5-2	29	0.60	0.100	31	0.040	29	0.104
1T5-9	-	-	-	11.8	0.030	11.2	0.034
1T5-10	-	-	-	6.7	0.020	6.4	0.018
1T5-6	4.7	0.100	--	4.6	0.020	4.2	0.014
1T5-3	7.5	0.150	0.025	--	--	--	--
1T5-5	4.9	0.100	0.025	5.3	0.010	5.0	0.028
1T6-2	-	-	-	39	0.060	36	0.122
1T6-1	15.0	0.33	0.050	15.1	0.040	14.4	0.042
1T6-3	-	-	-	6.5	0.020	6.4	0.016
1T6-4	-	-	-	4.4	0.020	4.2	0.012
1T6-5	-	-	-	3.4	0.020	3.4	0.008
1T6-6	-	-	-	2.4	0.160	2.3	0.008
1T6-7	-	-	-	2.2	0.020	2.1	0.010

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
\- = site measurement point not established.
-- = site measurement point dropped.
-- = data cannot be extrapolated.
/ = data not taken.

The 1988 60 Hz measurements at test sites showed the same trends in EM field magnitudes as were reported in 1986 and 1987. That is, the 60 Hz magnetic flux densities increased near the antenna wire(s) in comparison to measurements made at these sites prior to antenna construction. The longitudinal electric field intensities also increased significantly at many test sites. Both are the result of 60 Hz currents from power lines coupled to the ELF antenna elements, which then re-radiate 60 Hz EM fields.

Because of this coupling, year-to-year variations in the 60 Hz EM field levels at the test sites are effected by fluctuations in regional power line load currents. In 1988, 60 Hz coupling to the NS antenna element appears to have increased substantially. This correlates with large load increases on a transmission line that parallels this antenna element about four miles to the west. The purchase of the Presque Isle power plant by Wisconsin Electric Power Company in January 1988 and its subsequent operation as a major producer of electrical energy in the region suggests that this line will remain heavily loaded.

The EM fields generated by the 60 Hz currents on the antenna wires are localized near the antennas and do not affect the 60 Hz EM fields at the control sites. However, the 60 Hz EM field levels at these locations can be influenced directly by local power lines. The 60 Hz EM fields measured at the control sites in 1988 were generally consistent with measurements from previous years.

76 Hz measurements were made in 1988 with 75 ampere antenna currents, the predominant MTF operating mode from July through December. The EM field exposures at the study sites for the period prior to July can be estimated either by using the 15 ampere antenna current measurement data from 1987 or more accurately by using one-fifth the value of the 1988 75 ampere data.

Measurements at the new mouse enclosures (1T1-28 through 31) were made during a period of 44 Hz transmitter operation. A 44 Hz measurement was also taken nearby at 1T1-20 in order to establish the ratio of 76 Hz to 44 Hz EM field intensities. This ratio was then used to estimate the 76 Hz EM field levels reported for these new sites in the EM data tables.

The measured EM field magnitudes for each antenna element for 1986-1988 have been linearly extrapolated to the planned operational antenna current of

150 amperes. Extrapolations were not performed when the measurements indicated that the EM field magnitudes were below the minimum sensitivity of the EM field sensors.

The 1988 extrapolations are the most accurate predictions of the EM field levels at the planned operational antenna current because the 1988 half-power EM field measurements are more accurate than those made at lower antenna currents in previous years. The 1988 extrapolations also reflect the operational configuration and tuning of the antenna elements with the new power amplifiers.

The maximum 76 Hz EM field intensities that can occur during simultaneous operation of both antenna elements at any antenna phasing can be estimated by calculating the algebraic sum of the levels from the individual antenna element extrapolations; minimum intensities can be estimated by calculating the algebraic difference.

Plots of 60 and 76 Hz EM field gradients across nest box sites at Pirlot Road, Cleveland Homestead, North Turner Road, and Ford River North and South are given for 1987 and 1988 in Figures A-15 through A-35. As shown, the magnetic fields generated by the 60 Hz current on the antenna wire are localized near the antenna and fall off rapidly and uniformly with distance. The longitudinal electric fields also decrease with distance, but are much less uniform, and reflect local changes in ground elevation and soil conductivity. The 76 Hz EM fields measured in 1988 at a 75 ampere antenna current are typically 50 to 500 times greater than the 60 Hz EM fields and five times greater than the 76 Hz EM field measured in 1987 at a 15 ampere antenna current. The gradient shape of a given field measured at a 15 ampere antenna current, however, closely follows that of the corresponding field measured at a 75 ampere antenna current. The 76 Hz transverse electric field displayed an exponential decay along the transect length at each site. Deviations from the ideal gradient shape are typically the result of vegetation shielding the electric field. The 60 Hz transverse electric fields were too low to be detected at several measurement points and gradient plots were therefore not constructed. Using the gradient plot figures, the EM field exposure at any nest box can be estimated if the perpendicular distance from the box to the antenna wire is known.

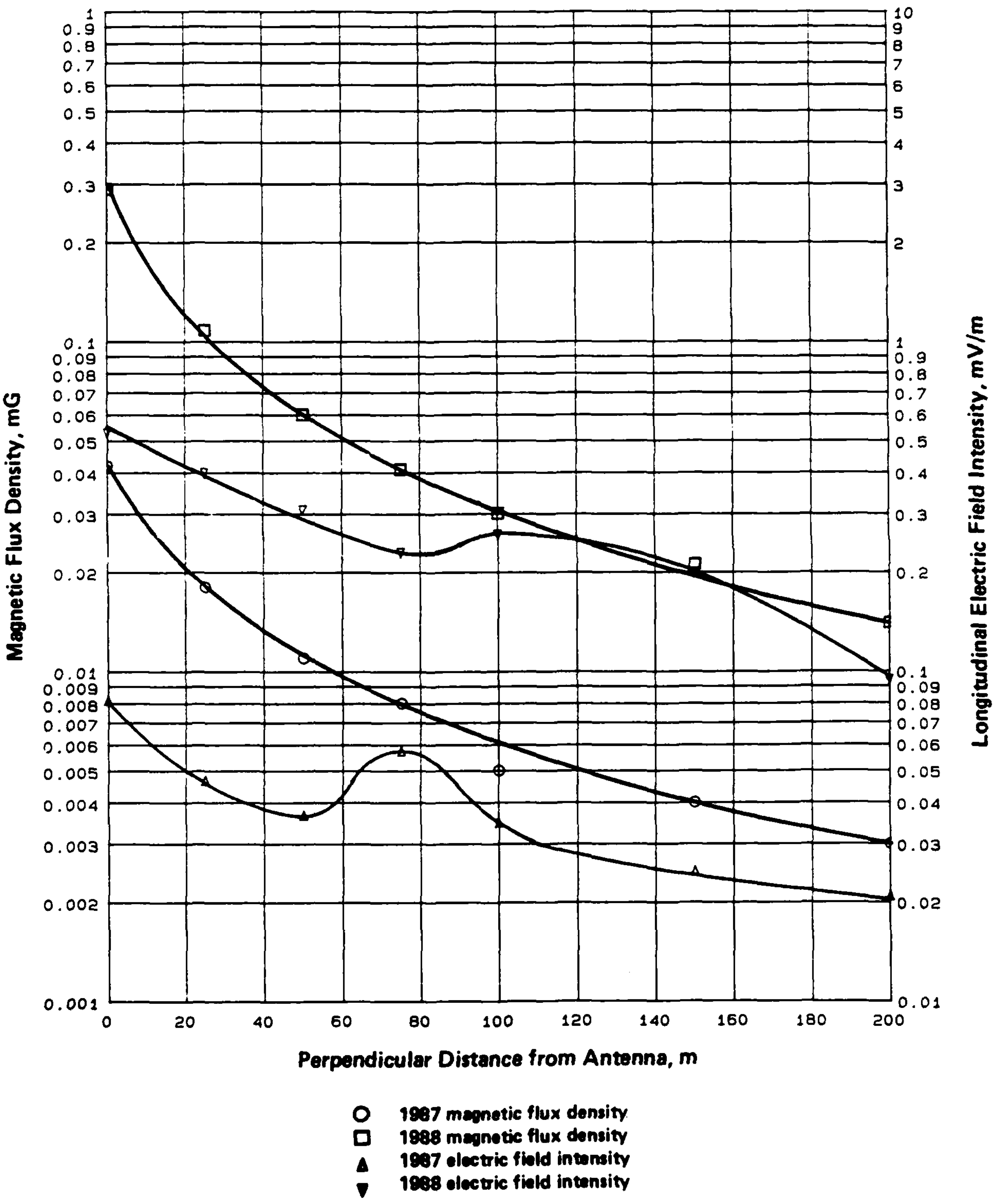


FIGURE A-15. 60 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD GRADIENTS, PIRLOT ROAD; 1T1-21 THROUGH 27.

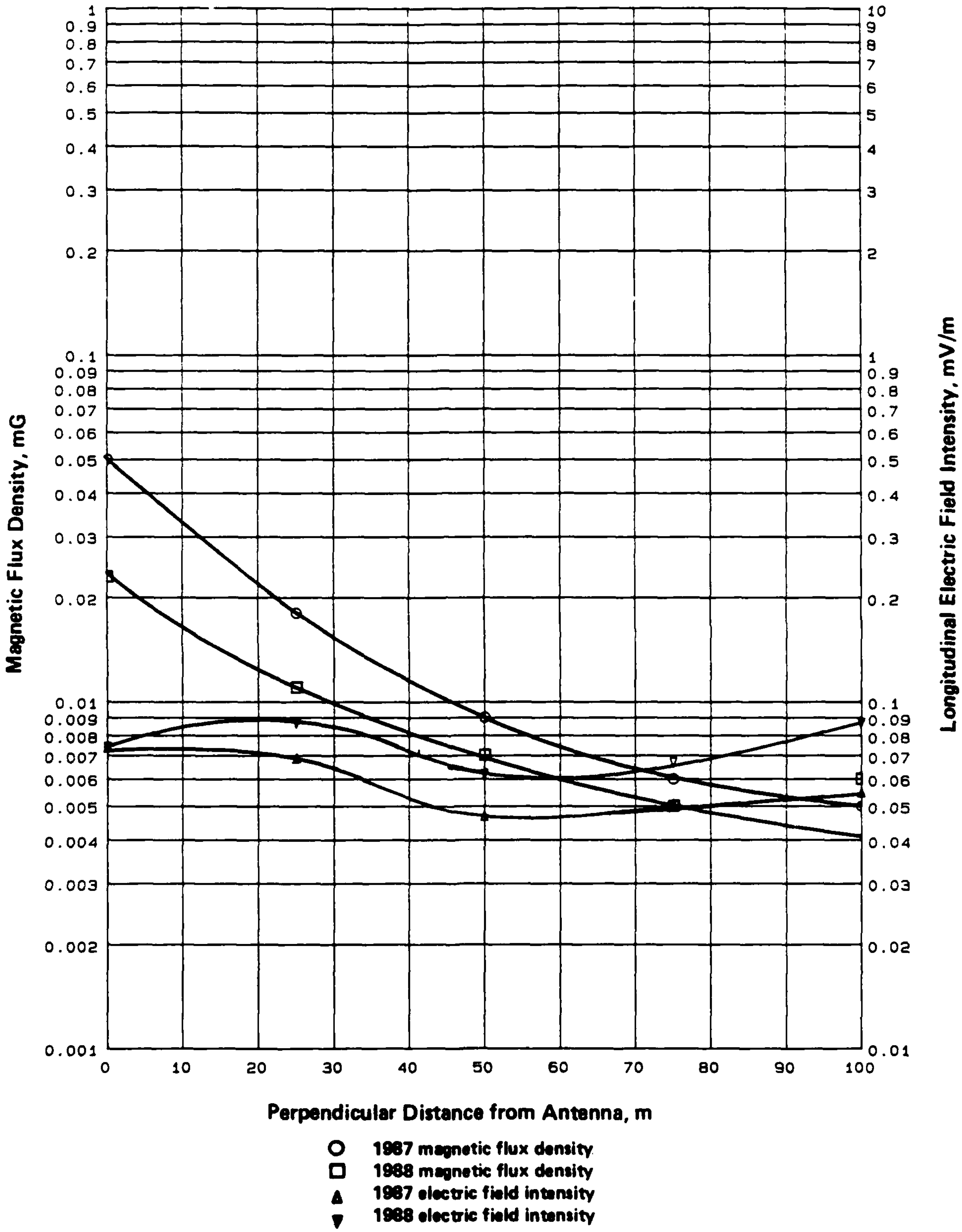


FIGURE A-16. 60 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD GRADIENTS, CLEVELAND HOMESTEAD; 1T2-5 THROUGH 9.

60297/189

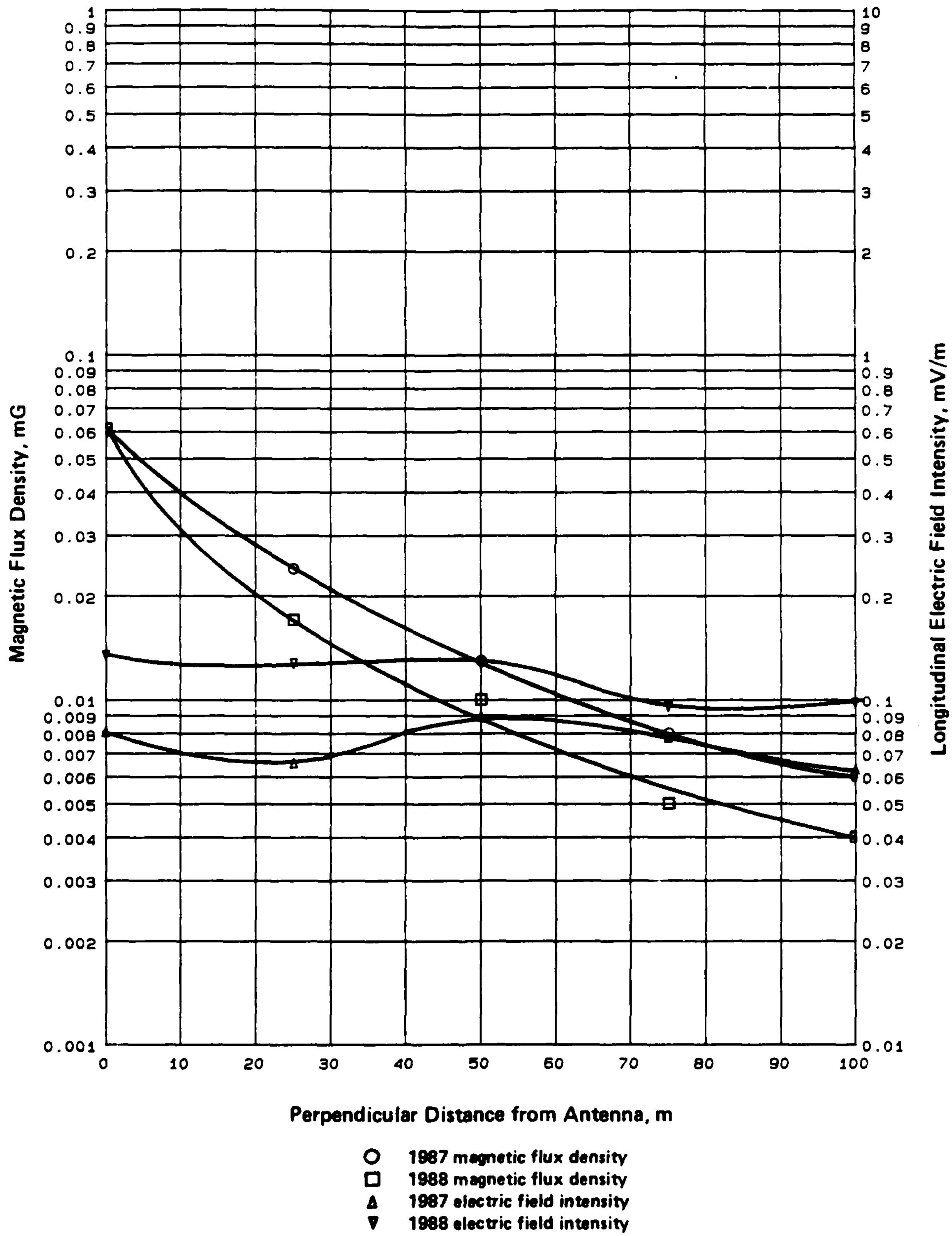


FIGURE A-17. 60 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD GRADIENTS, NORTH TURNER ROAD; 1T4-5 THROUGH 9.

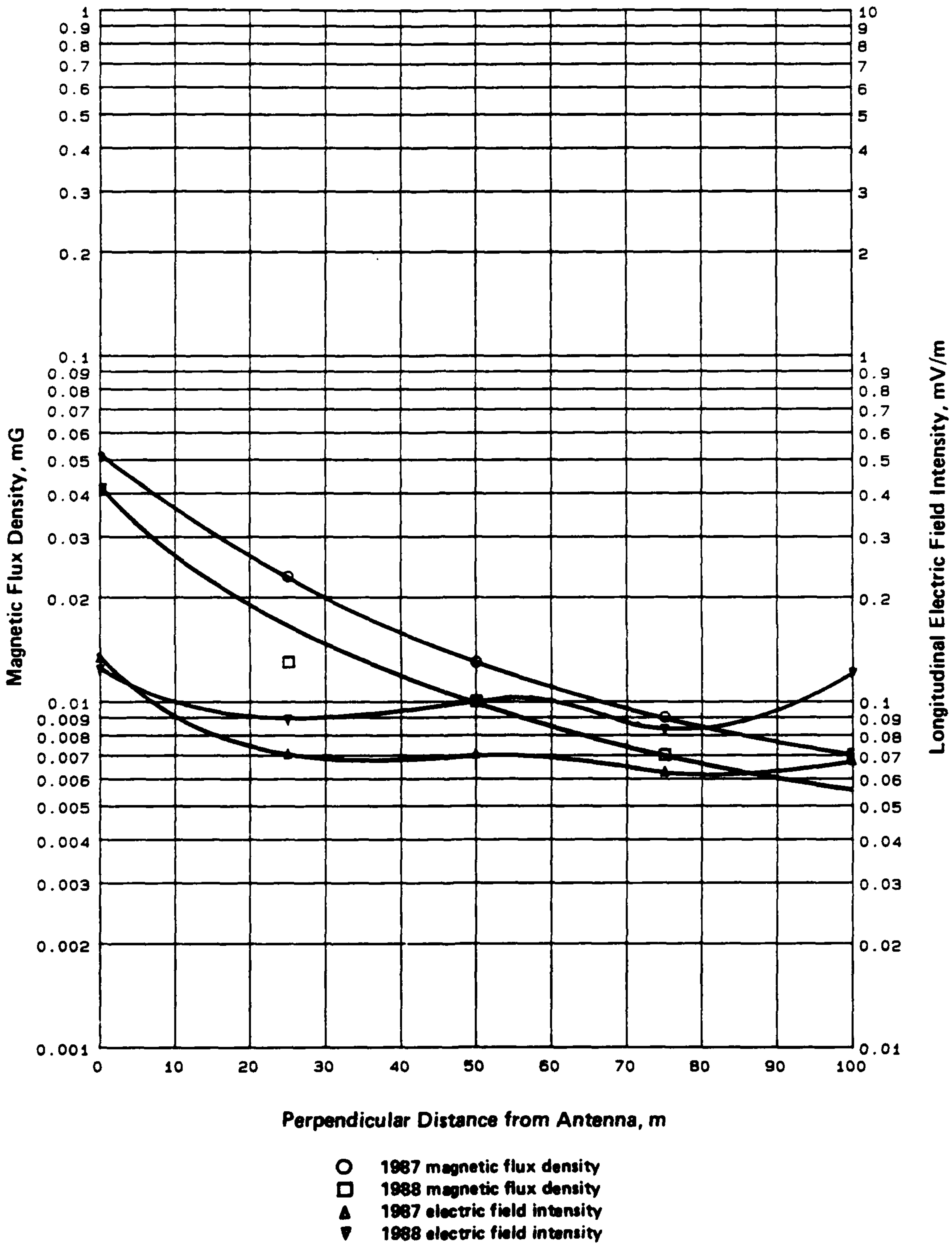


FIGURE A-18. 60 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD GRADIENTS, NORTH TURNER ROAD; 1T4-10 THROUGH 14.

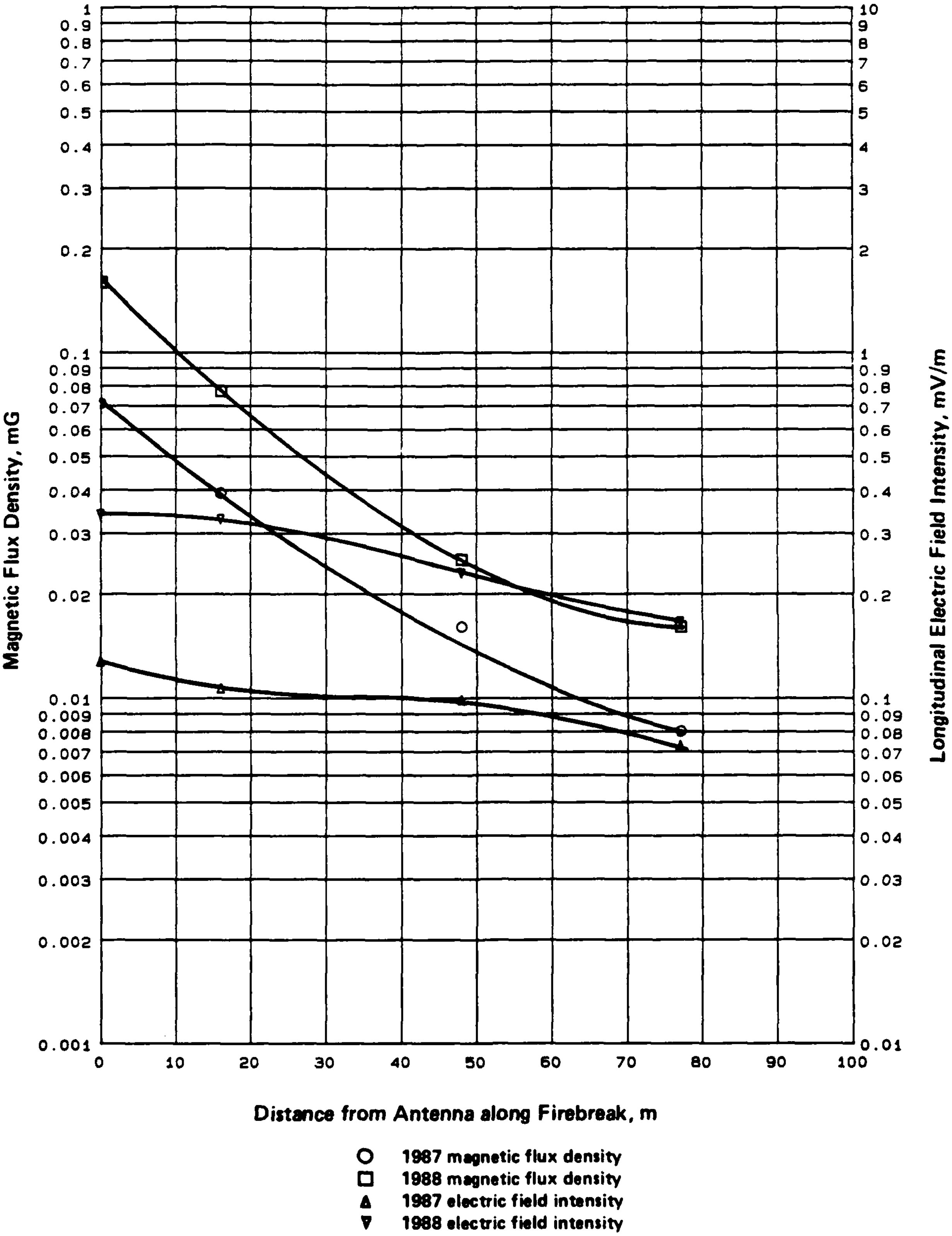


FIGURE A-19. 60 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD GRADIENTS, FORD RIVER NORTH; 1T5-1, 7, 8, 4.

60297/189

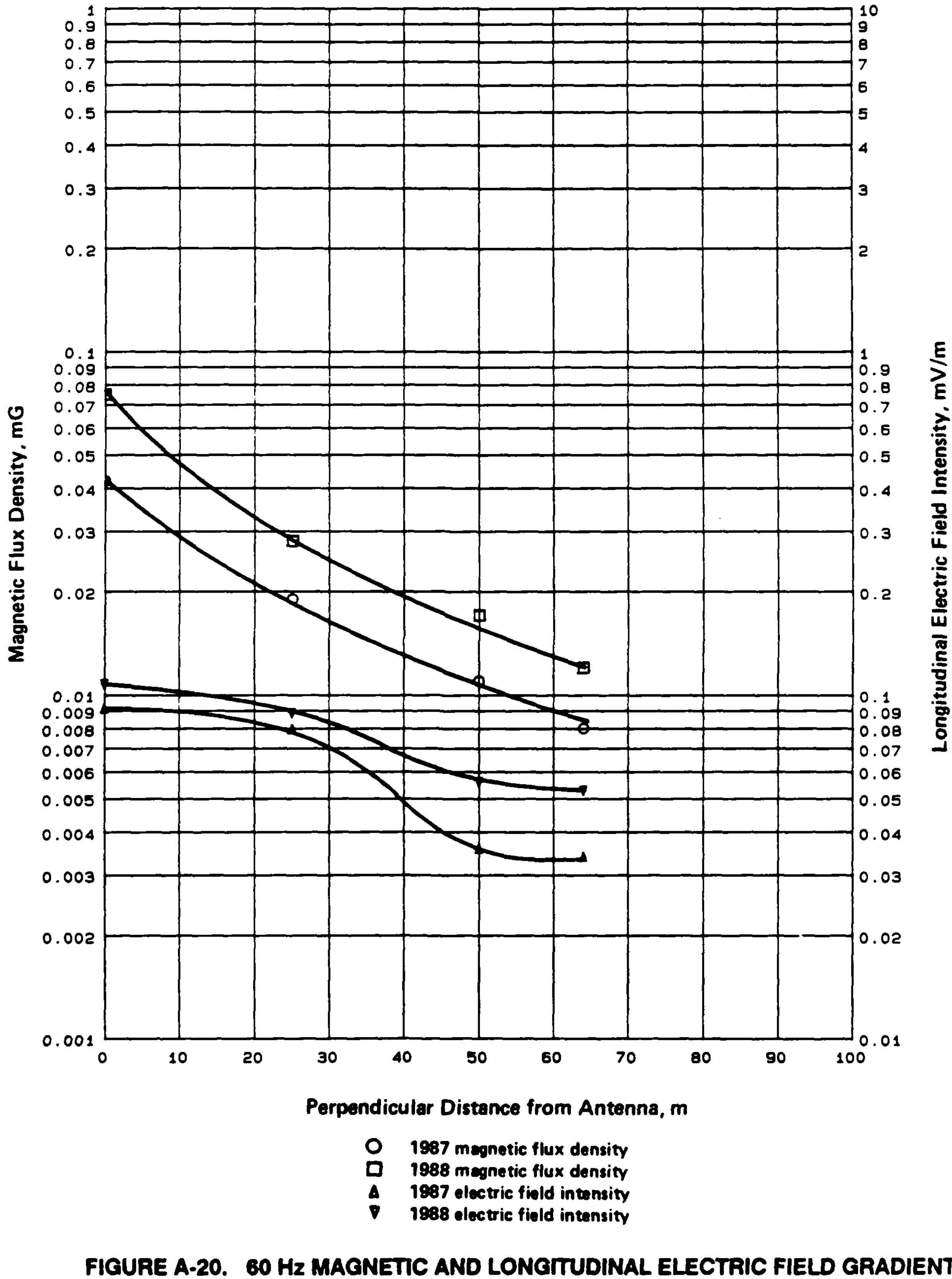


FIGURE A-20. 60 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD GRADIENTS, FORD RIVER NORTH; 1T5-2, 9, 10, 6.

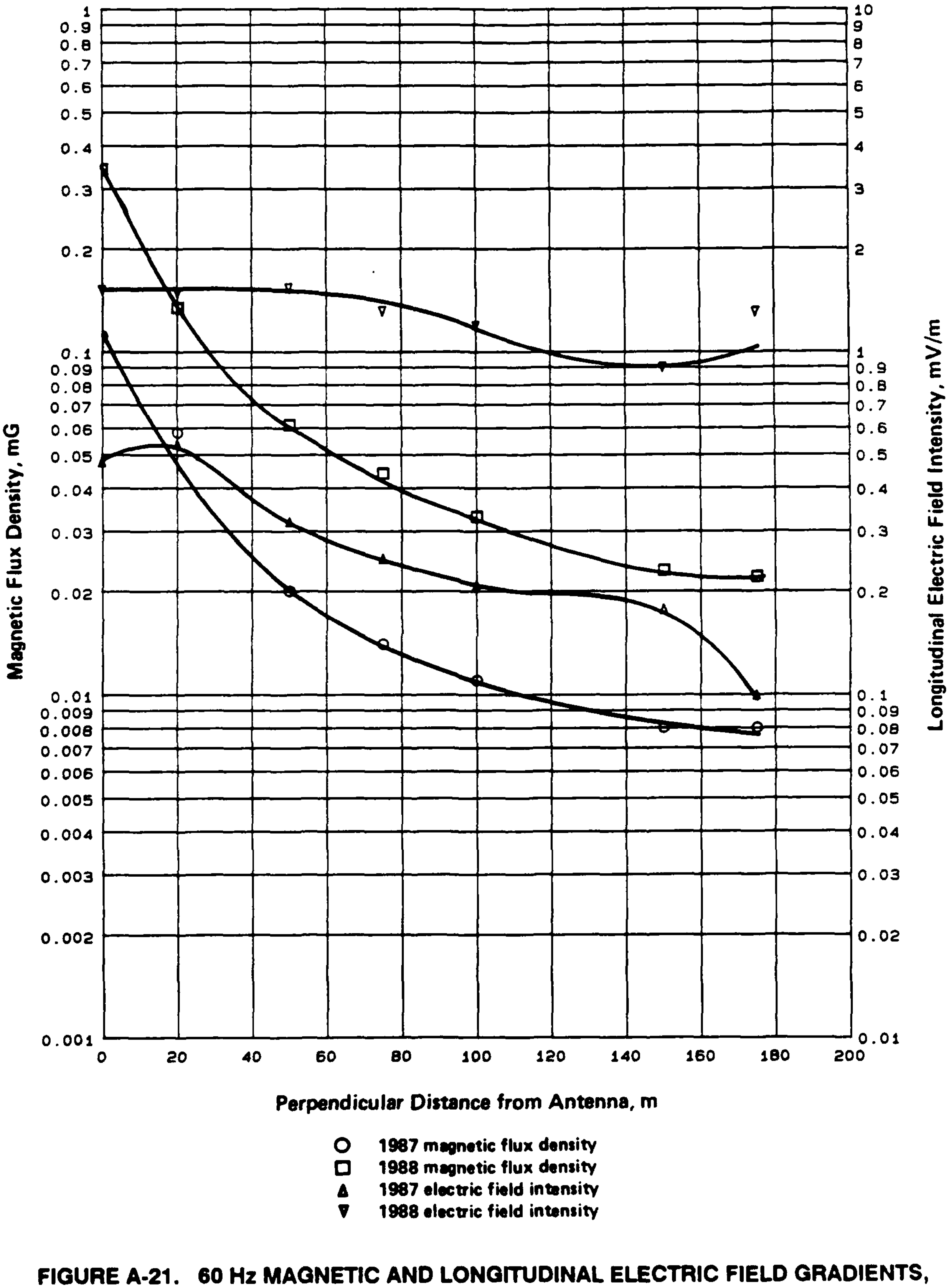
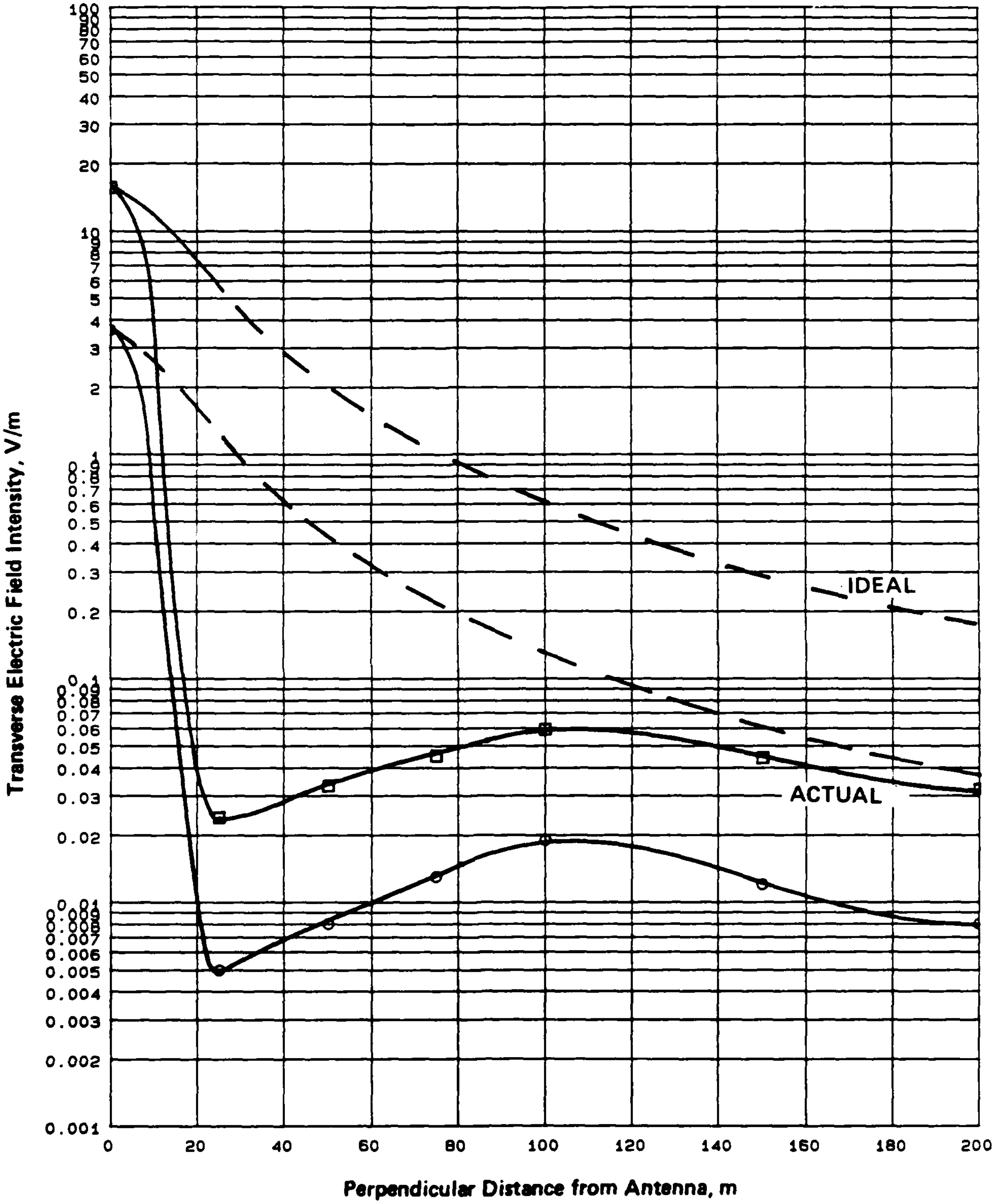


FIGURE A-21. 60 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD GRADIENTS, FORD RIVER SOUTH; 1T6-2, 1, 3, 4, 5, 6, 7.



O 1987 electric field intensity (15 A)

□ 1988 electric field intensity (75 A)

FIGURE A-22. 76 Hz TRANSVERSE ELECTRIC FIELD GRADIENTS, PIRLOT ROAD; 1T1-21 THROUGH 27.

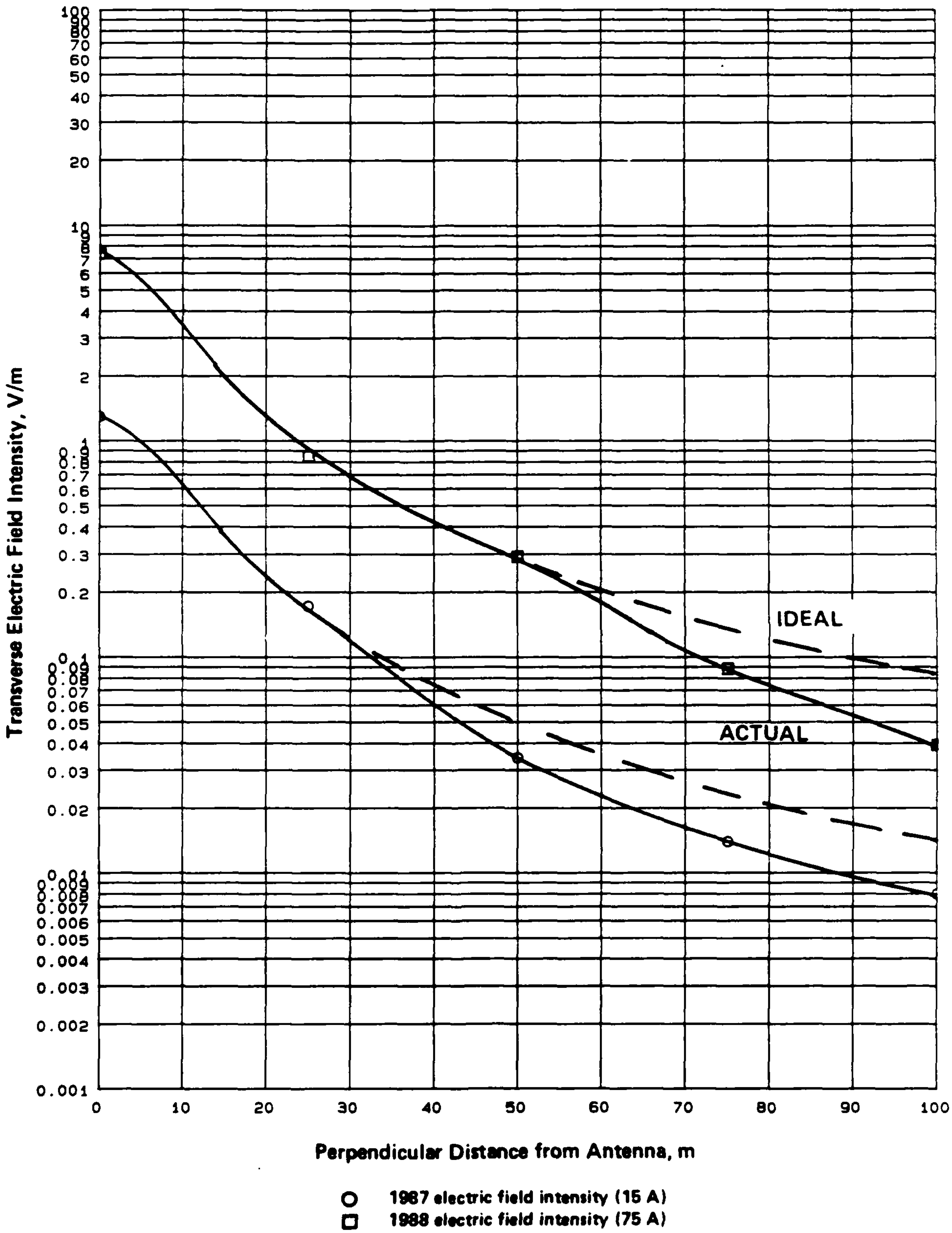


FIGURE A-23. 76 Hz TRANSVERSE ELECTRIC FIELD GRADIENTS, CLEVELAND HOMESTEAD; 1T2-5 THROUGH 9.

60297/189

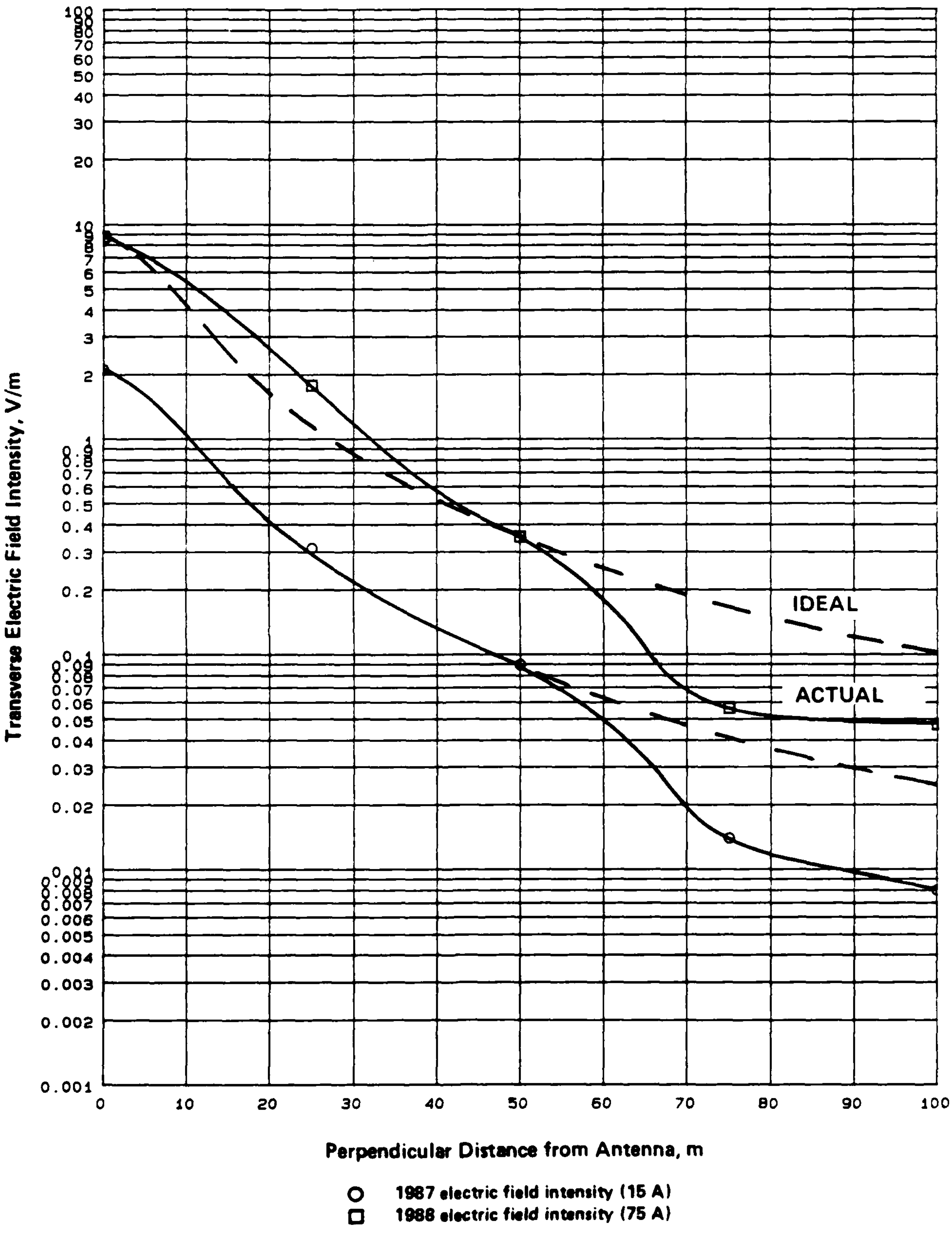
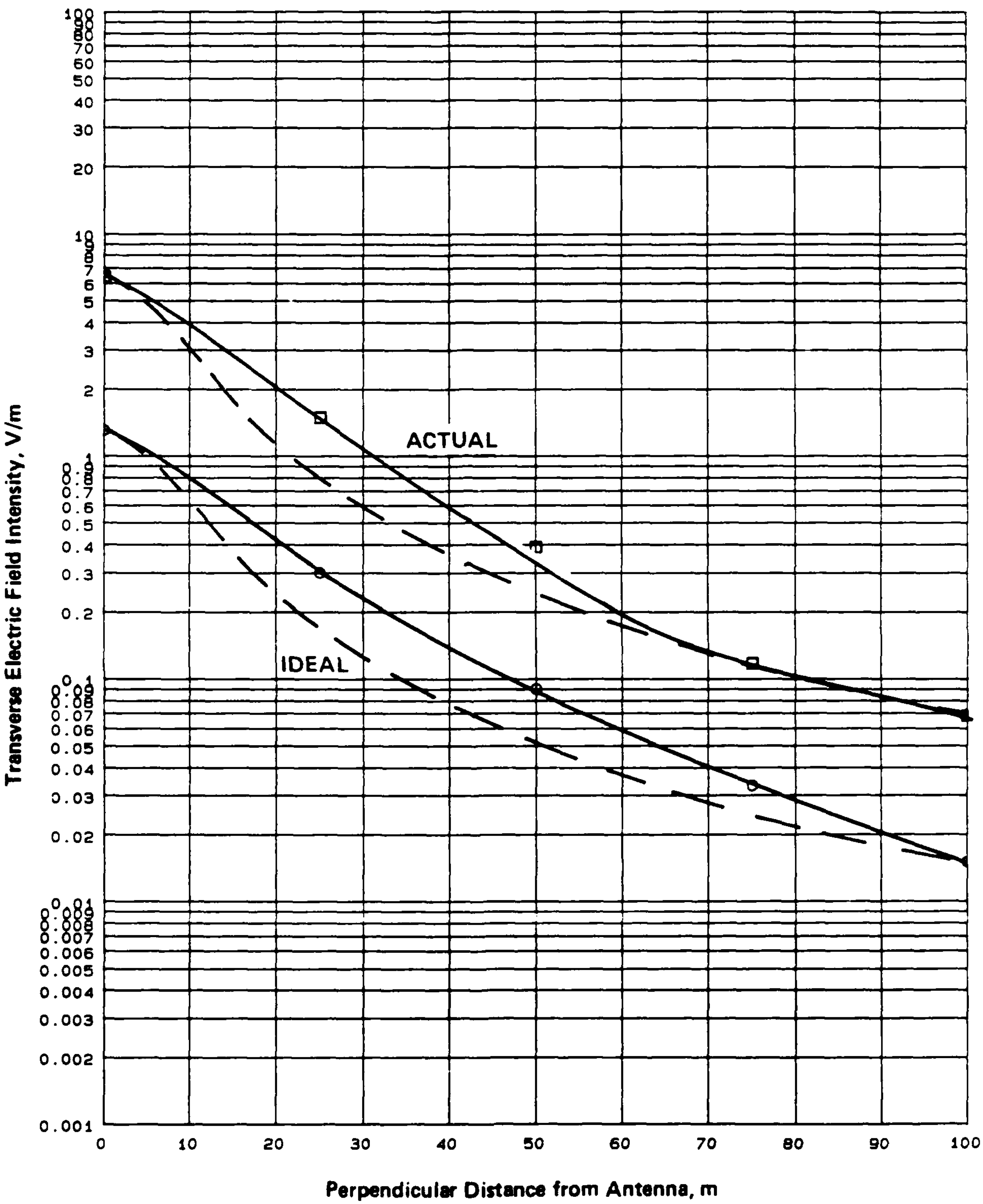


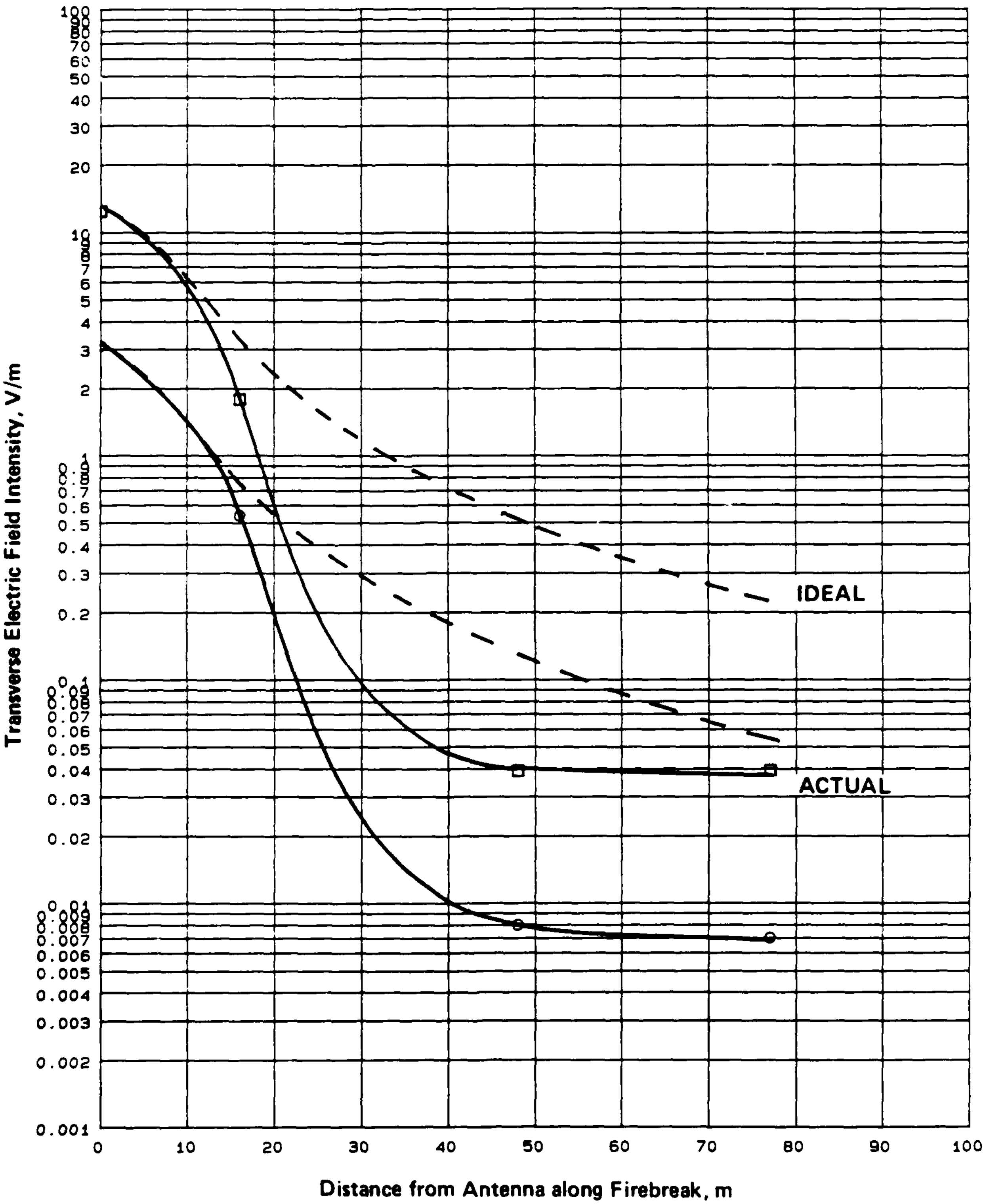
FIGURE A-24. 76 Hz TRANSVERSE ELECTRIC FIELD GRADIENTS, NORTH TURNER ROAD; 1T4-5 THROUGH 9.



O 1987 electric field intensity (15 A)
□ 1988 electric field intensity (75 A)

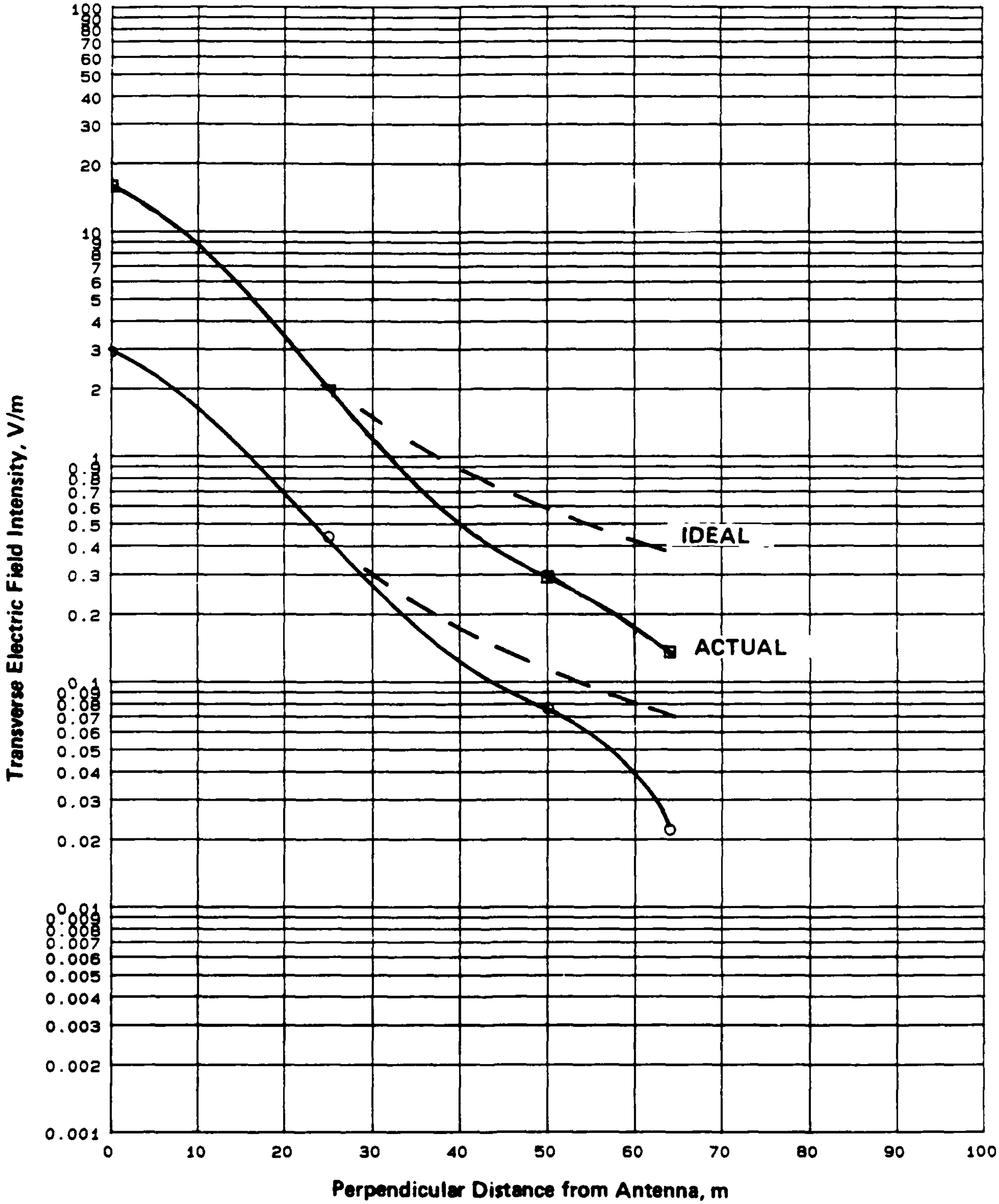
FIGURE A-25. 76 Hz TRANSVERSE ELECTRIC FIELD GRADIENTS, NORTH TURNER ROAD; 1T4-10 THROUGH 14.

60297/189



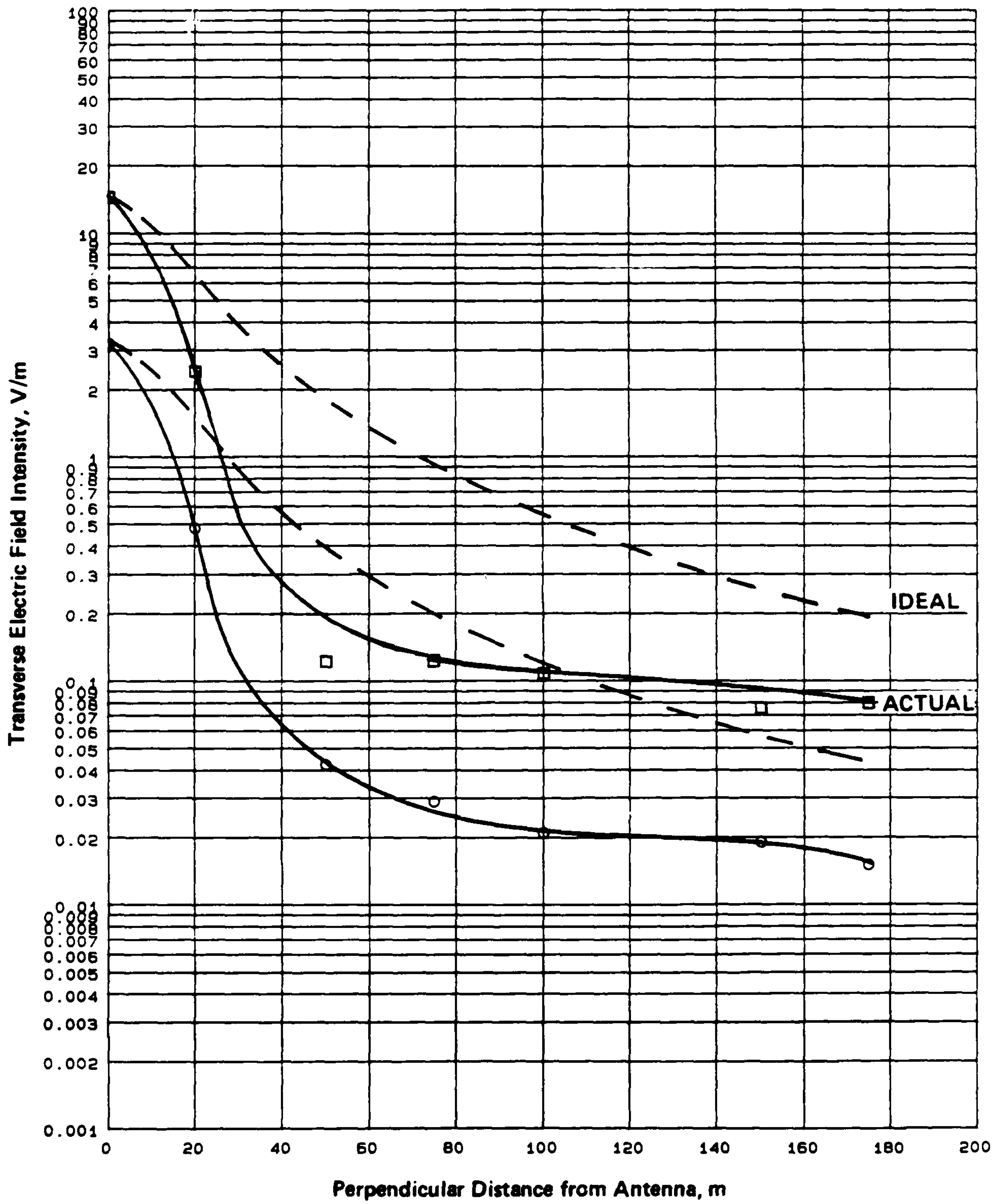
○ 1987 electric field intensity (15 A)
□ 1988 electric field intensity (75 A)

FIGURE A-26. 76 Hz TRANSVERSE ELECTRIC FIELD GRADIENTS, FORD RIVER NORTH; 1T5-1, 7, 8, 4.



○ 1987 electric field intensity (15 A)
□ 1988 electric field intensity (75 A)

FIGURE A-27. 76 Hz TRANSVERSE ELECTRIC FIELD GRADIENTS, FORD RIVER NORTH; 1T5, 2, 9, 10, 6.



○ 1987 electric field intensity (15 A)

□ 1988 electric field intensity (75 A)

FIGURE A-28. 76 Hz TRANSVERSE ELECTRIC FIELD GRADIENTS, FORD RIVER SOUTH; 1T6-2, 1, 3, 4, 5, 6, 7.

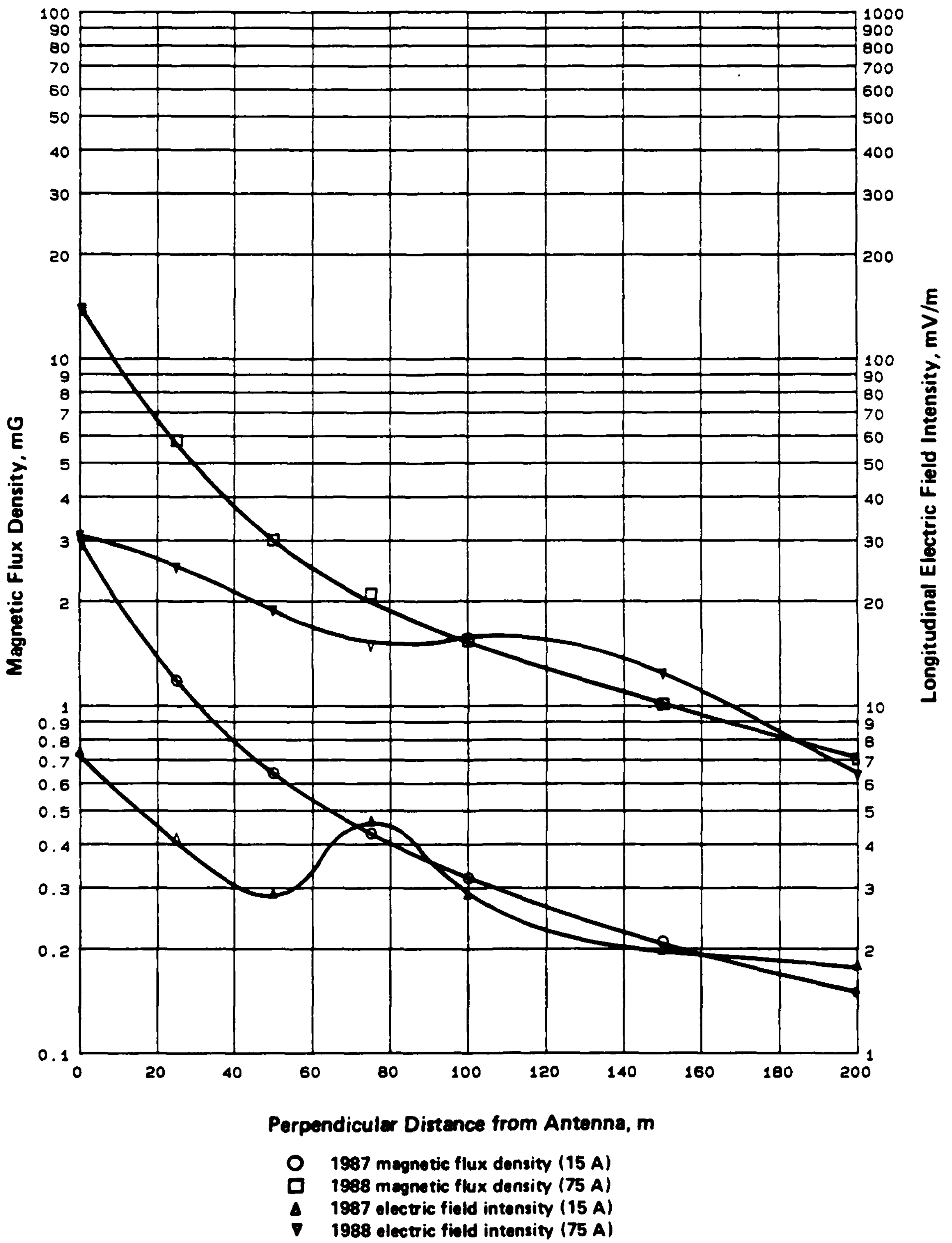


FIGURE A-29. 76 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD GRADIENTS, PIRLOT ROAD; 1T1-21 THROUGH 27.

60297/189

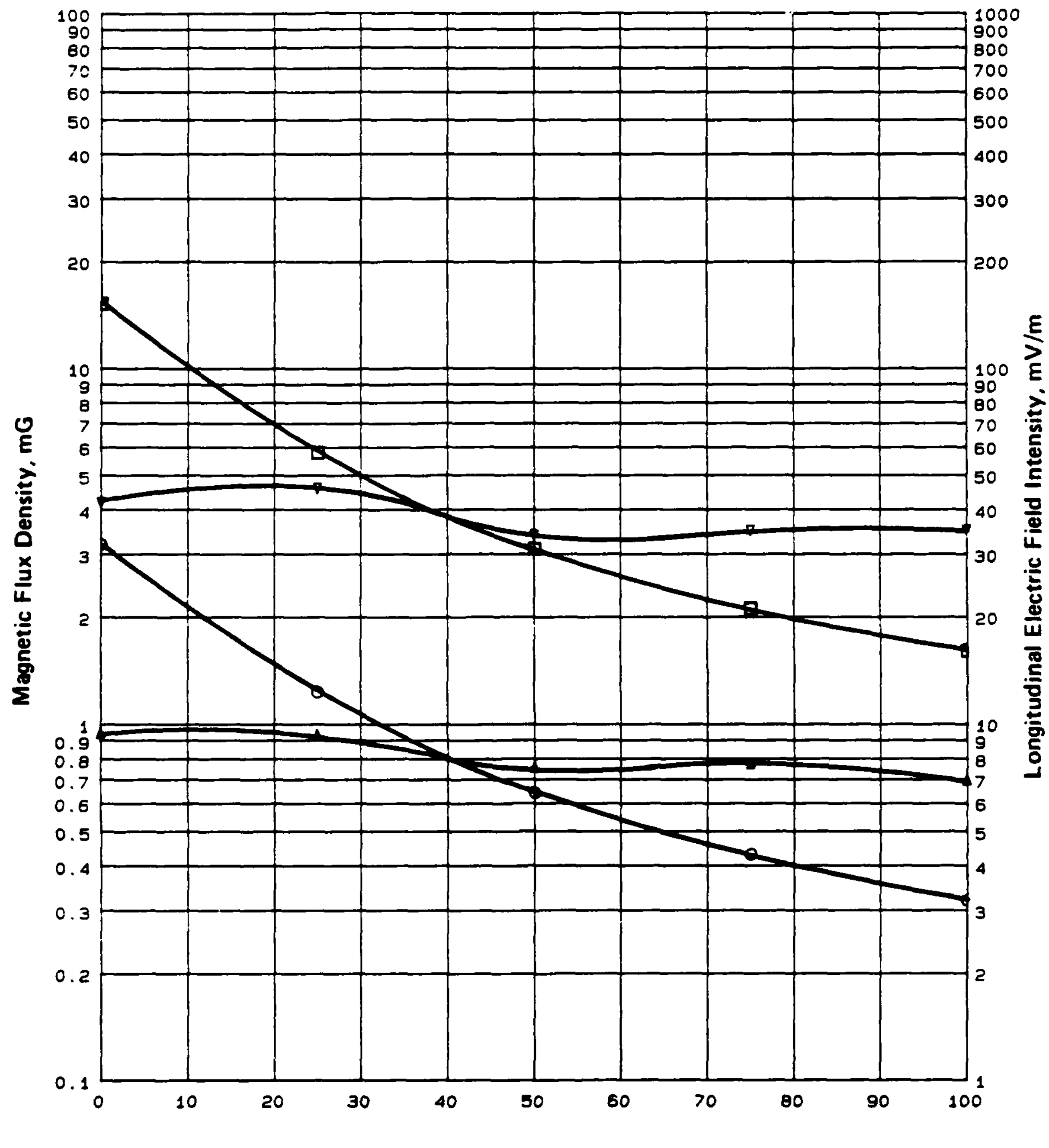


FIGURE A-30. 76 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD GRADIENTS, CLEVELAND HOMESTEAD; 1T2-5 THROUGH 9.

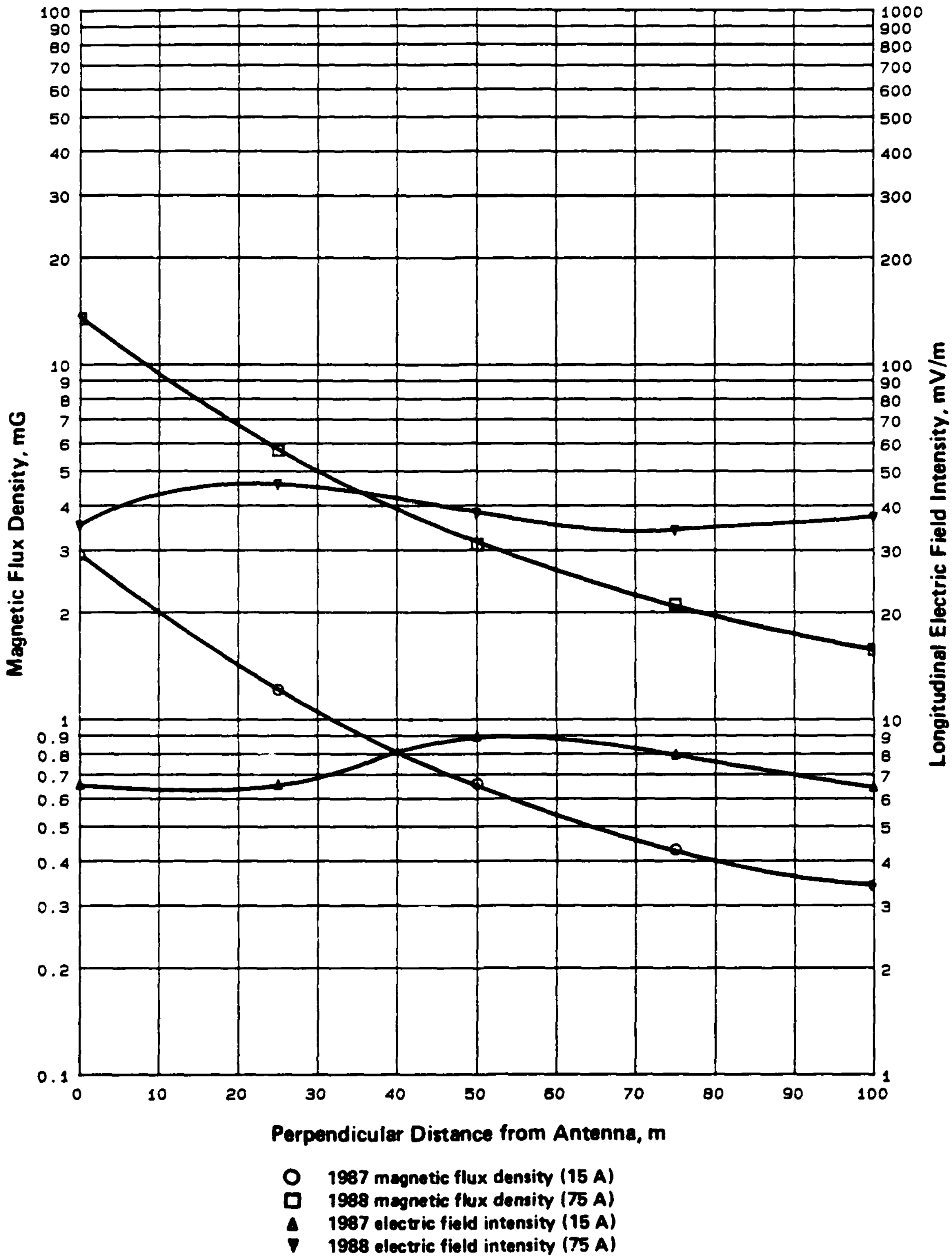


FIGURE A-31. 76 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD GRADIENTS, NORTH TURNER ROAD; 1T4-5 THROUGH 9.

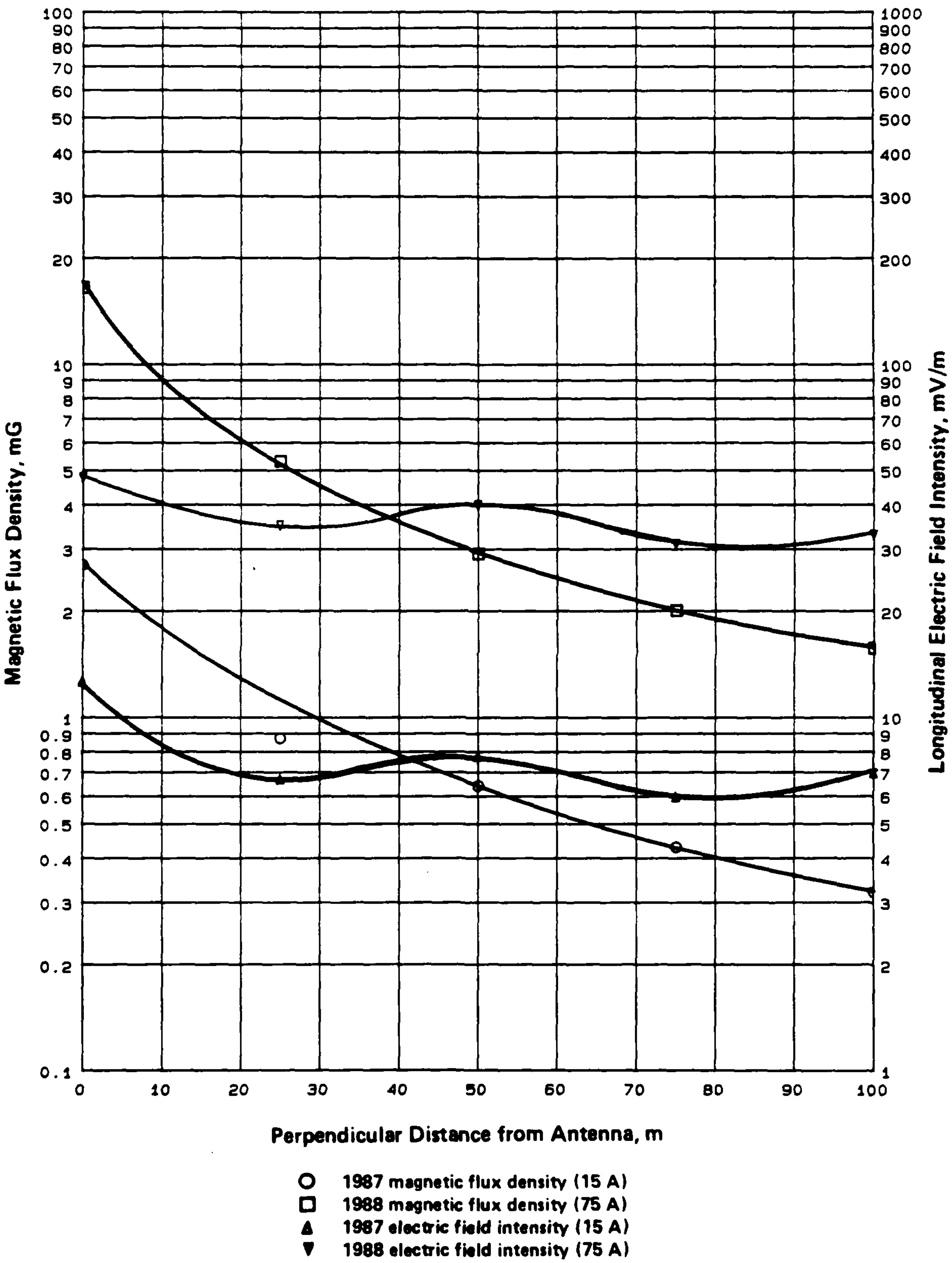


FIGURE A-32. 76 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD GRADIENTS, NORTH TURNER ROAD; 1T4-10 THROUGH 14.

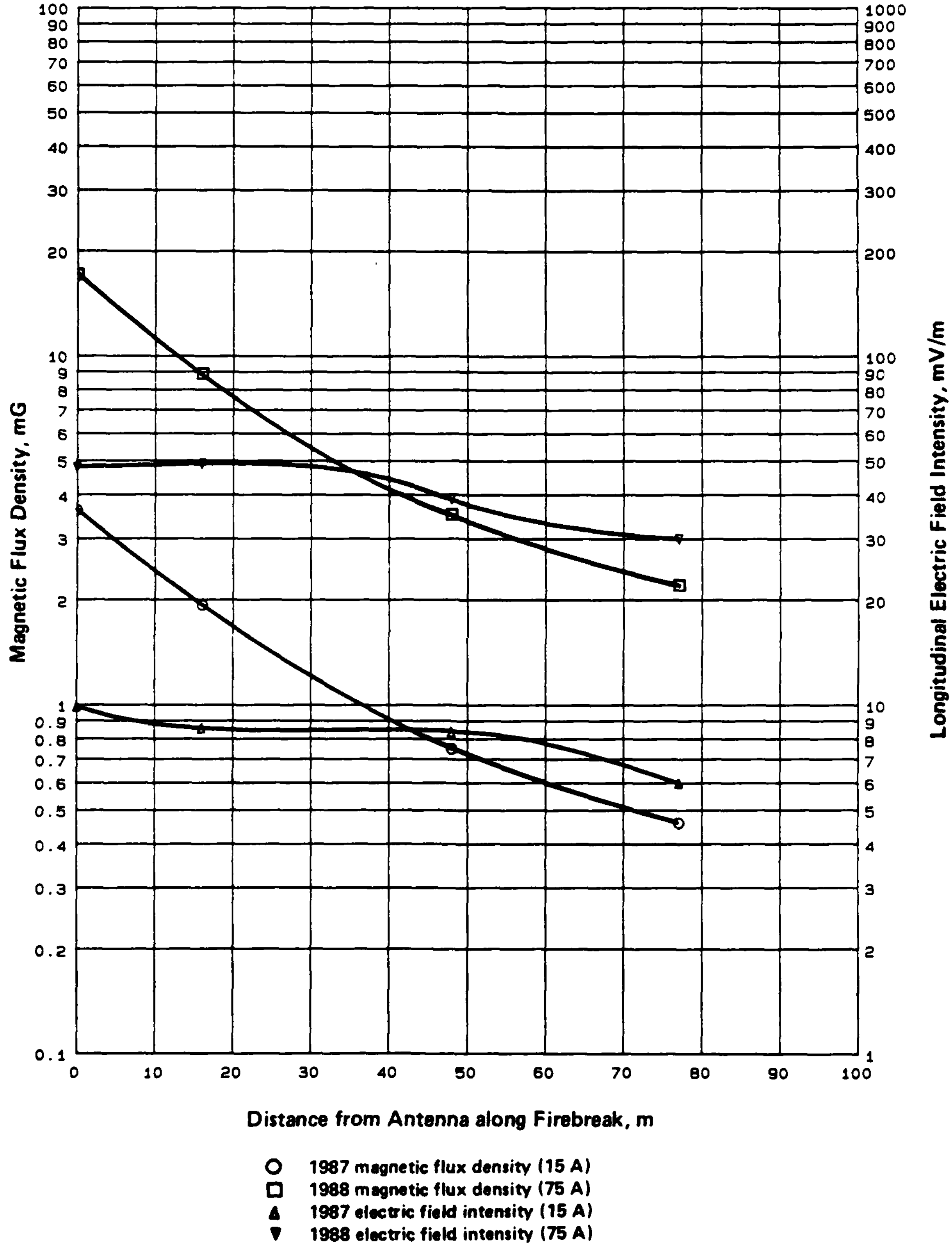


FIGURE A-33. 76 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD GRADIENTS, FORD RIVER NORTH; 1T5-1, 7, 8, 4.

60297/189

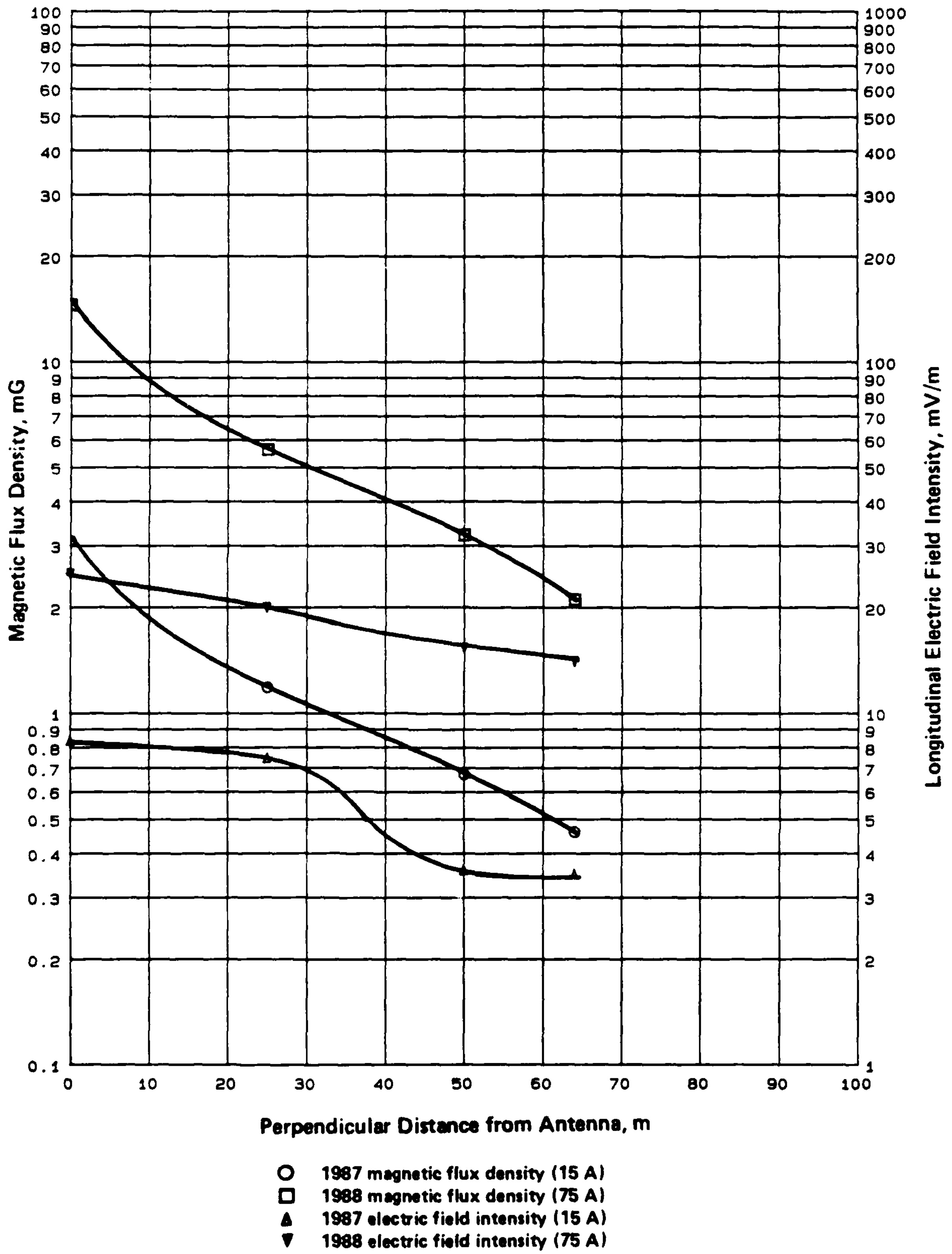


FIGURE A-34. 76 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD GRADIENTS, FORD RIVER NORTH; 1T5-2, 9, 10, 6.

60297/189

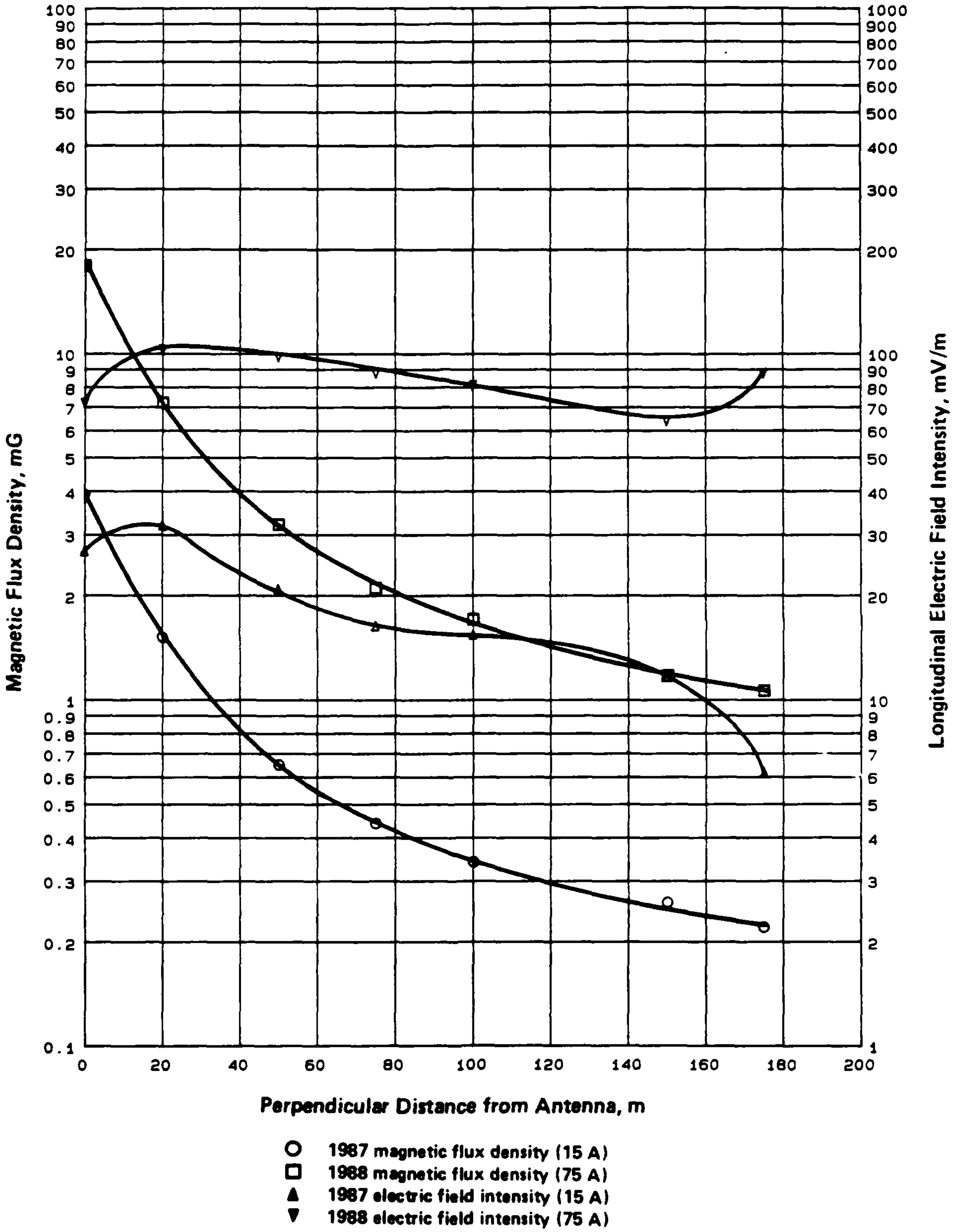


FIGURE A-35. 76 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD GRADIENTS, FORD RIVER SOUTH; 1T6-2, 1, 3, 4, 5, 6, 7.

60297/189

EM field measurements were made at the release points for the Cleveland Homestead, North Turner Road, and Panola Plains tree swallow homing transects. The EM field environment along the flight paths can be estimated using Figures A-36 and A-37 . The locations of the bird flight paths and the ELF antenna are shown relative to positions of high voltage 60 Hz transmission lines (Figure A-36) and 60 Hz power distribution lines (Figure A-37). The EM fields generated by the distribution lines are of magnitudes similar to those that will be generated by the ELF antenna when operating at the intended 150 ampere current level. The EM fields produced by the transmission lines can be considerably higher, depending on operating conditions. The transverse electric field generated by a transmission line may be as much as 100 times greater than that of the ELF antenna. The magnetic flux generated by a transmission line is dependent on the load current, and may be several times greater than that of the ELF antenna.

Study animals in the small mammals and nesting birds studies undergo laboratory examinations during the winter months. Prior to examination, the animals are kept in an outdoor holding facility. The original holding facility, located at the Crystal Falls laboratory, was determined to have relatively high 60 Hz EM field exposure, and a new holding facility was recommended. In December 1987, EM field measurements were made at two candidate holding facility locations (1L2-1 and 1L3-1) situated in the vicinity of the Panola Plains control site, about three miles south of Crystal Falls. These locations were found to be acceptable with respect to EM fields and content. A new holding facility (1L4-1) was erected near the candidate sites and was used during the 1987/1988 winter laboratory measurements. This site was measured for EM content in September 1988 and found to be acceptable. It will be used in future years.

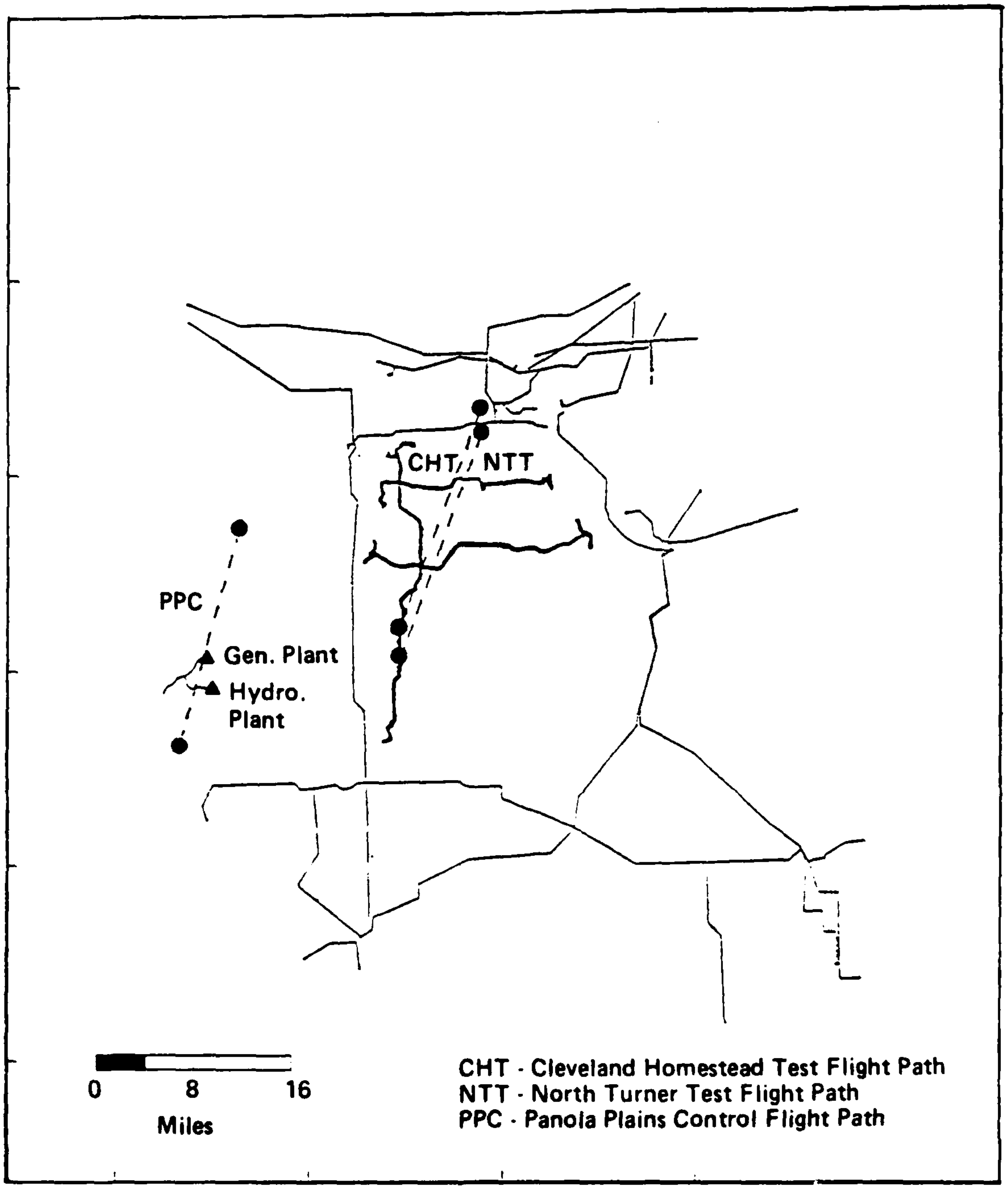


FIGURE A-36. BIRD DISPLACEMENT FLIGHT PATH LOCATIONS RELATIVE TO HIGH VOLTAGE 60 Hz TRANSMISSION LINES.

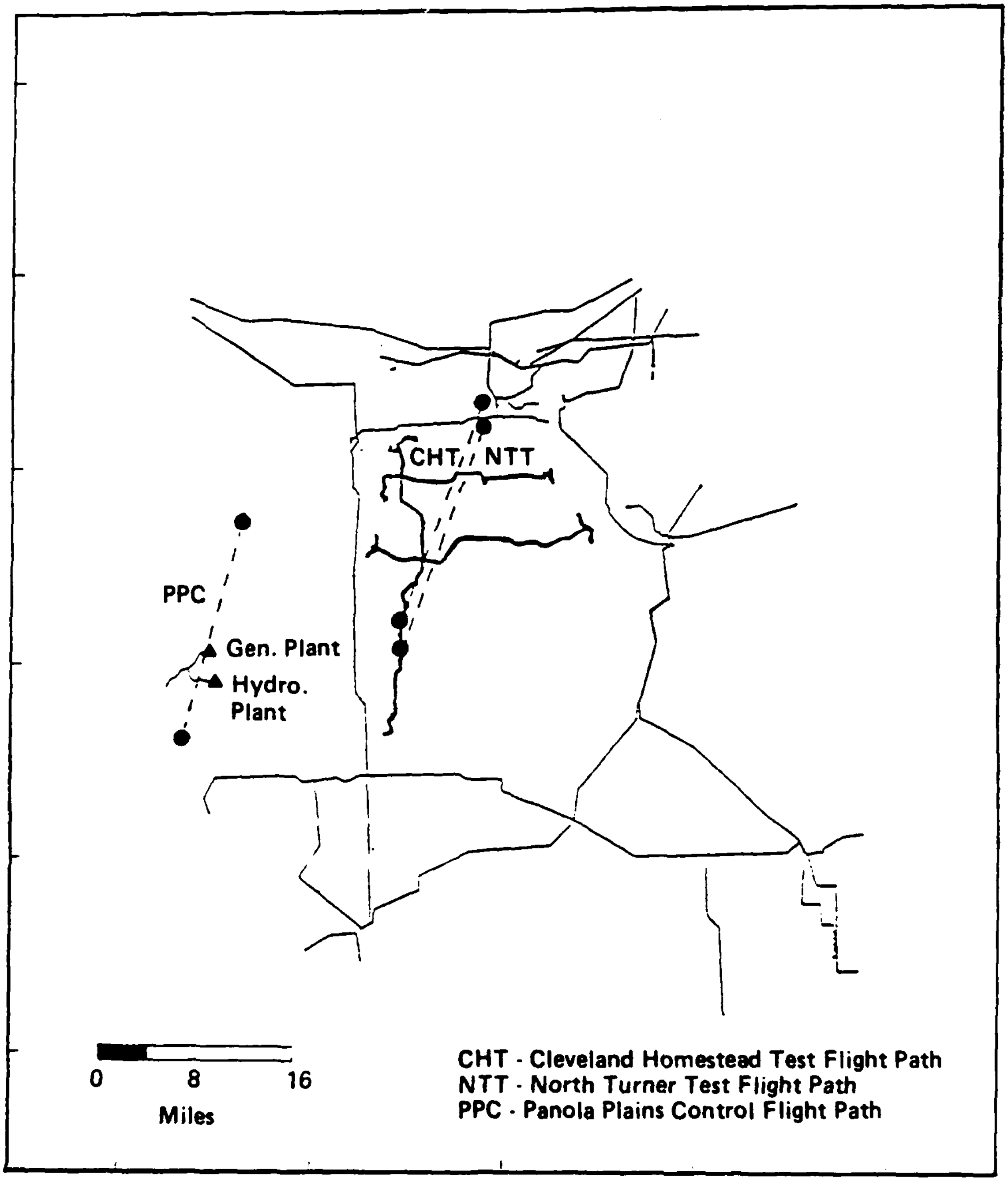


FIGURE A-37. BIRD DISPLACEMENT FLIGHT PATH LOCATIONS RELATIVE TO 60 Hz POWER DISTRIBUTION LINES.

APPENDIX B

NATIVE BEES STUDIES

NATIVE BEES STUDIES

On 19-22 and 28 September 1988, IITRI field crews made ELF electromagnetic (EM) field measurements at 18 measurement points at a total of two test and two control sites and at the Crystal Falls laboratory for the native bees studies. The test and control sites were the same as those measured in 1987. Three new measurement points (2L1-1, 2L1-2, 2L1-3) were added in 1988 to characterize the EM exposures at the Crystal Falls laboratory.

The positions of the five sites relative to the MTF are shown on the composite map in Figure B-1. The site numbers listed on the map are those used by IITRI. Table B-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are given in Figures B-2 through B-7.

TABLE B-1. SITE NO. CROSS-REFERENCE
Native Bees Studies

IITRI Site No.	Investigator's Site Name	Location				
		Township	:	Range	:	Section(s)
2T1	Ford 1 (F1)	T43N	:	R29W	:	14
2T2	Ford 2 (F2)	T43N	:	R29W	:	14
2C4	County Line Road (CL)	T43N	:	R30W	:	19
2C5	Camp 5 (C5)	T42N	:	R31W	:	13
2L1	Crystal Falls Laboratory	T43N	:	R32W	:	29

The native bees studies incorporate studies of both nesting and development traits. The electric and magnetic fields present in the air are considered the most important factors in the orientation and site tenacity of bees during their nesting cycle. The electric and magnetic fields in the earth near the surface may be of importance in developmental studies.

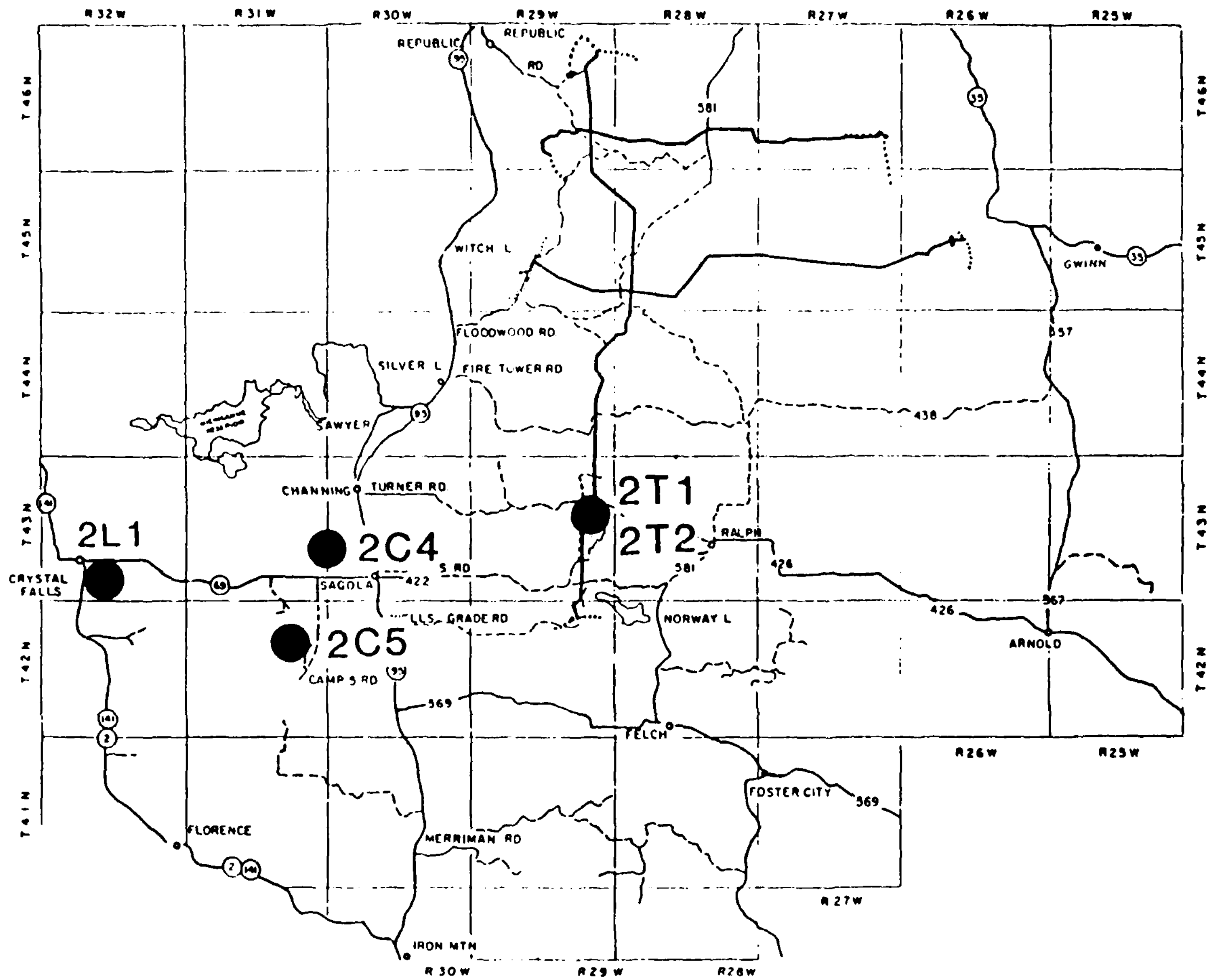


FIGURE B-1. POSITIONS OF NATIVE BEES STUDY SITES RELATIVE TO MICHIGAN TRANSMITTING FACILITY ANTENNA ELEMENTS.

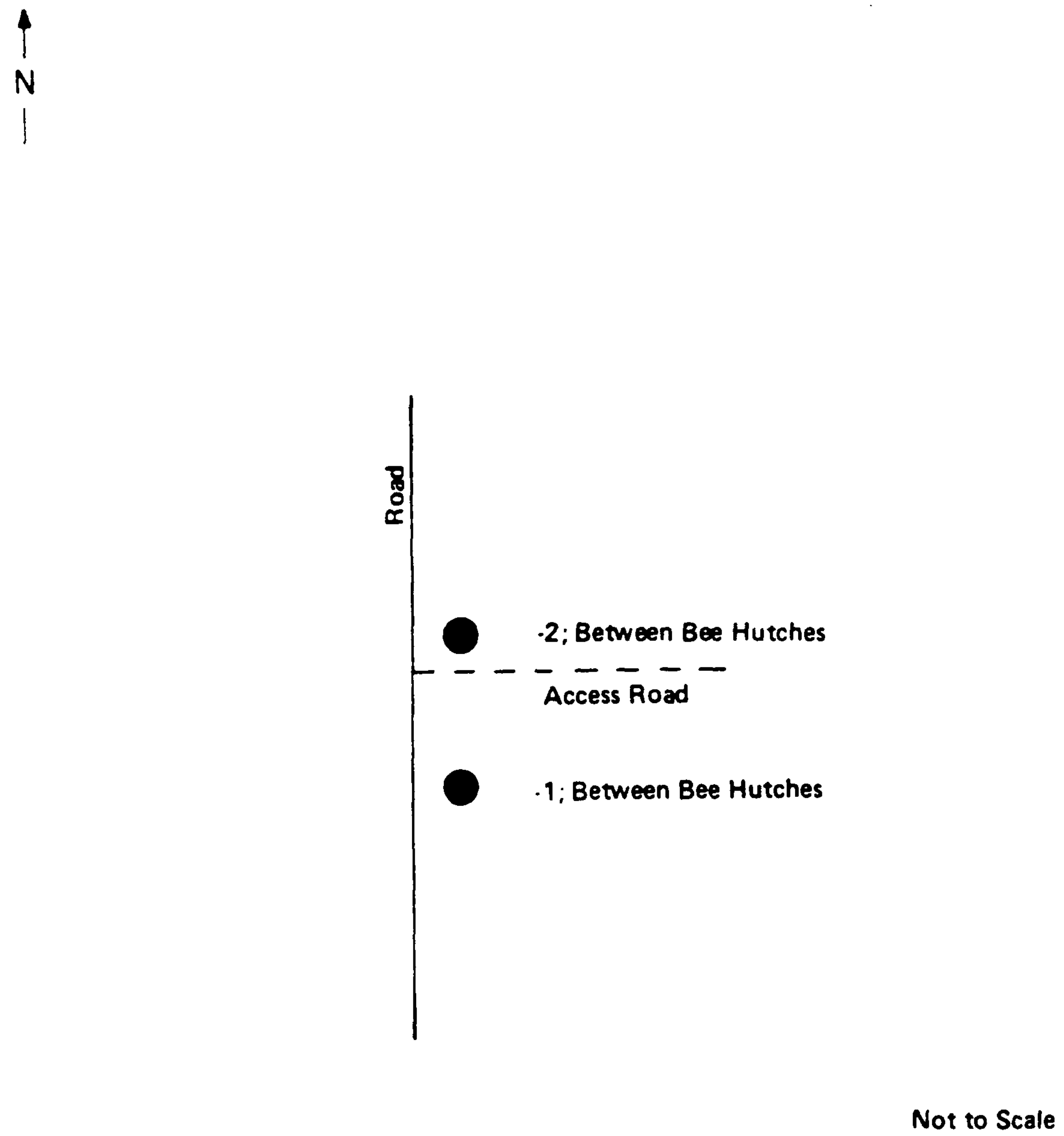


FIGURE B-2. MEASUREMENT POINTS AT COUNTY LINE ROAD (CL): 2C4-1, 2.

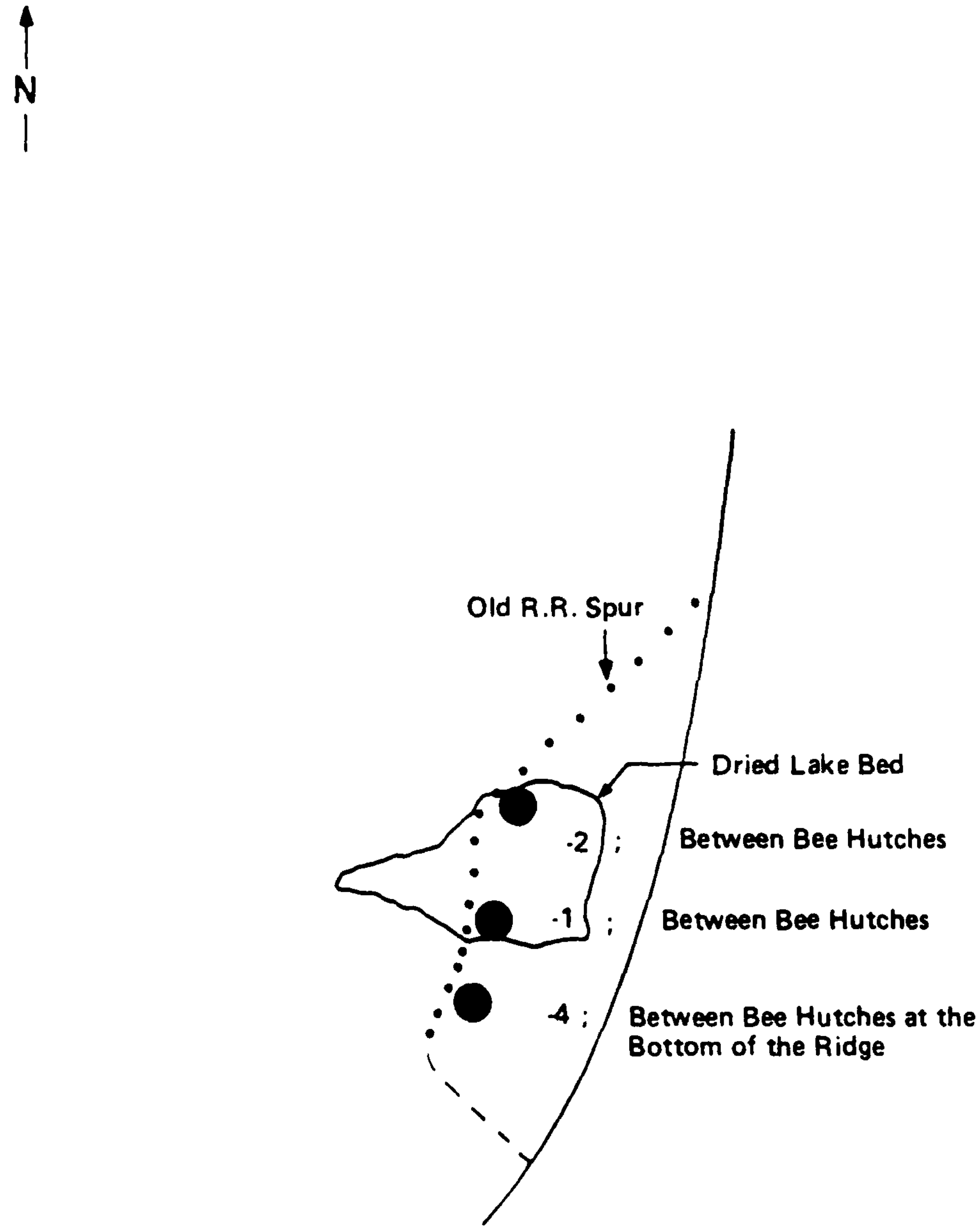


FIGURE B-3. MEASUREMENT POINTS AT CAMP 5 (C5); 2C5-1, 2, 4.

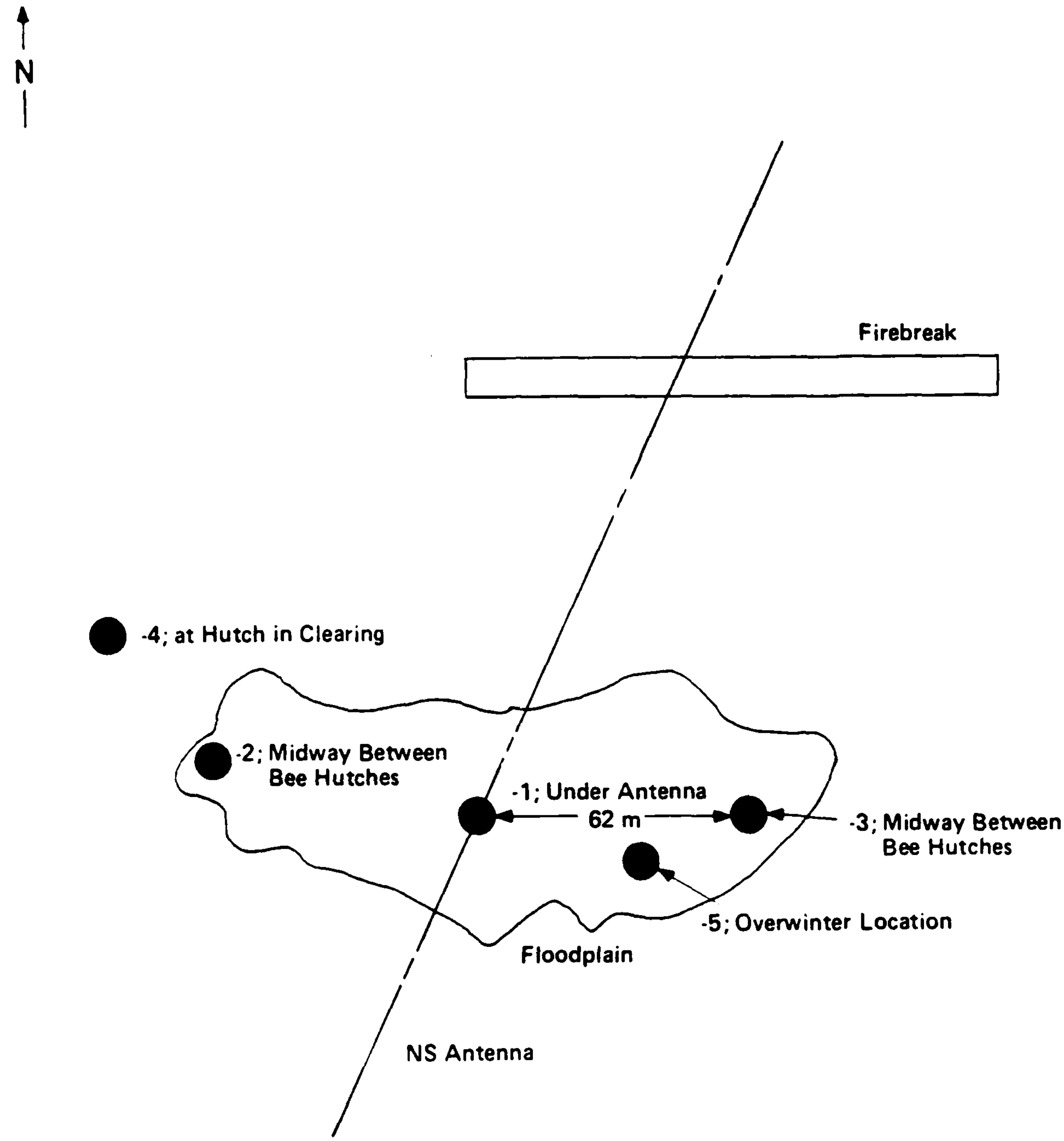


FIGURE B-4. MEASUREMENT POINTS AT FORD 1 (F1); 2T1-1, 2, 3, 4, 5.

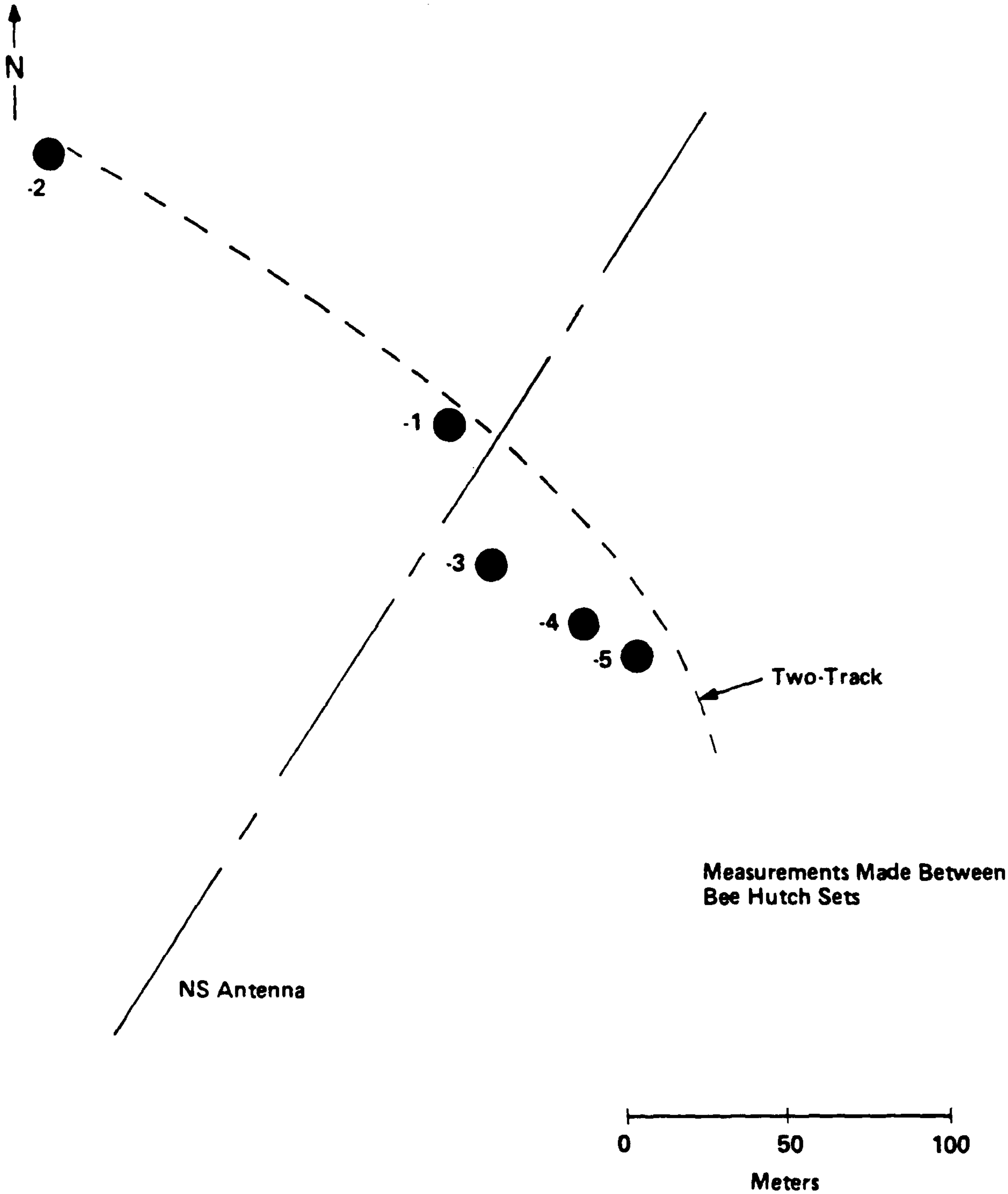


FIGURE B-5. MEASUREMENT POINTS AT FORD 2 (F2); 2T2-1 THROUGH 5.

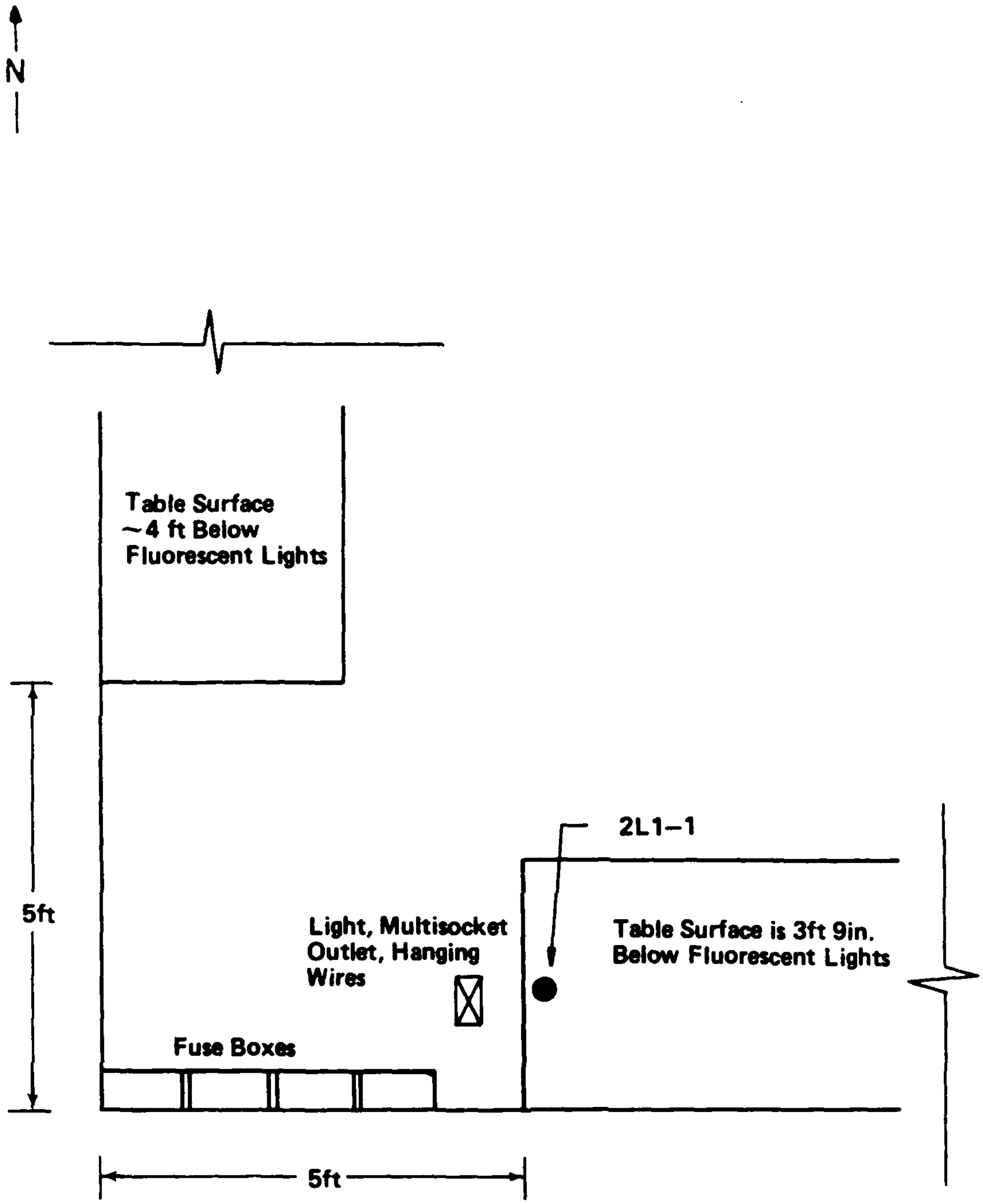


FIGURE B-6. MEASUREMENT POINT AT CRYSTAL FALLS LABORATORY BASEMENT; 2L1-1.

60297/189

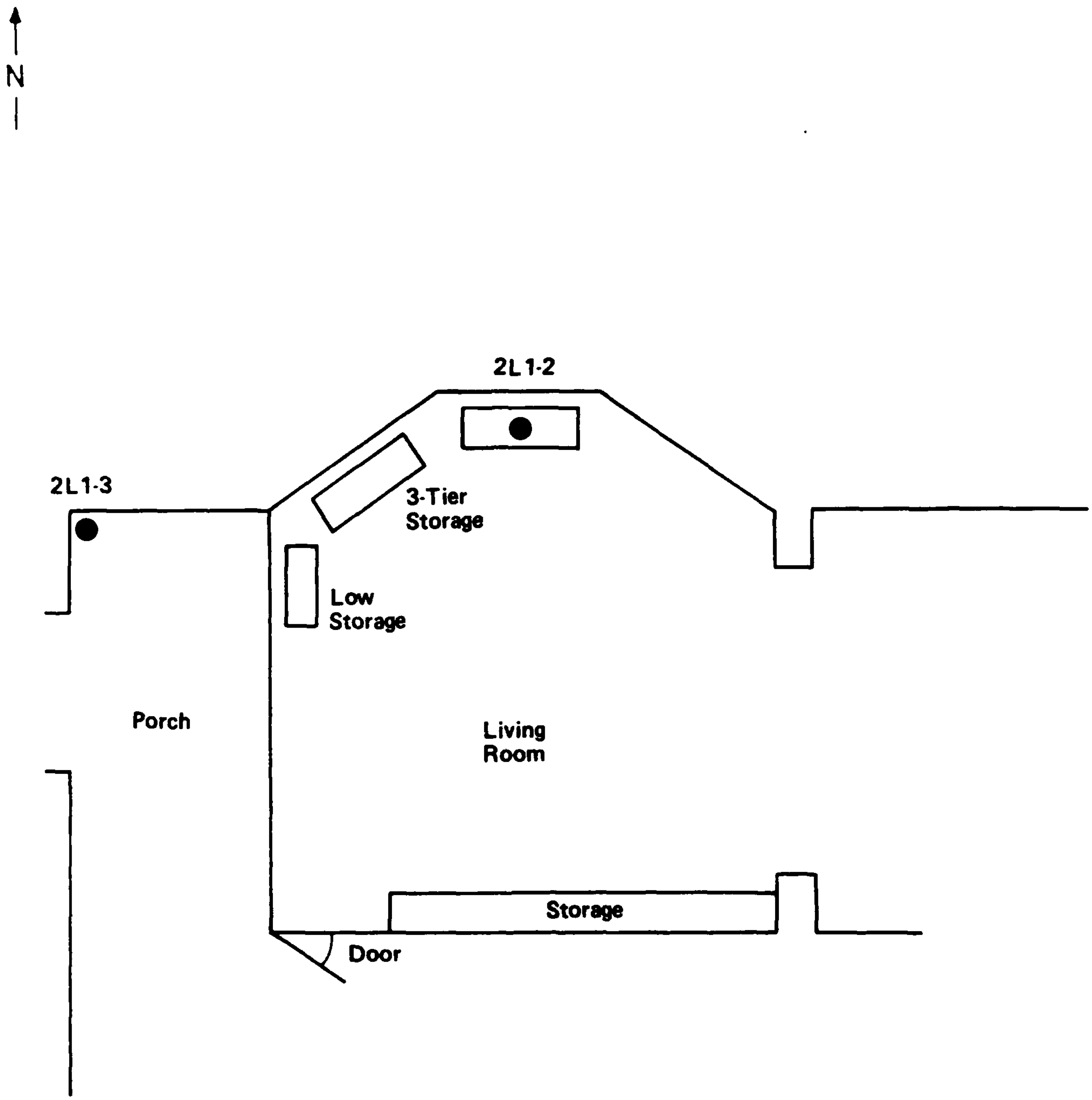


FIGURE B-7. MEASUREMENT POINTS AT CRYSTAL FALLS LABORATORY (LIVING ROOM, PORCH); 2L1-2, 3.

EM field measurements for 1988 and previous years are found in Tables B-2 through B-10. Tables B-2, B-3, and B-4 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables B-5, B-6, and B-7 present 76 Hz data for these three fields at 1986, 1987, and 1988 MTF operating currents. Tables B-8, B-9, and B-10 present 76 Hz data extrapolated to a full-power condition of 150 amperes.

The 1988 60 Hz measurements showed the same trends in EM field magnitudes as were reported in 1986 and 1987. That is, the 60 Hz magnetic flux densities increased and the longitudinal electric fields decreased near the antenna wire(s) in comparison to measurements made at these sites prior to antenna contruction. This is the result of 60 Hz currents from power lines coupled to the ELF antenna elements, which then reradiate 60 Hz EM fields. Because of this coupling, year-to-year variations in the 60 Hz EM field levels at the test sites are effected by and are generally consistent with expected fluctuations in regional power line load currents.

The EM fields generated by the 60 Hz currents on the antenna wires are localized near the antennas and do not affect the 60 Hz EM fields at the control sites or the laboratory. However, the 60 Hz EM field levels at these locations can be influenced directly by local power lines, and in the case of the laboratory, by building wiring and electrical equipment. The 60 Hz EM fields measured at the control sites in 1988 were consistent with measurements from previous years.

The 60 Hz EM fields measured at the Crystal Falls laboratory, while typical of ambient EM field levels in urban areas, were significantly higher (up to 1000 times higher) than the 60 Hz EM fields measured at any of the study sites. In several instances they were equal to or greater than the 76 Hz exposures at the test sites. These relatively high intensities could mask differences caused by exposures at test and control sites. Action will be taken in 1989 to minimize the 60 Hz EM field intensities and duration of exposure of the bees at the laboratory.

76 Hz measurements were made in 1988 with 75 ampere antenna currents, the predominant MTF operating mode from July through December. The EM field exposures at the study sites for the period prior to July can be estimated either by using 15 ampere antenna current measurement data from 1987 or more accurately by using one-fifth the value of the 1988 75 ampere data.

TABLE B-2. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Native Bees Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
2C4-1	<0.001	<0.001	~	~	~	~
2C4-2	-	-	~	~	~	~
2C5-1	-	<0.001	~	~	~	~
2C5-2	-	<0.001	~	~	~	~
2C5-4	-	-	~	~	~	~
2L1-1	-	-	-	-	-	79
2L1-2	-	-	-	-	-	22
2L1-3	-	-	-	-	-	0.25
2T1-1	0.004	<0.001	~	~	0.074	0.13
2T1-2	-	-	-	~	<0.001	0.001
2T1-3	-	-	-	~	<0.001	0.001
2T1-4	-	-	-	-	~	<0.001
2T1-5	-	-	-	-	/	0.006
2T2-1	<0.001	<0.001, 0.001	~	~	0.024	0.079
2T2-2	-	-	-	~	<0.001	<0.001
2T2-3	-	-	-	~	0.023	0.087
2T2-4	-	-	-	~	0.003	0.012
2T2-5	-	-	-	~	0.002	0.005

[a] = prior to antenna construction.
[b] = antenna elements grounded at transmitter (condition 2).
[c] = antenna elements connected to transmitter, transmitter off (condition 9).
\- = site measurement point not established.
~ = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.
/ = data not taken.

TABLE B-3. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Native Bees Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
2C4-1	0.011	0.102, 0.138, 0.160	0.104	0.133	0.178	0.134
2C4-2	-	-	0.21	0.21	0.26	0.23
2C5-1	-	0.64, 0.50, 0.93	0.69	0.49	0.38	0.23
2C5-2	-	0.23	0.40	0.160	0.23	0.099
2C5-4	-	-	0.148	0.090	0.098	0.078
2L1-1	-	-	-	-	-	/
2L1-2	-	-	-	-	-	/
2L1-3	-	-	-	-	-	/
2T1-1	0.23	0.26	0.22	0.042	0.092	0.108
2T1-2	-	-	-	0.051	0.034	0.053
2T1-3	-	-	-	0.077	0.051	0.059
2T1-4	-	-	-	-	0.040	0.152
2T1-5	-	-	-	-	0.050	0.151
2T2-1	0.071	0.65, 0.88	0.86, 0.88	0.23	0.54	1.49
2T2-2	-	-	-	0.092	0.100	1.31
2T2-3	-	-	-	0.123	0.25	0.84
2T2-4	-	-	-	0.078	0.186	0.67
2T2-5	-	-	-	0.120	0.23	1.11

[a] = prior to antenna construction.
[b] = antenna elements grounded at transmitter (condition 2).
[c] = antenna elements connected to transmitter, transmitter off (condition 9)
- = site measurement point not established.
/ = data not taken.

TABLE B-4. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Native Bees Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
2C4-1	0.004	0.003, 0.004	0.003	0.003	0.006	0.006
2C4-2	-	-	0.003	0.003	0.005	0.003
2C5-1	-	0.001, 0.002	0.002	0.001	0.002	0.001
2C5-2	-	<0.001	0.002	0.001	0.002	0.001
2C5-4	-	-	0.002	0.002	0.002	0.001
2L1-1	-	-	-	-	-	0.93
2L1-2	-	-	-	-	-	0.52
2L1-3	-	-	-	-	-	0.37
2T1-1	0.001	0.002	0.001	0.038	0.042	0.075
2T1-2	-	-	-	0.004	0.008	0.012
2T1-3	-	-	-	0.005	0.019	0.018
2T1-4	-	-	-	-	0.006	0.010
2T1-5	-	-	-	-	0.011	0.027
2T2-1	0.002	0.001	0.001	0.020	0.058	0.134
2T2-2	-	-	-	0.003	0.008	0.022
2T2-3	-	-	-	0.015	0.038	0.115
2T2-4	-	-	-	0.006	0.018	0.058
2T2-5	-	-	-	0.005	0.013	0.044

[a] = prior to antenna construction.
[b] = antenna elements grounded at transmitter (condition 2).
[c] = antenna elements grounded at transmitter, transmitter off (condition 9).
- = site measurement point not established.

TABLE B-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Native Bees Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)		1988 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M	NS(75) M	EW(75) M
2C4-1	~	~	~	~~	~	~	~	~
2C4-2	~	~	~	~~	~	~	~	~
2C5-1	~	~	~	~~	~	~	~	~
2C5-2	~	~	~	~~	~	~	~	~
2C5-4	~	~	~	~~	~	~	~	~
2L1-1	-	-	-	-	-	-	/	/
2L1-2	-	-	-	-	-	-	/	/
2L1-3	-	-	-	-	-	-	/	/
2T1-1	0.59	~	~	~~	2.9	0.003	15.8	0.056
2T1-2	0.009	~	~	~~	0.022	~	0.135	<0.001
2T1-3	0.005	~	~	~~	0.019	~	0.095	0.001
2T1-4	-	-	-	-	0.007	~	0.027	0.001
2T1-5	-	-	-	-	/	/	0.39	0.002
2T2-1	0.182	~	~	~~	0.48	<0.001	2.4	0.010
2T2-2	0.005	~	~	~~	0.015	<0.001	0.079	0.001
2T2-3	0.123	~	~	~~	0.42	<0.001	2.7	0.002
2T2-4	0.021	~	~	~~	0.061	<0.001	0.38	0.002
2T2-5	0.012	~	~	~~	0.039	<0.001	0.159	<0.001

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
- = site measurement point not established.
~ = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.
~~ = data cannot be extrapolated.
/ = data not taken.

TABLE B-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Native Bees Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)		1988 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M	NS(75) M	EW(75) M
2C4-1	/	/	/	/	0.006	0.003	0.027	0.017
2C4-2	0.002	0.001	0.001	0.002	0.006	0.004	0.030	0.022
2C5-1	0.008	0.004	0.006	0.010	0.022	0.018	0.112	0.110
2C5-2	/	/	/	/	0.008	0.008	0.041	0.042
2C5-4	/	/	/	/	0.001	0.005	0.020	0.027
2L1-1	-	-	-	-	-	-	/	/
2L1-2	-	-	-	-	-	-	/	/
2L1-3	-	-	-	-	-	-	/	/
2T1-1	1.97	0.064	0.108	0.180	8.2	0.23	24	0.77
2T1-2	1.08	0.037	0.070	0.117	3.3	0.21	13.1	0.98
2T1-3	1.31	0.051	0.101	0.168	5.2	0.33	23	1.40
2T1-4	-	-	-	-	4.5	0.191	30	1.38
2T1-5	-	-	-	-	/	/	22	0.96
2T2-1	5.4	0.159	0.086	0.143	32	0.25	102	1.03
2T2-2	1.63	0.054	0.067	0.112	6.0	0.178	87	1.41
2T2-3	3.0	0.087	0.063	0.105	13.5	0.21	56	0.76
2T2-4	1.93	0.053	0.071	0.118	10.4	0.25	43	1.04
2T2-5	3.6	0.101	0.096	0.160	14.0	0.24	75	1.05

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
- = site measurement point not established.
/ = data not taken.

TABLE B-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Native Bees Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)		1988 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M	NS(75) M	EW(75) M
2C4-1	/	/	/	/	0.001	<0.001	0.002	0.001
2C4-2	<0.001	<0.001	<0.001	--	0.001	<0.001	0.003	0.001
2C5-1	<0.001	<0.001	<0.001	--	<0.001	<0.001	0.001	0.001
2C5-2	/	/	/	/	<0.001	<0.001	0.001	0.001
2C5-4	/	/	/	/	<0.001	<0.001	0.001	0.001
2L1-1	-	-	-	-	-	-	/	/
2L1-2	-	-	-	-	-	-	/	/
2L1-3	-	-	-	-	-	-	/	/
2T1-1	0.77	0.024	0.004	0.007	3.1	0.004	14.1	0.052
2T1-2	0.125	0.004	<0.001	--	0.46	0.002	2.1	0.007
2T1-3	0.131	0.004	0.001	0.002	0.53	0.001	2.5	0.014
2T1-4	-	-	-	-	0.33	0.002	1.47	0.006
2T1-5	-	-	-	-	/	/	3.2	0.016
2T2-1	0.40	0.013	0.002	0.003	1.51	0.004	7.2	0.021
2T2-2	0.06	0.002	<0.001	--	0.22	0.002	1.05	0.005
2T2-3	0.35	0.011	0.002	0.003	1.33	0.002	6.2	0.026
2T2-4	0.158	0.005	0.001	0.002	0.58	0.001	2.9	0.015
2T2-5	0.124	0.004	0.001	0.002	0.46	0.001	2.2	0.013

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
\- = site measurement point not established.
-- = data cannot be extrapolated.
/ = data not taken.

TABLE B-8. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Native Bees Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations		1988 Extrapolations	
	NS	NEW	SEW	NS	EW	NS	EW
2C4-1	--	--	--	--	--	--	--
2C4-2	--	--	--	--	--	--	--
2C5-1	--	--	--	--	--	--	--
2C5-2	--	--	--	--	--	--	--
2C5-4	--	--	--	--	--	--	--
2L1-1	-	-	-	-	-	/	/
2L1-2	-	-	-	-	-	/	/
2L1-2	-	-	-	-	-	/	/
2T1-1	22	--	--	29	0.030	32	0.112
2T1-2	0.34	--	--	0.22	--	0.27	--
2T1-3	0.188	--	--	0.190	--	0.190	0.002
2T1-4	-	-	-	0.070	--	0.054	0.002
2T1-5	-	-	-	/	/	0.78	0.004
2T2-1	6.8	--	--	4.8	--	4.8	0.020
2T2-2	0.188	--	--	0.150	--	0.158	0.002
2T2-3	4.6	--	--	4.2	--	5.4	0.004
2T2-4	0.79	--	--	0.61	--	0.76	0.004
2T2-5	0.45	--	--	0.39	--	0.32	--

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
- = site measurement point not established.
-- = data cannot be extrapolated.
/ = data not taken.

TABLE B-9. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Native Bees Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations		1988 Extrapolations	
	NS	NEW	SEW	NS	EW	NS	EW
2C4-1	/	/	/	0.060	0.030	0.054	0.034
2C4-2	0.075	0.025	0.025	0.060	0.040	0.060	0.044
2C5-1	0.30	0.100	0.150	0.22	0.180	0.22	0.22
2C5-2	/	/	/	0.080	0.080	0.082	0.084
2C5-4	/	/	/	0.010	0.050	0.040	0.054
2L1-1	-	-	-	-	-	/	/
2L1-2	-	-	-	-	-	/	/
2L1-3	-	-	-	-	-	/	/
2T1-1	74.	1.60	2.7	82.	2.3	48	1.54
2T1-2	41.	0.93	1.75	33.	2.1	26	1.96
2T1-3	49.	1.28	2.5	52.	3.3	46	2.8
2T1-4	-	-	-	45.	1.91	60	2.8
2T1-5	-	-	-	/	/	44	1.92
2T2-1	200.	4.0	2.2	320.	2.5	200	2.1
2T2-2	61.	1.35	1.68	60.	1.78	174	2.8
2T2-3	113.	2.2	1.58	135.	2.1	112	1.52
2T2-4	72.	1.33	1.78	104.	2.5	86	2.1
2T2-5	135.	2.5	2.4	140.	2.4	150	2.1

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
\- = site measurement point not established.
-- = data cannot be extrapolated.
/ = data not taken.

TABLE B-10. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Native Bees Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations		1988 Extrapolations	
	NS	NEW	SEW	NS	EW	NS	EW
2C4-1	/	/	/	0.010	--	0.004	0.002
2C4-2	--	--	--	0.010	--	0.006	0.002
2C5-1	--	--	--	--	--	0.002	0.002
2C5-2	/	/	/	--	--	0.002	0.002
2C5-4	/	/	/	--	--	0.002	0.002
2L1-1	-	-	-	-	-	/	/
2L1-2	-	-	-	-	-	/	/
2L1-3	-	-	-	-	-	/	/
2T1-1	29	0.60	0.100	31	0.040	29	0.104
2T1-2	4.7	0.100	--	4.6	0.020	4.2	0.014
2T1-3	4.9	0.100	0.025	5.3	0.010	5.0	0.028
2T1-4	-	-	-	3.3	0.020	2.9	0.012
2T1-5	-	-	-	/	/	6.4	0.032
2T2-1	15.0	0.33	0.050	15.1	0.040	14.4	0.042
2T2-2	2.3	0.050	--	2.2	0.020	2.1	0.010
2T2-3	13.1	0.28	0.050	13.3	0.020	12.4	0.052
2T2-4	5.9	0.125	0.025	5.8	0.010	5.8	0.030
2T2-5	4.7	0.100	0.025	4.6	0.010	4.4	0.026

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
\- = site measurement point not established.
-- = data cannot be extrapolated.
/ = data not taken.

The measured EM field magnitudes for each antenna element for 1986-1988 have been linearly extrapolated to the planned operational antenna current of 150 amperes. Extrapolations were not performed when the measurements indicated that the EM field magnitudes were below the minimum sensitivity of the EM field sensors.

The 1988 extrapolations are the most accurate predictions of the EM field levels at the planned operational antenna current because the 1988 half-power EM field measurements are more accurate than those made at lower antenna currents in previous years. The 1988 extrapolations also reflect the operational configuration and tuning of the antenna elements with the new power amplifiers.

The maximum 76 Hz EM field intensities that can occur during simultaneous operation of both antenna elements at any antenna phasing can be estimated by calculating the algebraic sum of the levels from the individual antenna element extrapolations; minimum intensities can be estimated by calculating the algebraic difference.

APPENDIX C

SOIL ARTHROPODS AND EARTHWORMS STUDIES

SOIL ARTHROPODS AND EARTHWORMS STUDIES

On 26 September and 3 October 1988, IITRI field crews made ELF electromagnetic (EM) field measurements at a total of eight measurement points at one test and one control site for the soil arthropods and earthworms studies. The study sites and the measurement points within those sites were unchanged from 1987.

The positions of the two sites relative to the MTF are shown on the composite map in Figure C-1. The site numbers listed on the map are those used by IITRI. Table C-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are shown in Figures C-2 and C-3.

The soil arthropods and earthworms studies monitor species composition, population age structure, and distribution. The electric and magnetic fields in the earth are considered the most important EM factors influencing soil biota. The electric field in the air is not expected to have a significant impact on the objectives of these studies.

EM field measurements for 1988 and previous years are found in Tables C-2 through C-10. Tables C-2, C-3, and C-4 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables C-5, C-6, and C-7 present 76 Hz data for these fields at 1986, 1987, and 1988 MTF operating currents. Tables C-8, C-9, and C-10 present 76 Hz data extrapolated to a full-power condition of 150 amperes.

TABLE C-1. SITE NO. CROSS-REFERENCE
Soil Arthropods and Earthworms Studies

IITRI Site No.	Investigator's Site Name	Location		
		Township	Range	Section(s)
3T2	South Silver Lake	T44N	R29W	25
3C5	Turner Road	T43N	R30W	11

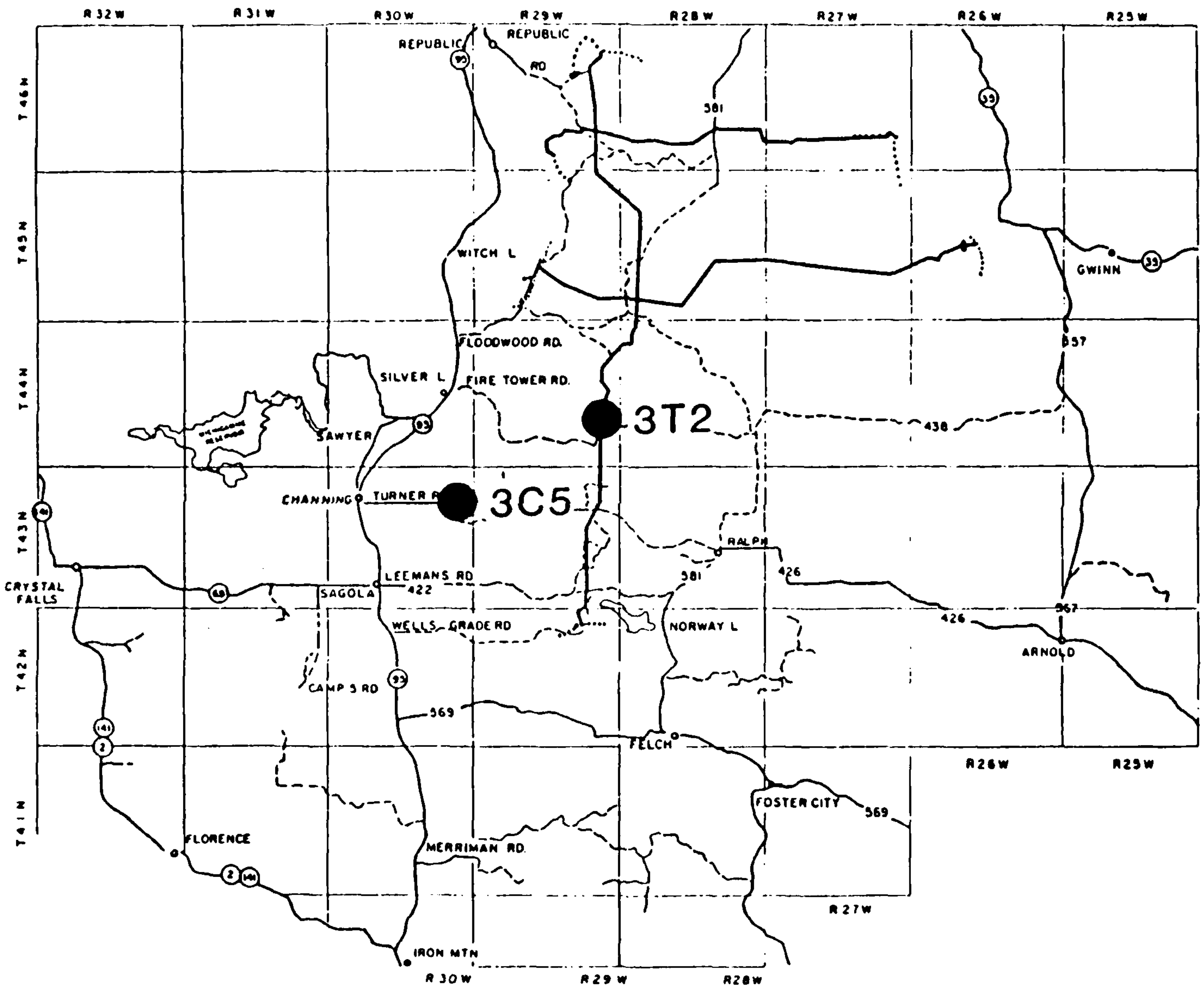


FIGURE C-1. POSITIONS OF SOIL ARTHROPODS AND EARTHWORMS STUDY SITES RELATIVE TO MICHIGAN TRANSMITTING FACILITY ANTENNA ELEMENTS.

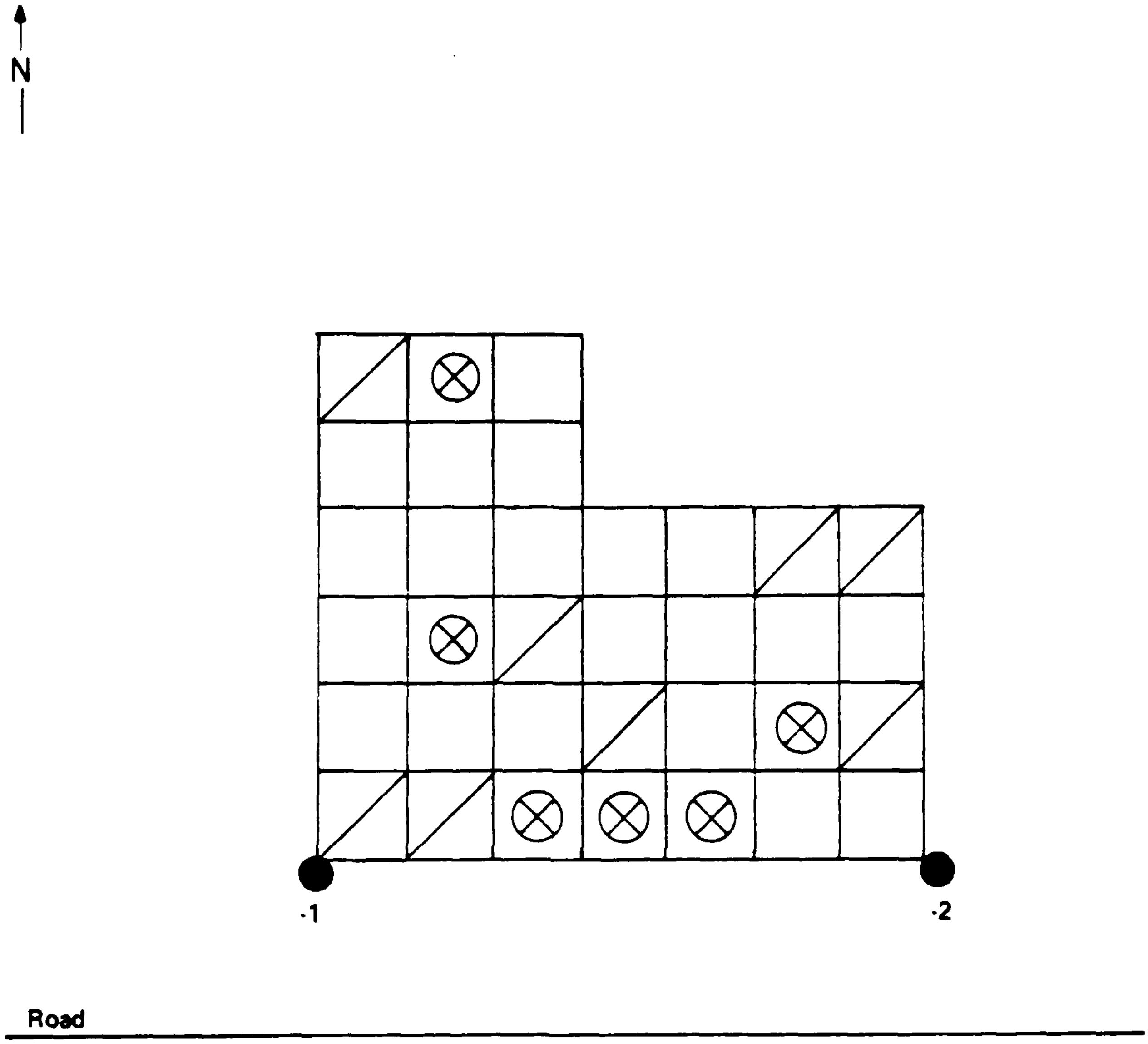


FIGURE C-2. MEASUREMENT POINTS AT TURNER ROAD; 3C5-1, 2.

60297/189

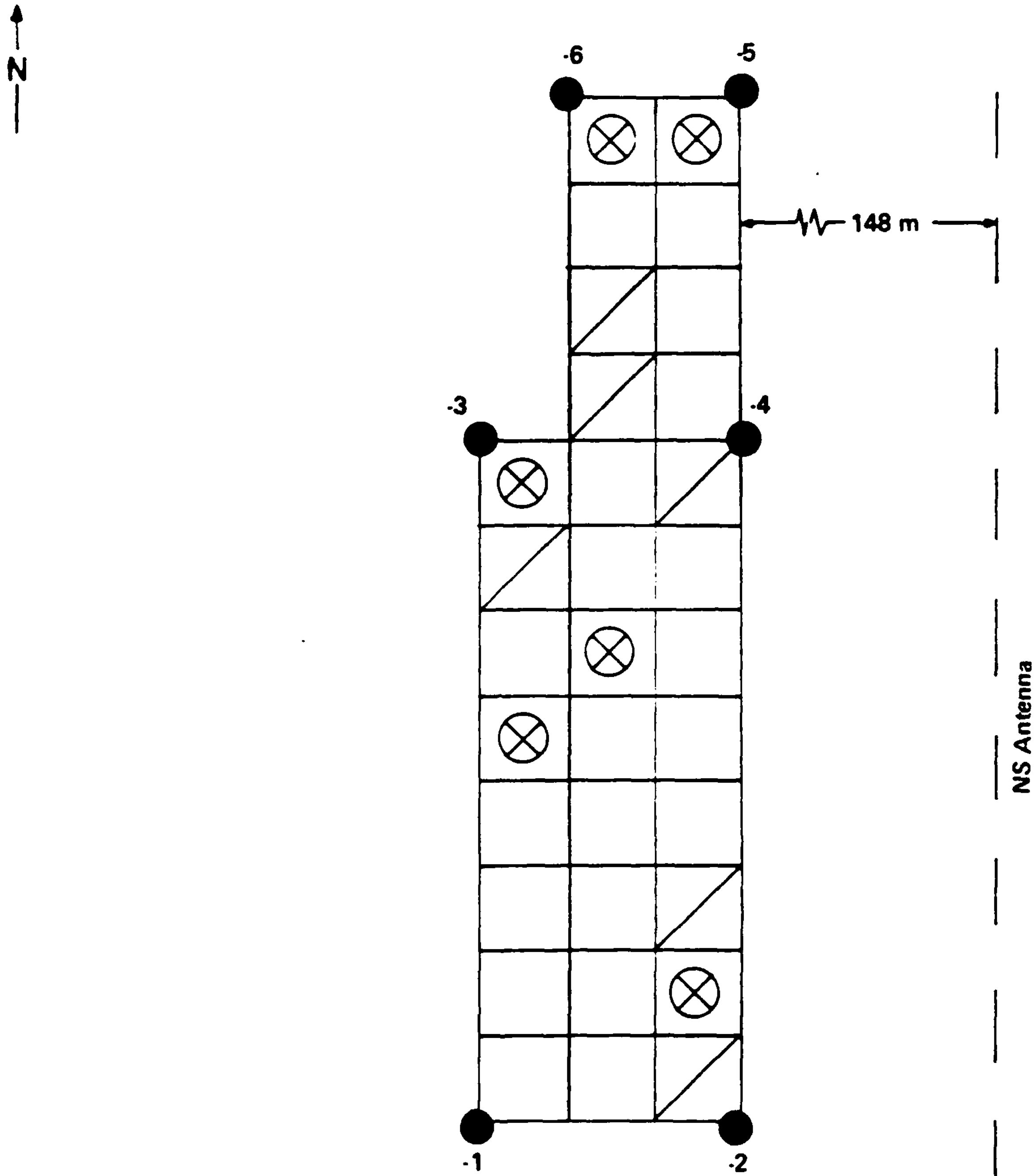


FIGURE C-3. MEASUREMENT POINTS AT SOUTH SILVER LAKE; 3T2-1 THROUGH 6.

TABLE C-2. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Soil Arthropods and Earthworms Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
3C5-1	<0.001	<0.001	~	~	~	~
3C5-2	-	-	-	~	~	~
3T2-1	<0.001	<0.001	~	~	~	~
3T2-2	-	-	-	~	~	~
3T2-3	-	-	-	~	~	~
3T2-4	-	-	-	~	~	~
3T2-5	-	-	-	~	~	~
3T2-6	-	-	-	~	~	~

[a] = prior to antenna construction.
[b] = antenna elements grounded at transmitter (condition 2).
[c] = antenna elements connected to transmitter, transmitter off (condition 9).
- = site measurement point not established.
~ = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.

TABLE C-3. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Soil Arthropods and Earthworms Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
3C5-1	0.063	0.018, 0.032	0.036	0.027	0.054	0.054
3C5-2	-	-	-	0.027	0.071	0.085
3T2-1	0.106	0.129, 0.27	0.194	0.045	0.042	0.091
3T2-2	-	-	-	0.068	0.049	0.093
3T2-3	-	-	-	0.038	0.043	0.084
3T2-4	-	-	-	0.045	0.039	0.087
3T2-5	-	-	-	0.044	0.045	0.084
3T2-6	-	-	-	0.048	0.033	0.087

[a] = prior to antenna construction.
[b] = antenna elements grounded at transmitter (condition 2).
[c] = antenna elements connected to transmitter, transmitter off (condition 9).
- = site measurement point not established.

TABLE C-4. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Arthropods and Earthworms Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
3C5-1	0.001	0.001	0.001	0.001	0.002	0.001
3C5-2	-	-	-	<0.001	0.001	0.001
3T2-1	<0.001	<0.001	0.001	0.005	0.002	0.004
3T2-2	-	-	-	0.006	0.003	0.006
3T2-3	-	-	-	0.004	0.003	0.003
3T2-4	-	-	-	0.005	0.003	0.005
3T2-5	-	-	-	0.005	0.003	0.004
3T2-6	-	-	-	0.004	0.003	0.003

a = prior to antenna construction.
b = antenna elements grounded at transmitter (condition 2).
c = antenna elements connected to transmitter, transmitter off (condition 9).
\- = site measurement point not established.

TABLE C-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Soil Arthropods and Earthworms Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps) NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	1987 Exposures; Antenna Element, Current (Amps) NS(15) M	EW(15) M	1988 Exposures; Antenna Element, Current (Amps) NS(75) M	EW(75) M
3C5-1	~	~	~	~~	~	~	~	~
3C5-2	~	~	~	~~	~	~	~	~
3T2-1	0.002	~	~	~~	0.006	~	0.031	0.003
3T2-2	0.002	~	~	~~	~	~	0.024	0.003
3T2-3	0.002	~	~	~~	0.006	~	0.028	0.003
3T2-4	0.002	~	~	~~	0.006	~	0.026	0.003
3T2-5	0.002	~	~	~~	0.006	~	0.029	0.005
3T2-6	0.002	~	~	~~	0.006	~	0.027	0.002

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
~ = measurement expected to be <0.001 based on the longitudinal electric field measurement.
~~ = data cannot be extrapolated.

TABLE C-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Soil Arthropods and Earthworms Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps) NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	1987 Exposures; Antenna Element, Current (Amps) NS(15) M	EW(15) M	1988 Exposures; Antenna Element, Current (Amps) NS(75) M	EW(75) M
3C5-1	0.005	0.001	0.002	0.003	0.020	0.006	0.093	0.027
3C5-2	0.009	0.001	0.003	0.005	0.034	0.009	0.170	0.021
3T2-1	1.33	0.057	0.188	0.31	5.4	0.54	27	2.6
3T2-2	1.46	0.064	0.24	0.40	6.3	0.71	26	3.0
3T2-3	1.19	0.047	0.149	0.25	5.3	0.60	27	2.7
3T2-4	1.47	0.060	0.20	0.33	5.6	0.47	29	2.6
3T2-5	1.56	0.070	0.23	0.38	5.7	0.61	27	2.8
3T2-6	1.20	0.056	0.180	0.30	5.5	0.54	27	2.4

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).

TABLE C-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Arthropods and Earthworms Studies
Measured (M) and Extrapolated (Ex) Data

	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)		1988 Exposures; Antenna Element, Current (Amps)	
Site No., Meas. Pt.	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M	NS(75) M	EW(75) M
3C5-1	<0.001	<0.001	<0.001	--	0.002	0.001	0.008	0.003
3C5-2	<0.001	<0.001	<0.001	--	0.002	0.001	0.007	0.002
3T2-1	0.048	0.001	0.001	0.002	0.187	0.003	0.88	0.012
3T2-2	0.060	0.002	0.001	0.002	0.23	0.003	1.11	0.012
3T2-3	0.046	0.001	0.001	0.002	0.182	0.002	0.89	0.012
3T2-4	0.055	0.002	0.001	0.002	0.23	0.003	1.08	0.012
3T2-5	0.057	0.002	0.001	0.002	0.22	0.003	1.03	0.012
3T2-6	0.049	0.001	0.001	0.002	0.190	0.003	0.90	0.012

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
-- = data cannot be extrapolated.

TABLE C-8. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Soil Arthropods and Earthworms Studies
Data Extrapolated to 150 Ampere Current

Site No.,	1986 Extrapolations			1987 Extrapolations		1988 Extrapolations	
Meas. Pt.	NS	NEW	SEW	NS	EW	NS	EW
3C5-1	--	--	--	--	--	--	--
3C5-2	--	--	--	--	--	--	--
3T2-1	0.075	--	--	0.060	--	0.062	0.006
3T2-2	0.075	--	--	--	--	0.048	0.006
3T2-3	0.075	--	--	0.060	--	0.056	0.006
3T2-4	0.075	--	--	0.060	--	0.052	0.006
3T2-5	0.075	--	--	0.060	--	0.058	0.010
3T2-6	0.075	--	--	0.060	--	0.054	0.004

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
-- = data cannot be extrapolated.

TABLE C-9. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Soil Arthropods and Earthworms Studies
Data Extrapolated to 150 Ampere Current

Site No.,	1986 Extrapolations			1987 Extrapolations		1988 Extrapolations	
Meas. Pt.	NS	NEW	SEW	NS	EW	NS	EW
3C5-1	0.188	0.025	0.050	0.20	0.060	0.186	0.054
3C5-2	0.34	0.025	0.075	0.34	0.090	0.34	0.042
3T2-1	50	1.43	4.7	54	5.4	54	5.2
3T2-2	55	1.60	6.0	63	7.1	52	6.0
3T2-3	45	1.18	3.7	53	6.0	54	5.4
3T2-4	55	1.50	5.0	56	4.7	58	5.2
3T2-5	59	1.75	5.8	57	6.1	54	5.6
3T2-6	45	1.40	4.5	55	5.4	54	4.8

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).

TABLE C-10. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Arthropods and Earthworms Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations NS	NEW	SEW	1987 Extrapolations NS	EW	1988 Extrapolations NS	EW
3C5-1	--	--	--	0.020	0.010	0.016	0.006
3C5-2	--	--	--	0.020	0.010	0.014	0.004
3T2-1	1.80	0.025	0.025	1.87	0.030	1.76	0.024
3T2-2	2.3	0.050	0.025	2.3	0.030	2.2	0.024
3T2-3	1.73	0.025	0.025	1.82	0.020	1.78	0.024
3T2-4	2.1	0.050	0.025	2.3	0.030	2.2	0.024
3T2-5	2.1	0.050	0.025	2.2	0.030	2.1	0.024
3T2-6	1.84	0.025	0.025	1.90	0.030	1.80	0.024

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
-- = data cannot be extrapolated.

The 1988 60 Hz measurements showed the same trends in EM field magnitudes as were reported in 1986 and 1987. That is, the 60 Hz magnetic flux densities increased and the longitudinal electric fields decreased near the antenna wire(s) in comparison to measurements made at this site prior to antenna construction. This is the result of 60 Hz currents from power lines coupled to the ELF antenna elements, which then reradiate 60 Hz EM fields. Because of this coupling, year-to-year variations in the 60 Hz EM field levels at the test site are effected by and are generally consistent with expected fluctuations in regional power line load currents.

The EM fields generated by the 60 Hz currents on the antenna wires are localized near the antennas and do not affect the 60 Hz EM fields at the control site. However, the 60 Hz EM field levels at this site can be influenced directly by local power lines. In any event, the 60 Hz EM fields measured at the control site in 1988 were consistent with measurements from previous years.

76 Hz measurements were made in 1988 with 75 ampere antenna currents, the predominant MTF operating mode from July through December. The EM field exposures at the study sites for the period prior to July can be estimated by using the 15 ampere antenna current measurement data from 1987 or more accurately by using one-fifth the value of the 1988 75 ampere data.

The measured EM field magnitudes for each antenna for 1986-1988 have been linearly extrapolated to the planned operational antenna current of 150 amperes. Extrapolations were not performed when the measurements indicated that the EM field magnitudes were below the minimum sensitivity of the EM field sensors.

The 1988 extrapolations are the most accurate predictions of the EM field levels at the planned operational antenna current because the 1988 half-power EM field measurements are more accurate than those made at lower antenna currents in previous years. The 1988 extrapolations also reflect the operational configuration and tuning of the antenna elements with the new power amplifiers.

The maximum 76 Hz EM field intensities that can occur during simultaneous operation of both antennas at any antenna phasing can be estimated by calculating the algebraic sum of the levels from the individual antenna extrapolations; minimum intensities can be estimated by calculating the algebraic difference.

APPENDIX D

UPLAND FLORA AND SOIL MICROFLORA STUDIES

UPLAND FLORA AND SOIL MICROFLORA STUDIES

On 22 September and 5-7 October 1988, IITRI field crews made ELF electromagnetic (EM) field measurements at 30 measurement points at a total of two test sites, one control site, and three sample collection points. The measurement points were the same as those used in 1987, with the exception of two locations at the antenna site (4T2-8, 4T2-12) that were considered redundant and dropped in 1988.

The positions of the study sites relative to the MTF are shown on the composite map in Figure D-1. The site numbers listed on the map are those used by IITRI. Table D-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are shown in Figures D-2 through D-6.

TABLE D-1. SITE NO. CROSS-REFERENCE
Upland Flora and Soil Microflora Studies

IITRI Site No.	Investigator's Site Name	Location		
		Township	Range	Section(s)
4T2	Martell's Lake (Overhead): ML	T45N	R29W	28
4T4	Martell's Lake (Buried): EP	T45N	R29W	28
4C1	Paint Pond Road Control	T41N	R32W	3
4S1	Red Maple Leaf Collection	T55N	R35W	21
4S2	Oak Leaf Collection	T41N	R32W	3
4S3	Pine Needle Collection	T54N	R34W	5

The test sites straddle the antenna and grounding elements of the MTF; the control site is located more than 28 miles from the nearest antenna element. The antenna test site and the control site are arranged in a similar manner, each consisting of three overstory tree plots (pole stands), three plots cleared and planted with red pine seedlings (plantations), and three plots set aside for the study of herbaceous plants (reserves). The grounding test site consists of only three plots cleared and planted with red pine. No overstory tree plots or herbaceous reserves were established at the grounding

60297/189

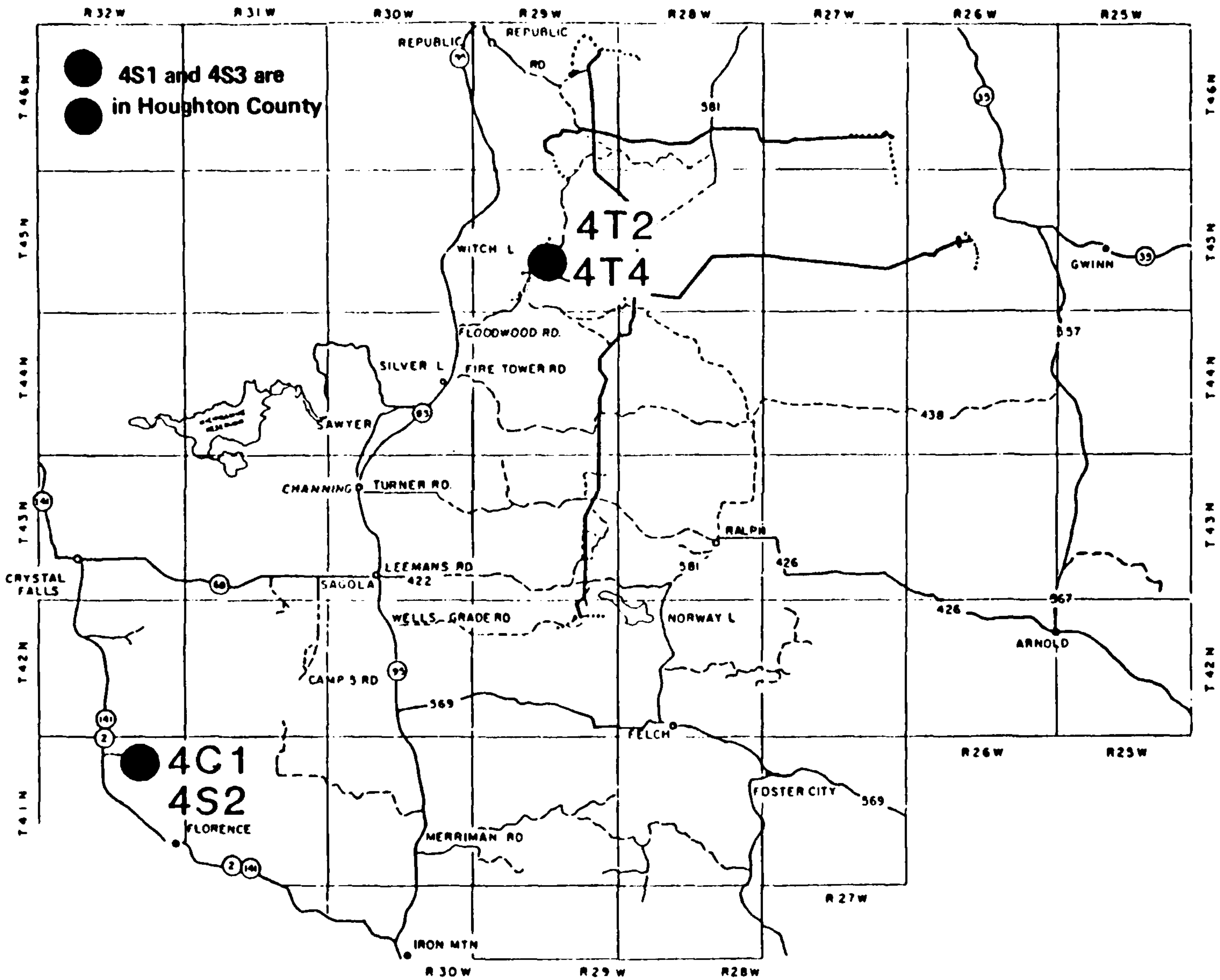


FIGURE D-1. POSITIONS OF UPLAND FLORA AND SOIL MICROFLORA STUDY SITES RELATIVE TO MICHIGAN TRANSMITTING FACILITY ANTENNA ELEMENTS.

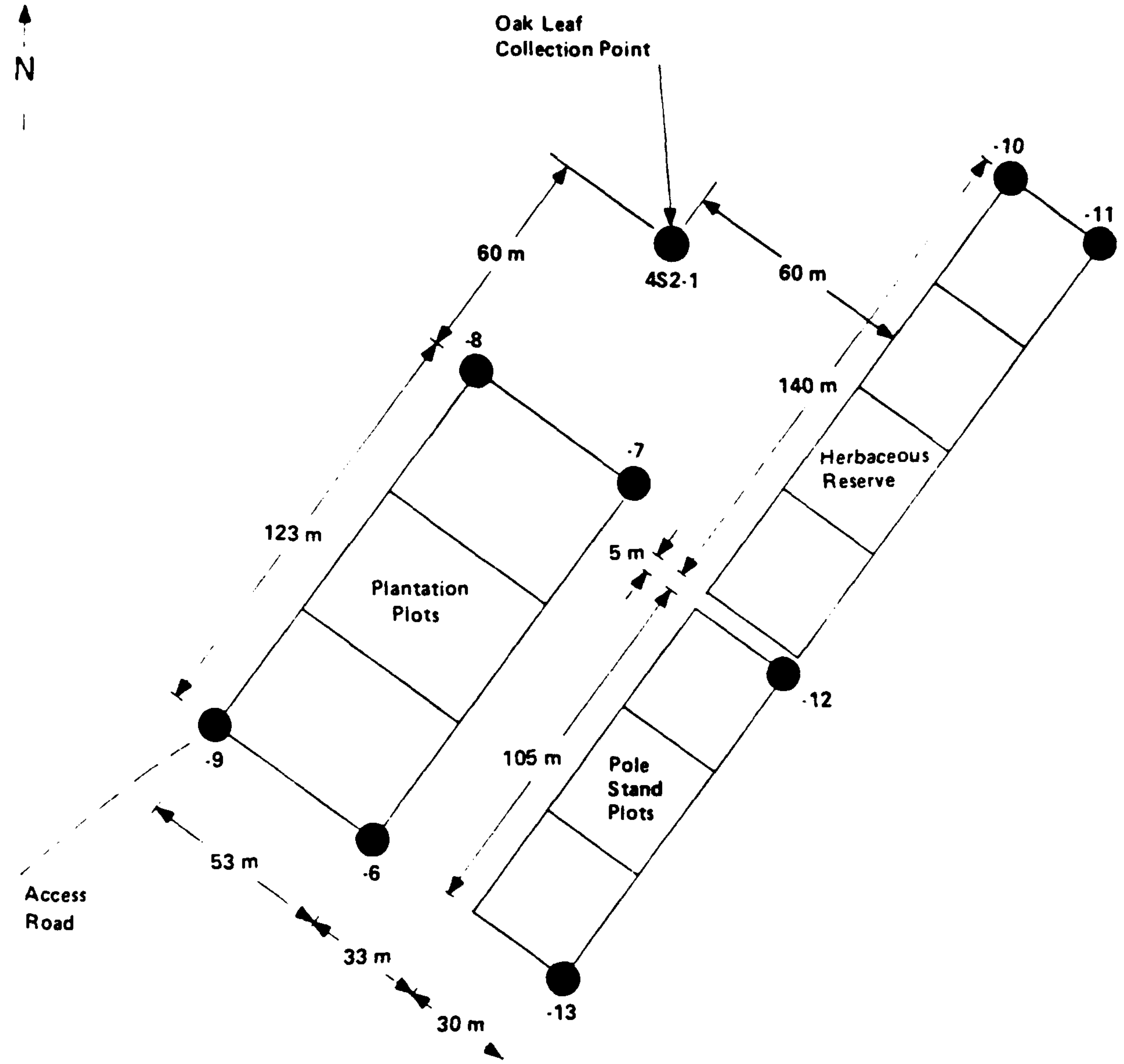


FIGURE D-2. MEASUREMENT POINTS AT PAINT POND ROAD CONTROL; 4C1-6 THROUGH 13, AND OAK LEAF COLLECTION SITE; 4S2-1.

60297/189

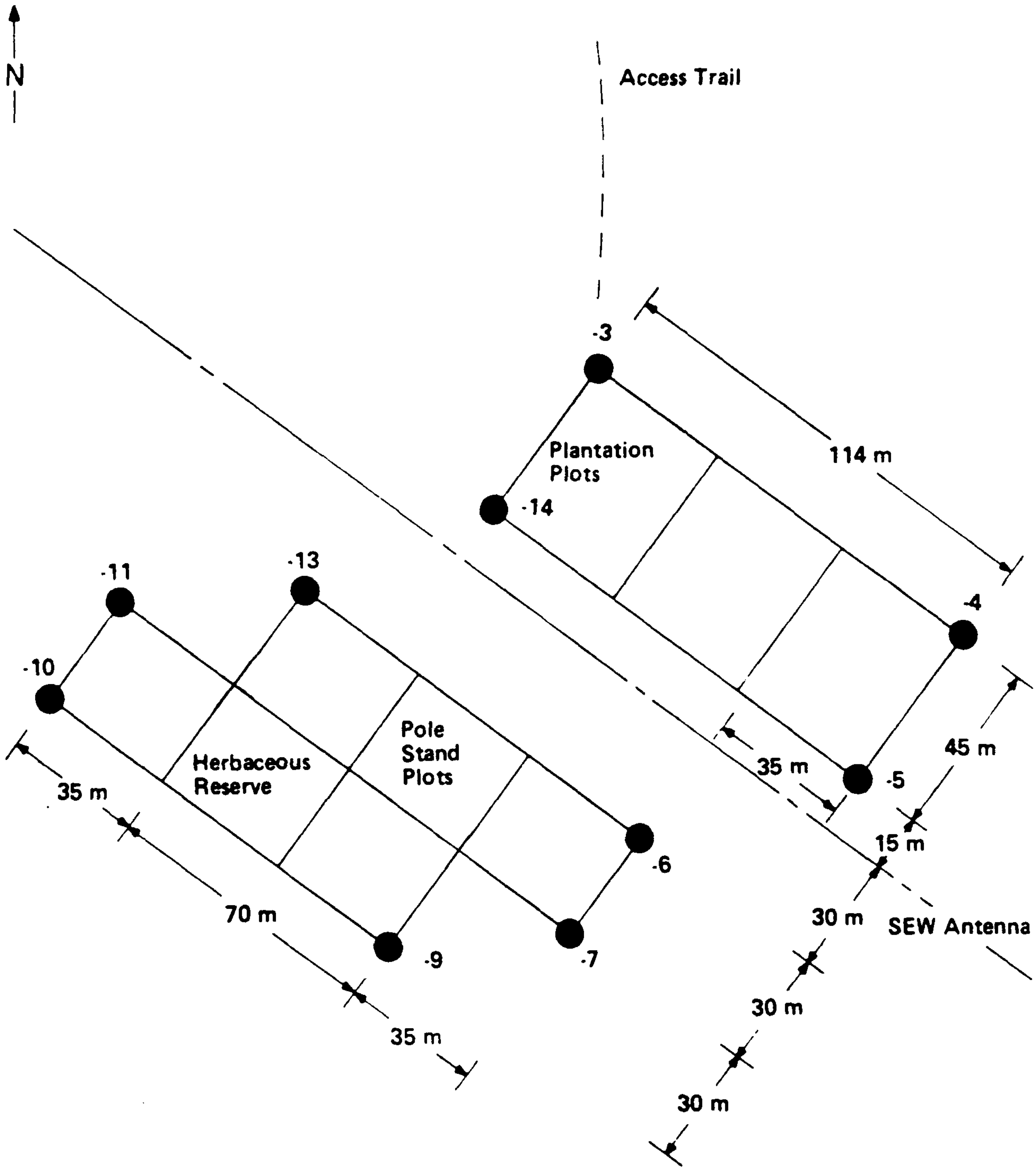


FIGURE D-3. MARTELL'S LAKE (OVERHEAD): ML; 4T2-3, 4, 5, 6, 7, 9, 10, 11, 13, 14.

60297/189

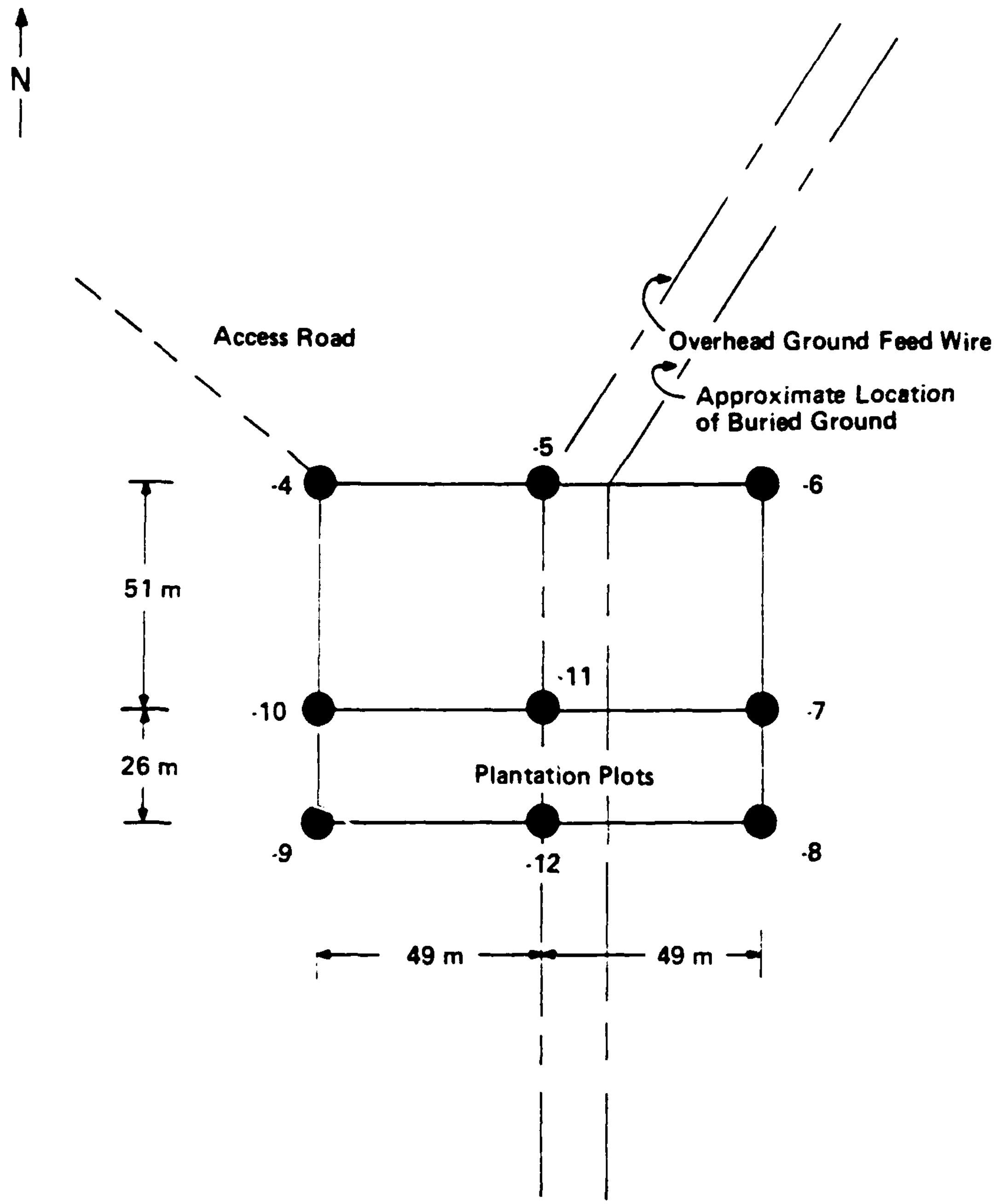


FIGURE D-4. MARTELL'S LAKE (BURIED): EP; 4T4-4 THROUGH 12.

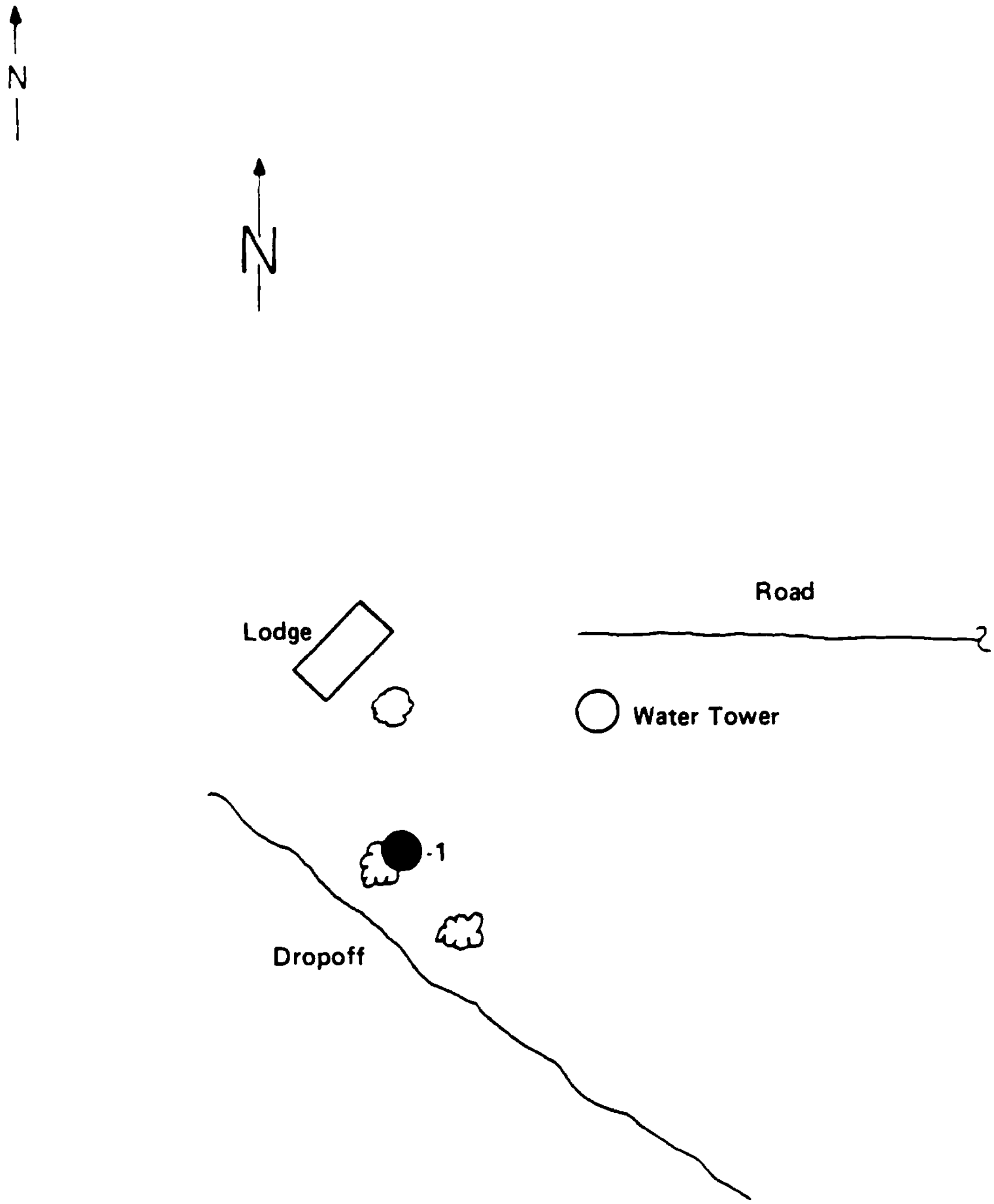


FIGURE D-5. MEASUREMENT POINT AT RED MAPLE LEAF SAMPLE COLLECTION SITE; 4S1-1.

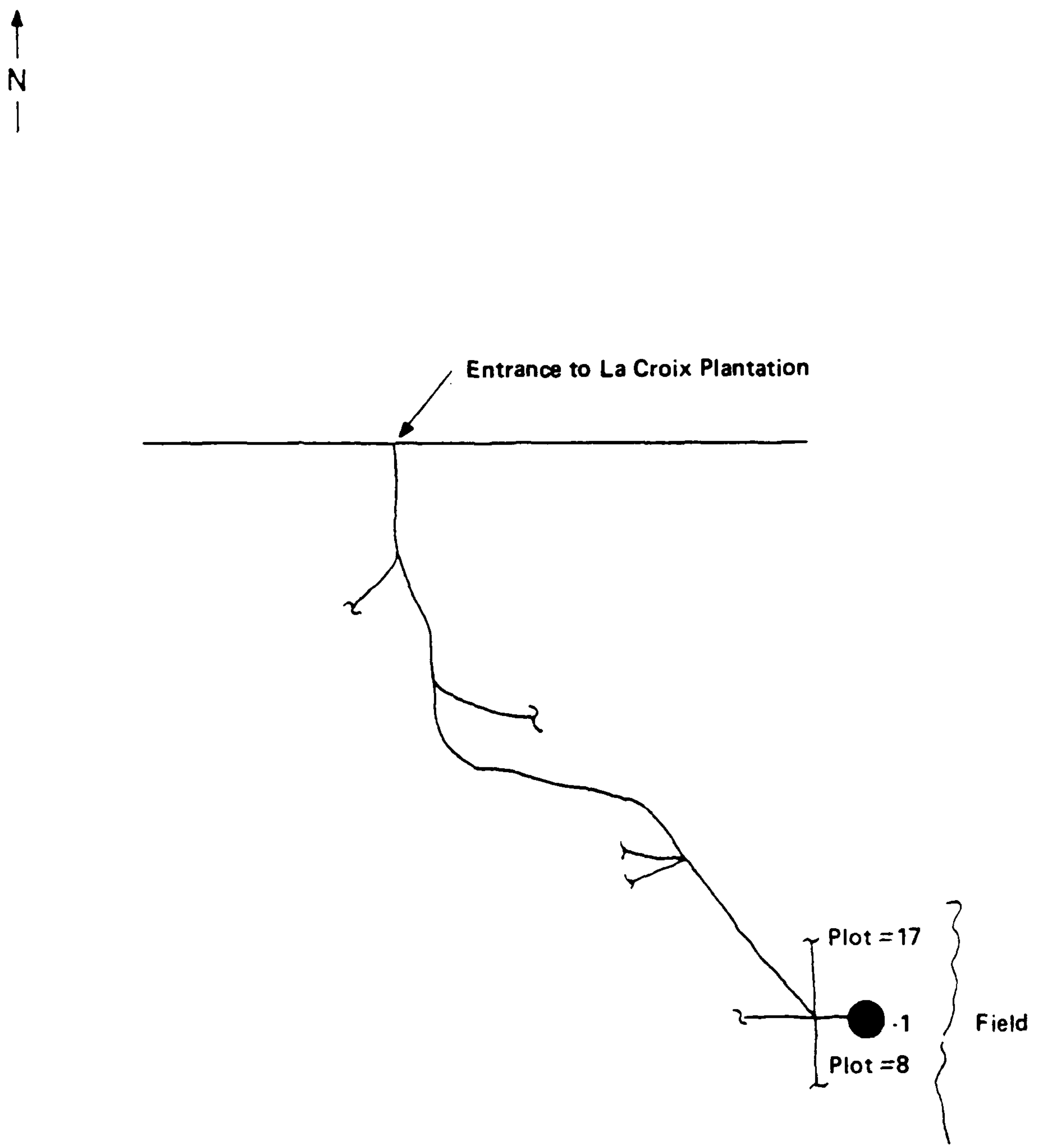


FIGURE D-6. MEASUREMENT POINT AT THE PINE NEEDLE SAMPLE COLLECTION SITE; 4S3-1.

test site because the required buffer strips would have resulted in the biota being at too great a distance from the grounding elements for meaningful EM field exposure.

The major themes of the upland flora and microflora studies are the functional and structural aspects of organic material cycling. These studies investigate and characterize trees, herbaceous plants, and microflora (fungi and streptomycetes) populations. The electric and magnetic fields in the earth are considered important EM factors influencing soil biota and processes. The electric and magnetic fields in the air might influence any object extending above the surface of the earth. Since the electric field in the air can be effectively shunted by trees or plants on the perimeter of a given study plot, special care was taken in characterizing the ambient electric field intensities across a plot.

EM field measurements for 1988 and previous years are found in Tables D-2 through D-10. Tables D-2, D-3, and D-4 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables D-5, D-6, and D-7 present 76 Hz data for these three fields at 1986, 1987, and 1988 MTF operating currents. Tables D-8, D-9, and D-10 present 76 Hz data extrapolated to a full-power condition of 150 amperes.

The 1988 60 Hz measurements showed the same trends in EM field magnitudes as were reported in 1986 and 1987. That is, the 60 Hz magnetic flux densities increased and the longitudinal electric fields decreased near the antenna wire(s) in comparison to measurements made at these sites prior to antenna construction. This is the result of 60 Hz currents from power lines coupled to the ELF antenna elements, which then reradiate 60 Hz EM fields. Because of this coupling, year-to-year variations in the 60 Hz EM field levels at the test sites are effected by and are generally consistent with expected fluctuations in regional power line load currents.

The EM fields generated by the 60 Hz currents on the antenna wires are localized near the antennas and do not affect the 60 Hz EM fields at the control site. However, the 60 Hz EM field levels at this location can be influenced directly by local power lines. The 60 Hz EM fields measured at the control site in 1988 were consistent with measurements from previous years.

TABLE D-2. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Upland Flora and Soil Microflora Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
4C1-6	-	0.003	~	~	~	~
4C1-7	-	0.006	~	~	~	~
4C1-8	-	0.004	~	~	~	~
4C1-9	-	0.002	~	~	~	~
4C1-10	-	-	~	~	~	~
4C1-11	-	-	~	~	~	~
4C1-12	-	-	~	~	~	~
4C1-13	-	-	~	~	~	~
4T2-3	-	0.001	~	~	~	0.002
4T2-4	-	-	~	~	~	0.001
4T2-5	-	-	~	~	~	0.011
4T2-6	-	-	~	~	~	<0.001
4T2-7	-	-	~	~	~	<0.001
4T2-8	-	-	~	~	~	--
4T2-9	-	-	~	~	~	~
4T2-10	-	-	~	~	~	~
4T2-11	-	-	~	~	~	~
4T2-12	-	-	~	~	~	--
4T2-13	-	-	~	~	~	<0.001
4T2-14	-	-	~	~	~	0.011
4T4-4	-	0.003	~	~	<0.001	<0.001
4T4-5	-	-	~	~	0.006	0.003
4T4-6	-	-	~	~	~	~
4T4-7	-	-	~	~	~	~
4T4-8	-	-	~	~	~	~
4T4-9	-	-	~	~	~	~
4T4-10	-	-	~	~	~	~
4T4-11	-	-	~	~	0.010	0.009
4T4-12	-	-	-	~	0.005	0.007
4S1-1	-	-	-	-	0.013	0.033
4S2-1	-	-	-	-	~	~
4S3-1	-	-	-	-	<0.001	<0.001

a = prior to antenna construction.
b = antenna elements grounded at transmitter (condition 2).
c = antenna elements connected to transmitter, transmitter off (condition 9).
\- = site measurement point not established.
~ = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.

TABLE D-3. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
4C1-6	-	0.022	0.016	0.005	0.043	0.023
4C1-7	-	0.143	0.123	0.077	0.178	0.118
4C1-8	-	0.104	0.117	0.077	0.131	0.078
4C1-9	-	0.011	0.019	0.024	0.034	0.032
4C1-10	-	-	0.090	0.068	0.118	0.106
4C1-11	-	-	0.160	0.107	0.132	0.146
4C1-12	-	-	0.104	0.101	0.075	0.093
4C1-13	-	-	0.040	0.030	0.046	0.065
4T2-3	-	0.51	0.39	0.194	0.27	0.28
4T2-4	-	-	0.27	0.24	0.30	0.25
4T2-5	-	-	0.43	0.32	0.20	0.20
4T2-6	-	-	0.66	0.46	0.192	0.22
4T2-7	-	-	0.42	0.52	0.197	0.28
4T2-8	-	-	0.47	0.190	0.22	--
4T2-9	-	-	0.49	0.31	0.183	0.25
4T2-10	-	-	0.44	0.32	0.155	0.166
4T2-11	-	-	0.51	0.40	0.31	0.43
4T2-12	-	-	0.47	0.38	0.24	--
4T2-13	-	-	0.76	0.31	0.31	0.25
4T2-14	-	-	0.61	0.29	0.35	0.21
4T4-4	-	0.72	0.42	0.185	0.56	0.079
4T4-5	-	-	0.58	0.58	4.3	1.12
4T4-6	-	-	0.22	0.16	0.61	0.188
4T4-7	-	-	0.44	0.29	0.64	0.22
4T4-8	-	-	0.42	0.193	0.40	0.23
4T4-9	-	-	0.50	0.21	0.27	0.073
4T4-10	-	-	0.42	0.22	0.29	0.063
4T4-11	-	-	0.40	0.60	2.7	1.27
4T4-12	-	-	-	0.75	3.4	1.35
4S1-1	-	-	-	-	8.5	12.2
4S2-1	-	-	-	-	0.155	0.109
4S3-1	-	-	-	-	0.65	1.73

[a] = prior to antenna construction.
[b] = antenna elements grounded at transmitter (condition 2).
[c] = antenna elements connected to transmitter, transmitter off (condition 9).
\- = site measurement point not established.
-- = site measurement point dropped.

TABLE D-4. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Upland Flora and Soil Microflora Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
4C1-6	-	0.003	0.003	0.003	0.002	0.003
4C1-7	-	0.003	0.002	0.001	0.003	0.002
4C1-8	-	0.003	0.003	0.002	0.003	0.002
4C1-9	-	0.003	0.003	0.002	0.001	0.002
4C1-10	-	-	0.002	0.002	0.002	0.002
4C1-11	-	-	0.002	0.002	0.002	0.002
4C1-12	-	-	0.002	0.003	0.001	0.002
4C1-13	-	-	0.002	0.003	0.001	0.003
4T2-3	-	0.002	0.001	0.001	0.003	0.005
4T2-4	-	-	0.001	0.001	0.003	0.006
4T2-5	-	-	0.001	0.007	0.017	0.030
4T2-6	-	-	0.001	0.006	0.006	0.014
4T2-7	-	-	0.001	0.004	0.004	0.007
4T2-8	-	-	0.001	0.002	0.004	--
4T2-9	-	-	0.001	0.003	0.003	0.005
4T2-10	-	-	0.001	0.003	0.003	0.005
4T2-11	-	-	0.001	0.004	0.005	0.007
4T2-12	-	-	0.002	0.004	0.005	--
4T2-13	-	-	0.001	0.005	0.008	0.013
4T2-14	-	-	0.002	0.011	0.018	0.029
4T4-4	-	0.004	0.002	0.001	0.003	0.003
4T4-5	-	-	0.002	0.006	0.010	0.017
4T4-6	-	-	0.002	0.001	0.004	0.007
4T4-7	-	-	0.001	0.001	0.004	0.005
4T4-8	-	-	0.002	0.001	0.004	0.005
4T4-9	-	-	0.002	0.001	0.002	0.003
4T4-10	-	-	0.001	0.001	0.002	0.002
4T4-11	-	-	0.002	0.002	0.012	0.019
4T4-12	-	-	-	0.002	0.010	0.016
4S1-1	-	-	-	-	0.035	0.043
4S2-1	-	-	-	-	0.003	0.002
4S3-1	-	-	-	-	0.036	0.095

[a] = prior to antenna construction.
[b] = antenna elements grounded at transmitter (condition 2).
[c] = antenna elements connected to transmitter, transmitter off (condition 9).
- = site measurement point not established.
-- = site measurement point dropped.

TABLE D-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Upland Flora and Soil Microflora Studies
Measured (M) and Extrapolated (Ex) Data (page 1 of 2)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps) NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	1987 Exposures; Antenna Element, Current (Amps) NS(15) M	EW(15) M	1988 Exposures; Antenna Element, Current (Amps) NS(75) M	EW(75) M
4C1-6	~	~	~	~~	~	~	~	~
4C1-7	~	~	~	~~	~	~	~	~
4C1-8	~	~	~	~~	~	~	~	~
4C1-9	~	~	~	~~	~	~	~	~
4C1-10	~	~	~	~~	~	~	~	~
4C1-11	~	~	~	~~	~	~	~	~
4C1-12	~	~	~	~~	~	~	~	~
4C1-13	~	~	~	~~	~	~	~	~
4T2-3	~	~	0.004	0.007	0.002	0.014	0.006	0.125
4T2-4	~	~	0.005	0.008	0.001	0.014	0.017	0.113
4T2-5	0.018	~	0.092	0.153	0.003	0.23	0.033	2.6
4T2-6	~	~	0.005	0.008	0.003	0.013	0.014	0.142
4T2-7	~	~	0.007	0.012	0.001	0.018	0.020	0.165
4T2-8	~	~	0.004	0.007	0.002	0.012	--	--
4T2-9	~	~	0.005	0.008	0.002	0.010	0.019	0.137
4T2-10	~	~	0.004	0.007	0.002	0.011	0.020	0.112
4T2-11	~	~	0.003	0.005	0.002	0.012	0.010	0.130
4T2-12	~	~	0.002	0.003	0.002	0.014	--	--
4T2-13	~	~	0.005	0.008	0.002	0.012	0.010	0.121
4T2-14	0.030	~	0.155	0.26	0.003	0.186	0.026	2.5
4T4-4	~	~	0.006	0.010	0.002	0.005	0.008	0.028
4T4-5	0.033	0.008	0.20	0.33	0.019	0.27	0.089	1.31
4T4-6	0.005	~	0.023	0.038	0.002	0.021	0.011	0.064
4T4-7	~	~	0.006	0.010	0.002	0.015	0.008	0.090
4T4-8	~	~	0.008	0.013	0.002	0.016	0.007	0.083

TABLE D-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Upland Flora and Soil Microflora Studies
Measured (M) and Extrapolated (Ex) Data (page 2 of 2)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps) NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	1987 Exposures; Antenna Element, Current (Amps) NS(15) M	EW(15) M	1988 Exposures; Antenna Element, Current (Amps) NS(75) M	EW(75) M
4T4-9	¯	¯	0.009	0.015	0.001	0.008	0.009	0.047
4T4-10	¯	¯	0.007	0.012	0.001	0.001	0.011	0.057
4T4-11	¯	0.005	0.38	0.63	0.025	0.43	0.20	4.4
4T4-12	0.055	0.005	0.43	0.72	0.017	0.30	0.150	2.1
4S1-1	-	-	-	-	¯	¯	¯	¯
4S2-1	-	-	-	-	¯	¯	¯	¯
4S3-1	-	-	-	-	¯	¯	¯	¯

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
\- = site measurement point not established.
-- = site measurement point dropped.
¯ = measurement expected to be <0.001 based on the longitudinal electric field measurement.
¯¯ = data cannot be extrapolated.

TABLE D-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Studies
Measured (M) and Extrapolated (Ex) Data (page 1 of 2)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)		1988 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M	NS(75) M	EW(75) M
4C1-6	<0.001	<0.001	<0.001	--	0.002	0.002	0.007	0.005
4C1-7	<0.001	<0.001	<0.001	--	0.005	0.006	0.024	0.023
4C1-8	<0.001	<0.001	<0.001	--	0.004	0.004	0.017	0.016
4C1-9	<0.001	<0.001	<0.001	--	0.002	0.002	0.007	0.006
4C1-10	<0.001	<0.001	<0.001	--	0.005	0.004	0.026	0.023
4C1-11	<0.001	<0.001	<0.001	--	0.006	0.005	0.028	0.028
4C1-12	<0.001	<0.001	<0.001	--	0.004	0.003	0.016	0.016
4C1-13	<0.001	<0.001	<C.001	--	0.002	0.002	0.012	0.011
4T2-3	1.31	0.22	6.3	10.5	1.36	15.2	7.7	76
4T2-4	1.05	0.22	5.0	8.3	1.70	10.7	6.2	68
4T2-5	1.18	0.24	5.3	8.8	1.46	12.7	8.2	62
4T2-6	1.11	0.27	4.4	7.3	2.2	12.4	10.4	56
4T2-7	1.13	0.23	5.3	8.8	1.31	9.7	8.8	71
4T2-8	1.32	0.25	5.7	9.5	1.81	15.8	--	--
4T2-9	1.17	0.21	5.1	8.5	1.46	13.7	7.1	63
4T2-10	0.97	0.22	4.1	6.8	1.84	10.5	8.1	50
4T2-11	1.14	0.21	5.0	8.3	2.2	10.7	9.6	122
4T2-12	1.06	0.21	4.3	7.2	1.93	13.5	--	--
4T2-13	1.12	0.64	5.4	9.0	1.74	14.9	8.2	71
4T2-14	1.07	0.175	5.1	8.5	1.66	14.3	6.6	56
4T4-4	0.33	0.181	1.46	2.4	1.63	3.7	7.2	16.5
4T4-5	13.8	2.0	81	135	14.0	194	68	910
4T4-6	1.22	0.22	6.2	10.3	2.2	12.9	10.3	62
4T4-7	0.94	0.175	5.5	9.2	2.0	14.1	9.1	62
4T4-8	0.91	0.188	5.3	8.8	1.36	10.7	6.8	65

TABLE D-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Studies
Measured (M) and Extrapolated (Ex) Data (page 2 of 2)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps) NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	1987 Exposures; Antenna Element, Current (Amps) NS(15) M	EW(15) M	1988 Exposures; Antenna Element, Current (Amps) NS(75) M	EW(75) M
4T4-9	0.29	0.130	1.32	2.2	1.08	3.0	7.5	18.1
4T4-10	0.29	0.169	1.63	2.7	1.35	3.9	5.1	16.0
4T4-11	0.59	1.82	89	148	10.7	178	50	850
4T4-12	21	2.2	118	197	13.8	260	40	760
4S1-1	-	-	-	-	<0.001	<0.001	<0.001	<0.001
4S2-1	-	-	-	-	0.005	0.005	0.026	0.026
4S3-1	-	-	-	-	<0.001	<0.001	<0.001	<0.001

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
\- = site measurement point not established.
-- = site measurement point dropped.
~~ = data cannot be extrapolated.

TABLE D-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Upland Flora and Soil Microflora Studies
Measured (M) and Extrapolated (Ex) Data (page 1 of 2)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)		1988 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M	NS(75) M	EW(75) M
4C1-6	<0.001	<0.001	<0.001	--	<0.001	<0.001	0.001	0.001
4C1-7	<0.001	<0.001	<0.001	--	<0.001	<0.001	0.001	<0.001
4C1-8	<0.001	<0.001	<0.001	--	<0.001	<0.001	0.001	<0.001
4C1-9	<0.001	<0.001	<0.001	--	<0.001	<0.001	0.001	0.001
4C1-10	<0.001	<0.001	<0.001	--	<0.001	<0.001	0.001	<0.001
4C1-11	<0.001	<0.001	<0.001	--	<0.001	<0.001	0.001	<0.001
4C1-12	<0.001	<0.001	<0.001	--	<0.001	<0.001	0.001	<0.001
4C1-13	<0.001	<0.001	<0.001	--	<0.001	<0.001	0.001	0.001
4T2-3	0.047	0.001	0.22	0.37	0.008	0.55	0.040	2.8
4T2-4	0.049	0.001	0.24	0.40	0.008	0.57	0.041	2.9
4T2-5	0.197	<0.001	1.00	1.67	0.011	2.4	0.061	12.4
4T2-6	0.058	0.001	0.44	0.73	0.006	1.16	0.020	5.0
4T2-7	0.046	0.001	0.22	0.37	0.006	0.59	0.024	2.6
4T2-8	0.045	0.001	0 22	0.37	0.006	0.59	--	--
4T2-9	0.029	0.001	0.138	0.23	0.007	0.38	0.027	1.72
4T2-10	0.033	0.001	0.149	0.25	0.006	0.39	0.027	1.78
4T2-11	0.043	0.001	0.21	0.35	0.006	0.56	0.025	2.6
4T2-12	0.047	0.001	0.23	0.38	0.006	0.61	--	--
4T2-13	0.086	<0.001	0.43	0.72	0.005	1.14	0.020	5.1
4T2-14	0.21	<0.001	1.03	1.72	0.012	2.5	0.061	11.9
4T4-4	0.019	<0.001	0.096	0.160	0.005	0.24	0.027	1.15
4T4-5	0.114	0.001	0.57	0.95	0.008	1.40	0.033	6.9
4T4-6	0.045	0.001	0.22	0.37	0.008	0.53	0.034	2.7
4T4-7	0.038	0.001	0.186	0.31	0.008	0.45	0.033	2.3
4T4-8	0.035	0.001	0.179	0.30	0.007	0.43	0.033	2.1

TABLE D-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Upland Flora and Soil Microflora Studies
Measured (M) and Extrapolated (Ex) Data (page 2 of 2)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps) NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	1987 Exposures; Antenna Element, Current (Amps) NS(15) M	EW(15) M	1988 Exposures; Antenna Element, Current (Amps) NS(75) M	EW(75) M
4T4-9	0.025	0.21	0.118	0.197	0.005	0.29	0.027	1.41
4T4-10	0.022	<0.001	0.116	0.193	0.005	0.27	0.027	1.33
4T4-11	0.161	0.001	0.80	1.33	0.011	1.89	0.042	8.9
4T4-12	0.115	0.001	0.58	0.97	0.010	1.37	0.041	7.1
4S1-1	-	-	-	-	<0.001	<0.001	<0.001	<0.001
4S2-1	-	-	-	-	<0.001	<0.001	0.001	<0.001
4S3-1	-	-	-	-	<0.001	<0.001	<0.001	<0.001

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
\- = site measurement point not established.
-- = site measurement point dropped.
~~ = data cannot be extrapolated.

TABLE D-8. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Upland Flora and Soil Microflora Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations NS	1986 Extrapolations NEW	1986 Extrapolations SEW	1987 Extrapolations NS	1987 Extrapolations EW	1988 Extrapolations NS	1988 Extrapolations EW
4C1-6	--	--	--	--	--	--	--
4C1-7	--	--	--	--	--	--	--
4C1-8	--	--	--	--	--	--	--
4C1-9	--	--	--	--	--	--	--
4C1-10	--	--	--	--	--	--	--
4C1-11	--	--	--	--	--	--	--
4C1-12	--	--	--	--	--	--	--
4C1-13	--	--	--	--	--	--	--
4T2-3	--	--	0.100	0.020	0.140	0.012	0.25
4T2-4	--	--	0.125	0.010	0.140	0.034	0.23
4T2-5	0.68	--	2.3	0.030	2.3	0.066	5.2
4T2-6	--	--	0.125	0.030	0.130	0.028	0.28
4T2-7	--	--	0.175	0.010	0.180	0.040	0.33
4T2-8	--	--	0.100	0.020	0.120	--	--
4T2-9	--	--	0.125	0.020	0.100	0.038	0.27
4T2-10	--	--	0.100	0.020	0.110	0.040	0.22
4T2-11	--	--	0.075	0.020	0.120	0.020	0.26
4T2-12	--	--	0.050	0.020	0.140	--	--
4T2-13	--	--	0.125	0.020	0.120	0.020	0.24
4T2-14	1.13	--	3.9	0.030	1.86	0.052	5.0
4T4-4	--	--	0.150	0.020	0.050	0.016	0.056
4T4-5	1.24	0.20	5.0	0.190	2.7	0.178	2.6
4T4-6	0.188	--	0.58	0.020	0.21	0.022	0.128
4T4-7	--	--	0.150	0.020	0.150	0.016	0.180
4T4-8	--	--	0.20	0.020	0.160	0.014	0.166
4T4-9	--	--	0.23	0.010	0.080	0.018	0.094
4T4-10	--	--	0.175	0.010	0.010	0.022	0.114
4T4-11	--	0.125	9.5	0.25	4.3	0.40	8.8
4T4-12	2.1	0.125	10.8	0.170	3.0	0.30	4.2
4S1-1	-	-	-	--	--	--	--
4S2-1	-	-	-	--	--	--	--
4S3-1	-	-	-	--	--	--	--

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
\- = site measurement point not established.
-- = site measurement point dropped.
-- = data cannot be extrapolated.

TABLE D-9. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Studies
Data Extrapolated to 150 Ampere Current

Site No.,	1986 Extrapolations			1987 Extrapolations		1988 Extrapolations	
Meas. Pt.	NS	NEW	SEW	NS	EW	NS	EW
4C1-6	--	--	--	0.020	0.020	0.014	0.010
4C1-7	--	--	--	0.050	0.060	0.048	0.046
4C1-8	--	--	--	0.040	0.040	0.034	0.032
4C1-9	--	--	--	0.020	0.020	0.014	0.012
4C1-10	--	--	--	0.050	0.040	0.052	0.046
4C1-11	--	--	--	0.060	0.050	0.056	0.056
4C1-12	--	--	--	0.040	0.030	0.032	0.032
4C1-13	--	--	--	0.020	0.020	0.024	0.022
4T2-3	49	5.5	158	13.6	152	15.4	152
4T2-4	39	5.5	125	17.0	107	12.4	136
4T2-5	44	6.0	133	14.6	127	16.4	124
4T2-6	42	6.8	110	22	124	21	112
4T2-7	42	5.8	133	13.1	97	17.6	142
4T2-8	50	6.3	143	18.1	158	--	--
4T2-9	44	5.3	128	14.6	137	14.2	126
4T2-10	36	5.5	103	18.4	105	16.2	100
4T2-11	43	5.3	125	22	107	19.2	240
4T2-12	40	5.3	108	19.3	135	--	--
4T2-13	42	16.0	135	17.4	149	16.4	142
4T2-14	40	4.4	128	16.6	143	13.2	112
4T4-4	12.4	4.5	37	16.3	37	14.4	33
4T4-5	520	50	2000	140	1940	136	1820
4T4-6	46	5.5	155	22	129	21	124
4T4-7	35	4.4	138	20	141	18.2	124
4T4-8	34	4.7	133	13.6	107	13.6	130
4T4-9	10.9	3.3	33	10.8	30	15.0	36
4T4-10	10.9	4.2	41	13.5	39	10.2	32
4T4-11	22	46	2200	107	1780	100	1700
4T4-12	790	55	3000	138	2600	80	1520
4S1-1	-	-	-	--	--	--	--
4S2-1	-	-	-	0.050	0.050	0.052	0.052
4S3-1	-	-	-	--	--	--	--

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
\- = site measurement point not established.
-- = site measurement point dropped.
-- = data cannot be extrapolated.

TABLE D-10. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Upland Flora and Soil Microflora Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations		1988 Extrapolations	
	NS	NEW	SEW	NS	EW	NS	EW
4C1-6	--	--	--	--	--	0.002	0.002
4C1-7	--	--	--	--	--	0.002	--
4C1-8	--	--	--	--	--	0.002	--
4C1-9	--	--	--	--	--	0.002	0.002
4C1-10	--	--	--	--	--	0.002	--
4C1-11	--	--	--	--	--	0.002	--
4C1-12	--	--	--	--	--	0.002	--
4C1-13	--	--	--	--	--	0.002	0.002
4T2-3	1.76	0.025	5.5	0.080	5.5	0.080	5.6
4T2-4	1.84	0.025	6.0	0.080	5.7	0.082	5.8
4T2-5	7.4	--	25	0.110	24	0.122	25
4T2-6	2.2	0.025	11.0	0.060	11.6	0.040	10.0
4T2-7	1.73	0.025	5.5	0.060	5.9	0.048	5.2
4T2-8	1.69	0.025	5.5	0.060	5.9	--	--
4T2-9	1.09	0.025	3.5	0.070	3.8	0.054	3.4
4T2-10	1.24	0.025	3.7	0.060	3.9	0.054	3.6
4T2-11	1.61	0.025	5.3	0.060	5.6	0.050	5.2
4T2-12	1.76	0.025	5.8	0.060	6.1	--	--
4T2-13	3.2	--	10.8	0.050	11.4	0.040	10.2
4T2-14	7.9	--	26	0.120	25	0.122	24
4T4-4	0.71	--	2.4	0.050	2.4	0.054	2.3
4T4-5	4.3	0.025	14.3	0.080	14.0	0.066	13.8
4T4-6	1.69	0.025	5.5	0.080	5.3	0.068	5.4
4T4-7	1.43	0.025	4.7	0.080	4.5	0.066	4.6
4T4-8	1.31	0.025	4.5	0.070	4.3	0.066	4.2
4T4-9	0.94	5.3	3.0	0.050	2.9	0.054	2.8
4T4-10	0.83	--	2.9	0.050	2.7	0.054	2.7
4T4-11	6.0	0.025	20	0.110	18.9	0.084	17.8
4T4-12	4.3	0.025	14.5	0.100	13.7	0.082	14.2
4S1-1	-	-	-	--	--	--	--
4S2-1	-	-	-	--	--	0.002	--
4S3-1	-	-	-	--	--	--	--

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
\- = site measurement point not established.
-- = site measurement point dropped.
-- = data cannot be extrapolated.

76 Hz measurements were made in 1988 with 75 ampere antenna currents, the predominant MTF operating mode from July through December. The EM field exposures at the study sites for the period prior to July can be estimated either by using the 15 ampere antenna current measurement data from 1987 or more accurately by using one-fifth the value of the 1988 75 ampere data. This ratio is quite accurate for all EM fields and sites with the exception of the longitudinal electric field at the ground site. Here, the electric field behaves more erratically, most likely because of local variations in soil conductivity. Variations in soil conductivity are expected to affect the longitudinal electric field near ground terminals to a greater degree than other fields for the reasons discussed in Section 4.5 of this report.

The measured EM field magnitudes for each antenna element for 1986-1988 have been linearly extrapolated to the planned operational antenna current of 150 amperes. Extrapolations were not performed when the measurements indicated that the field magnitudes were below the minimum sensitivity of the EM field sensors.

The 1988 extrapolations are the most accurate predictions of the EM field levels at the planned operational antenna current because the 1988 half-power EM field measurements are more accurate than those made at lower antenna currents in previous years. The 1988 extrapolations also reflect the operational configuration and tuning of the antenna elements with the new power amplifiers.

The maximum 76 Hz EM field intensities that can occur during simultaneous operation of both antenna elements at any antenna phasing can be estimated by calculating the algebraic sum of the levels from the individual antenna element extrapolations; minimum intensities can be estimated by calculating the algebraic difference.

APPENDIX E

AQUATIC ECOSYSTEMS STUDIES

AQUATIC ECOSYSTEMS STUDIES

On 26 and 28-30 September 1988, IITRI field crews made ELF electromagnetic (EM) field measurements at 18 measurement points at a total of six test and four control sites for the aquatic ecosystems studies. The measurement points were the same as those used in 1987, with the exception of one new measurement point added at the FCD site (5C1-5).

The positions of the 10 sites relative to the MTF are shown on the composite map in Figure E-1. The site numbers listed on the map are those used by IITRI. Table E-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are given in Figures E-2 through E-7.

The approach of the aquatic ecosystems studies is to integrate the major interrelated and interactive components of aquatic ecosystems (periphytic algae, aquatic insects, and fish) and to monitor events and processes critical to stream ecosystems. The electric field in the earth near the surface and the magnetic field are considered the most important factors influencing the aquatic ecosystems studies. The electric field in the air is not expected to have any impact on the components of these studies.

EM field measurements for 1988 and previous years are found in Tables E-2 through E-10. Tables E-2, E-3, and E-4 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables E-5, E-6, and E-7 present 76 Hz data for these three fields at 1986, 1987, and 1988 MTF operating currents. Tables E-8, E-9, and E-10 present 76 Hz data extrapolated to a full-power condition of 150 amperes.

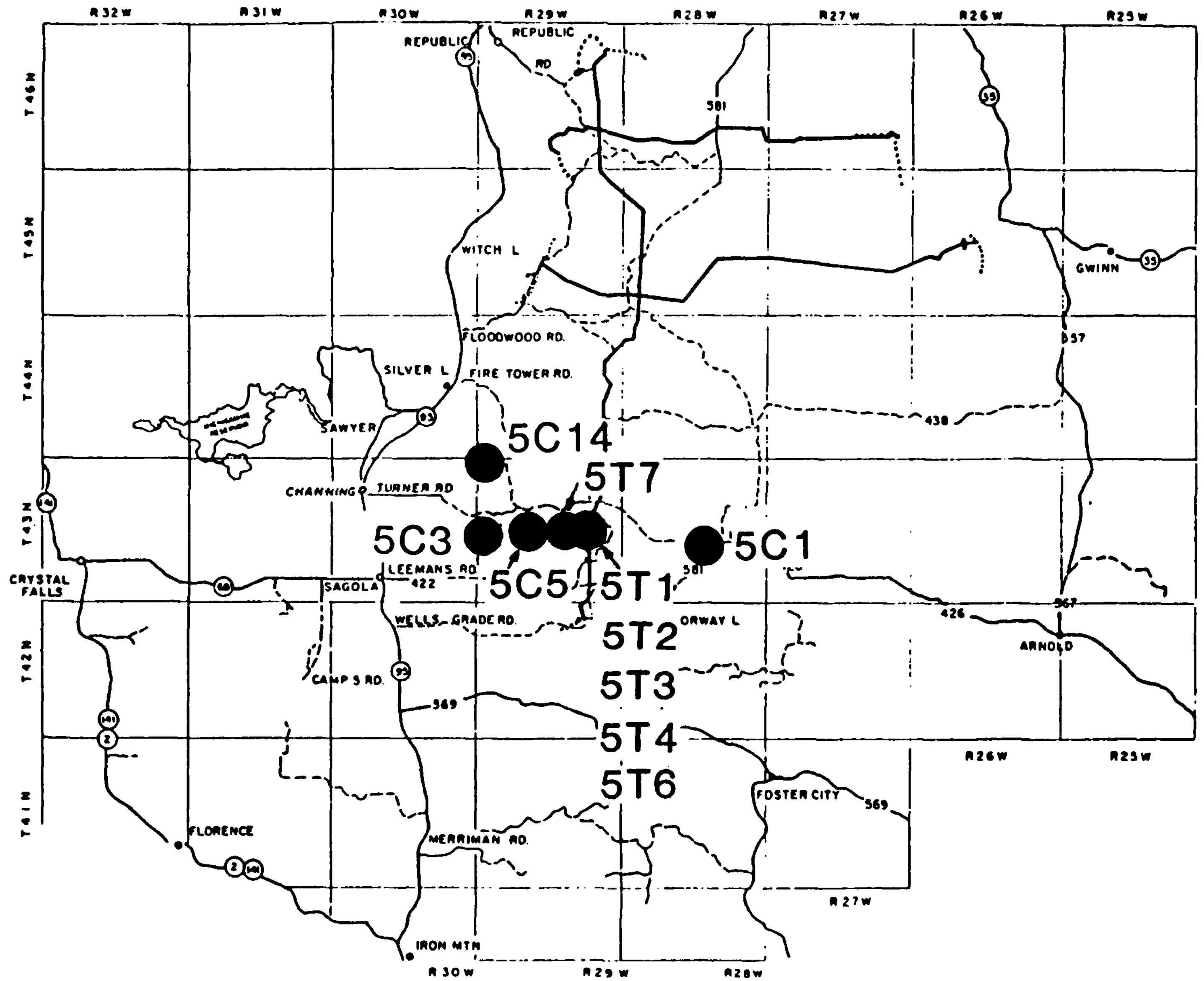


FIGURE E-1. POSITIONS OF AQUATIC ECOSYSTEMS STUDY SITES RELATIVE TO MICHIGAN TRANSMITTING FACILITY ANTENNA ELEMENTS.

TABLE E-1. SITE NO. CROSS-REFERENCE
Aquatic Ecosystems Studies

IITRI Site No.	Investigator's Site Name	Location Township	:	Range	:	Section(s)
5T1-1*	FEX 1; Fish Parasites	T43N	:	R29W	:	11
5T1-2	FEX 1; Insect Substrates	T43N	:	R29W	:	14
5T2-1	FEX 2; Ambient Monitoring	T43N	:	R29W	:	14
5T2-2	FEX 2; Periphyton	T43N	:	R29W	:	14
5T2-3	FEX 2; Insect Movement	T43N	:	R29W	:	14
5T3-1	FEX 3; Fish Population	T43N	:	R29W	:	14
5T4-1*	FEX 4; Fish Parasites	T43N	:	R29W	:	14
5T4-2*	FEX 4; Fish Feeding	T43N	:	R29W	:	14(11)
5T6-1*	FEX 6; Fish Parasites	T43N	:	R29W	:	13
5T7-1	FEX 7; Fish Population (future)	T43N	:	R29W	:	14
5C1-1	FCD; Ambient Monitoring, Periphyton, Insect Substrates	T43N	:	R28W	:	21
5C1-2*	FCD; Fish Parasites	T43N	:	R28W	:	21
5C1-3	FCD; Insect Movement	T43N	:	R28W	:	21
5C1-4	FCD; Fish Population	T43N	:	R28W	:	21
5C1-5	FCD; Insect Substrates	T43N	:	R28W	:	21
5C3-2	FCU; Fish Parasites, Fish Population	T43N	:	R29W	:	18
5C5-1	FS1; Fish Population	T43N	:	R29W	:	16
5C14-1	TM; Fish Population	T43N	:	R29W	:	8

*Location is currently inactive.

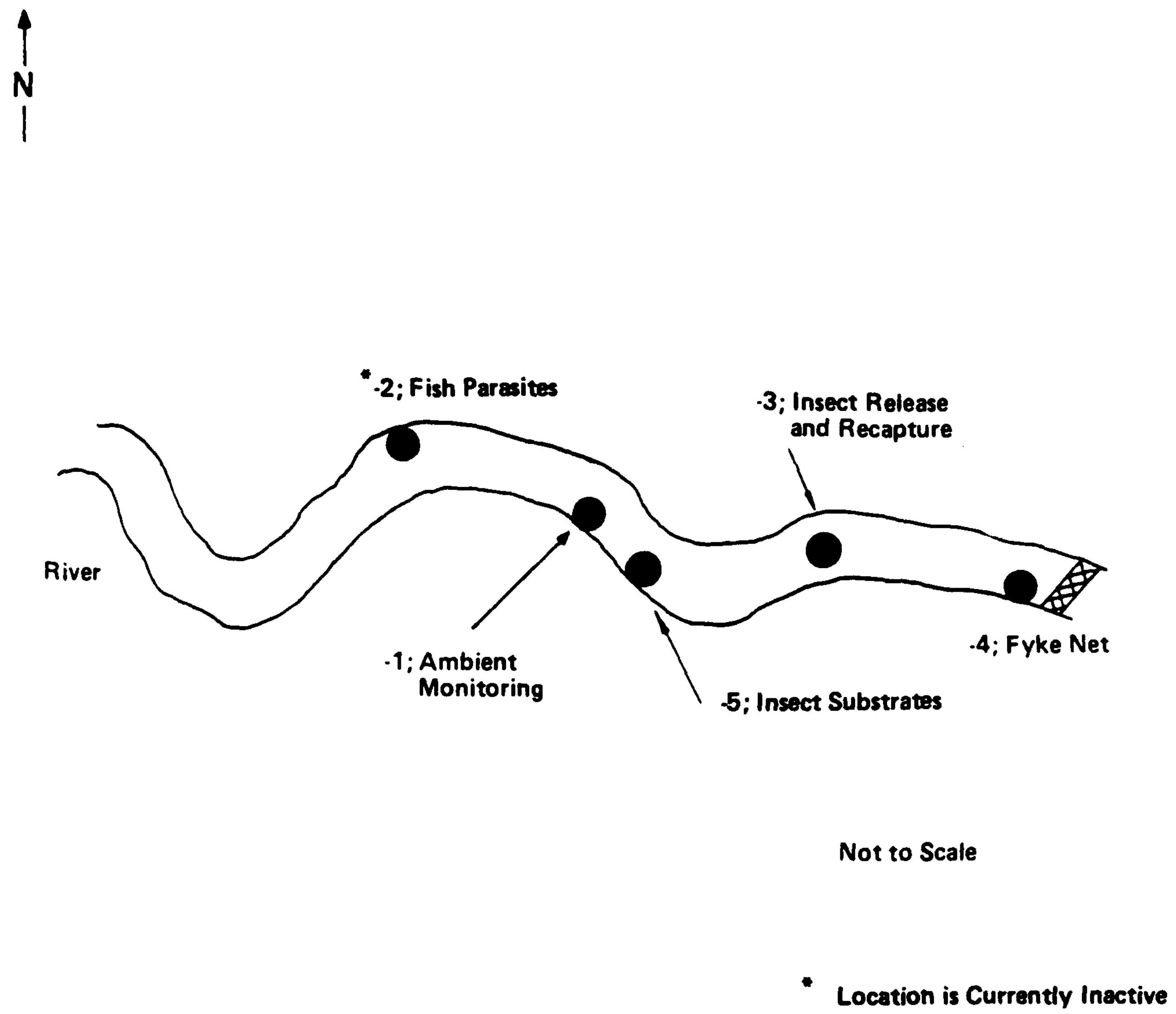


FIGURE E-2. MEASUREMENT POINTS AT FCD; 5C1-1 THROUGH 5.

60297/189

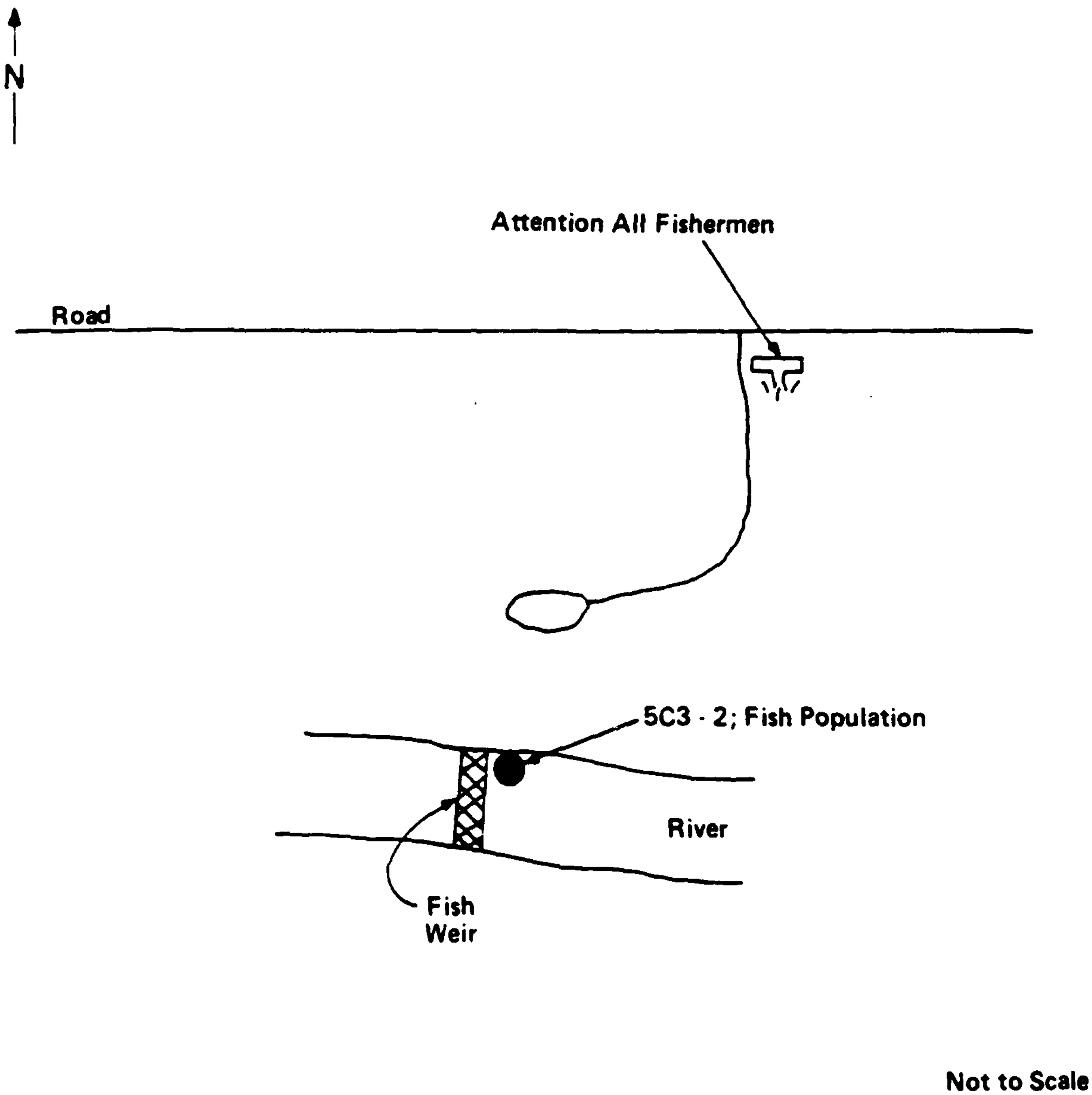


FIGURE E-3. MEASUREMENT POINT AT FCU; 5C3-2.

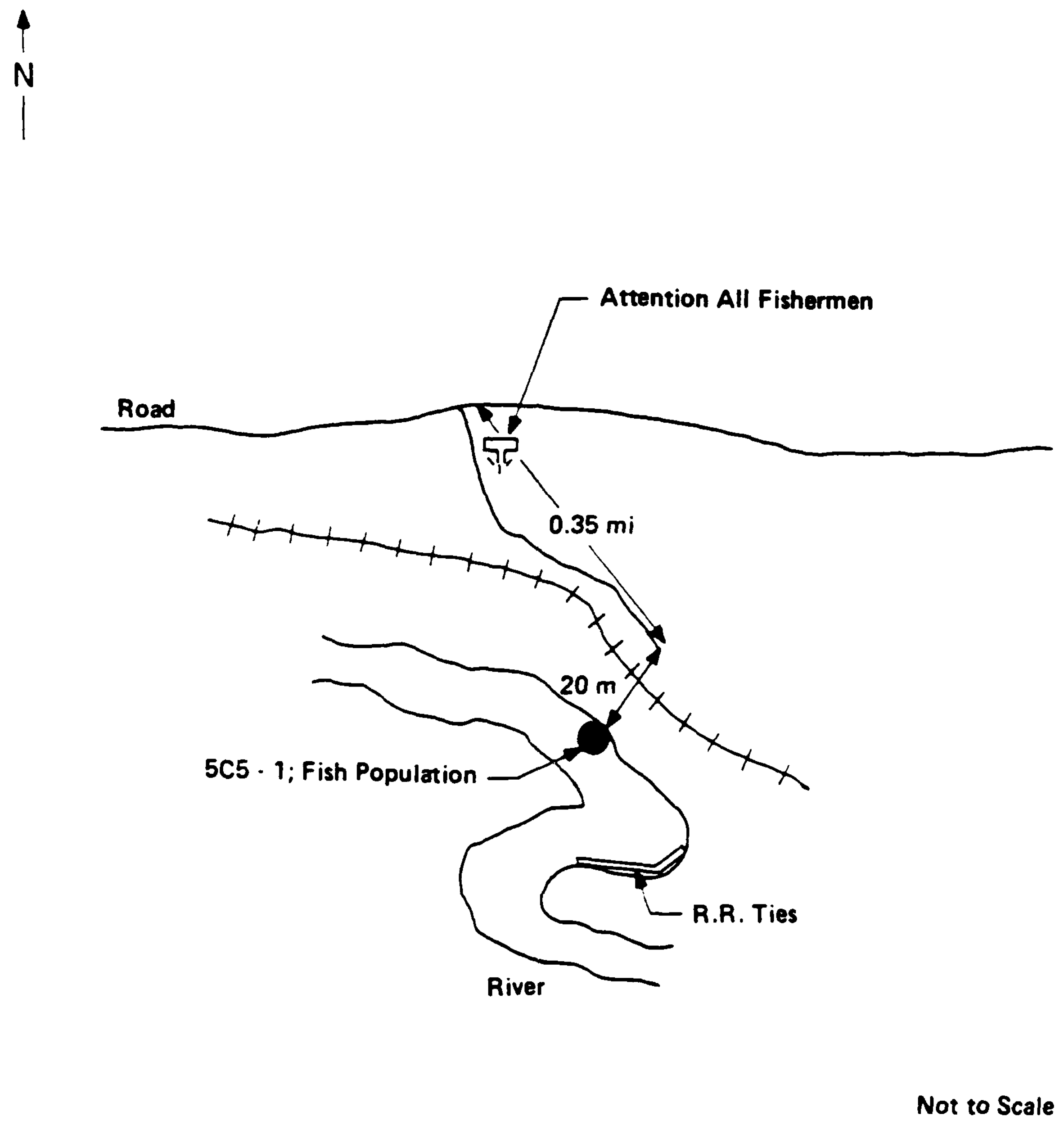


FIGURE E-4. MEASUREMENT POINT AT FS1; 5C5-1.

60297/189

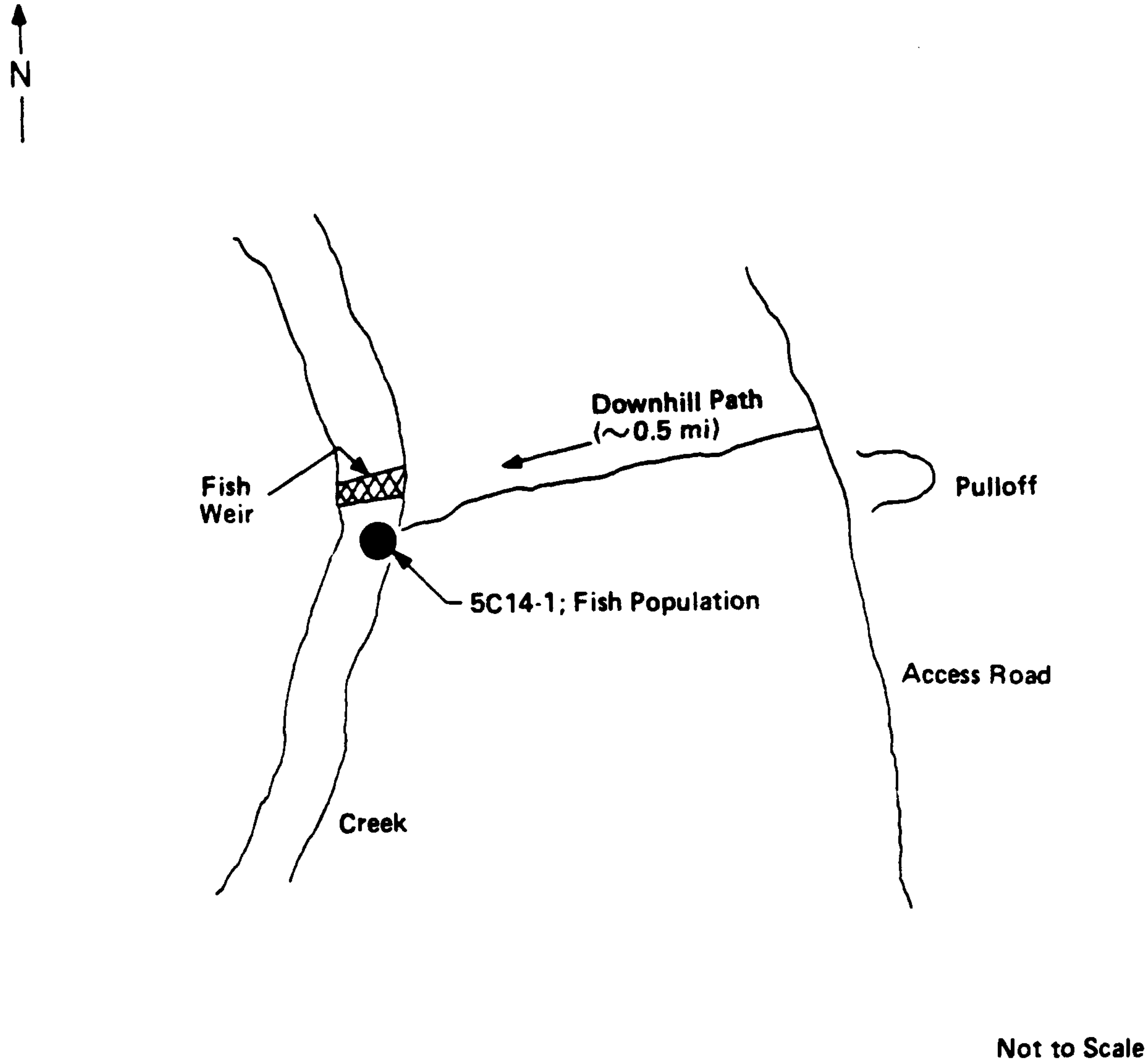


FIGURE E-5. MEASUREMENT POINT AT TM; 5C14-1.

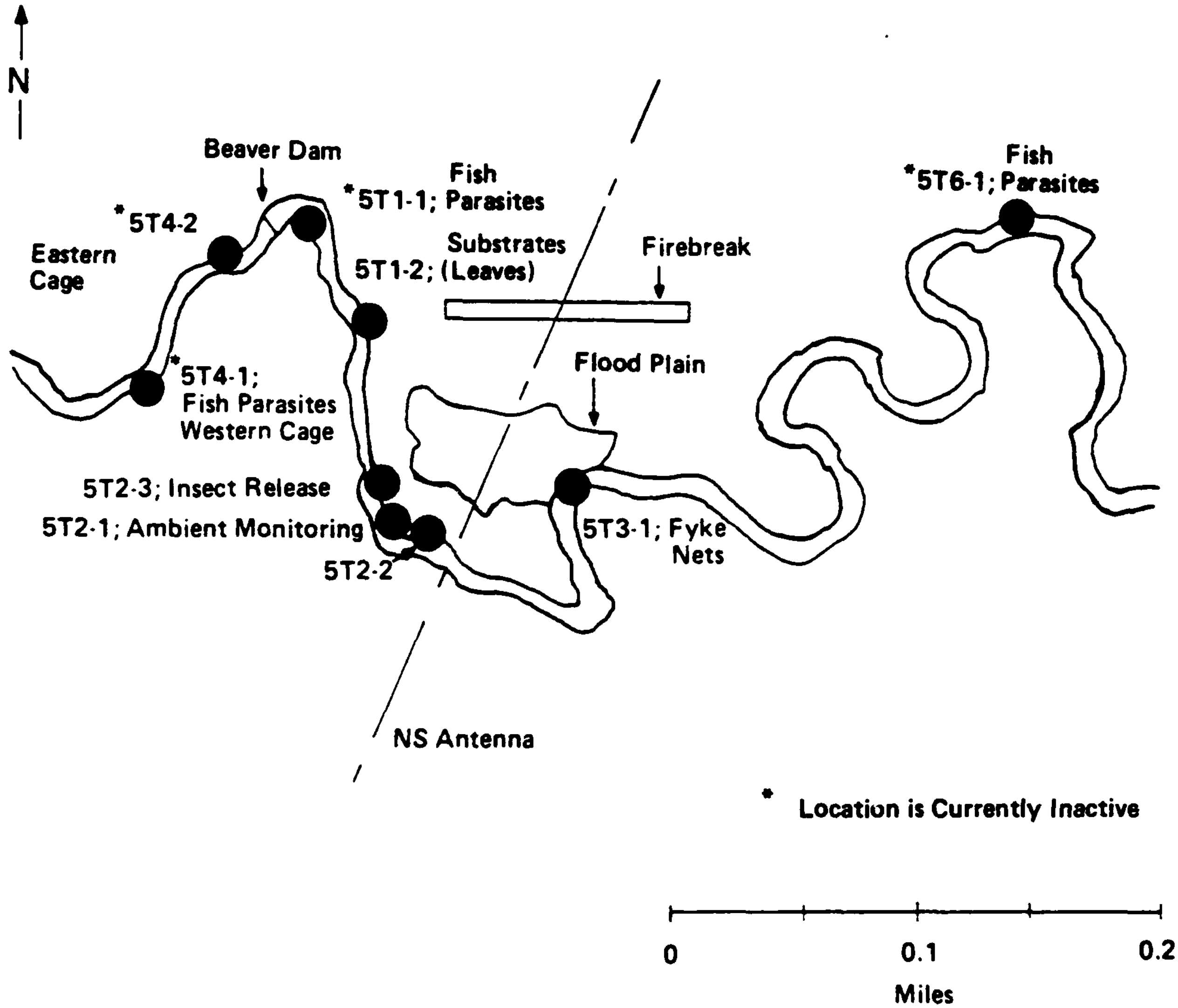
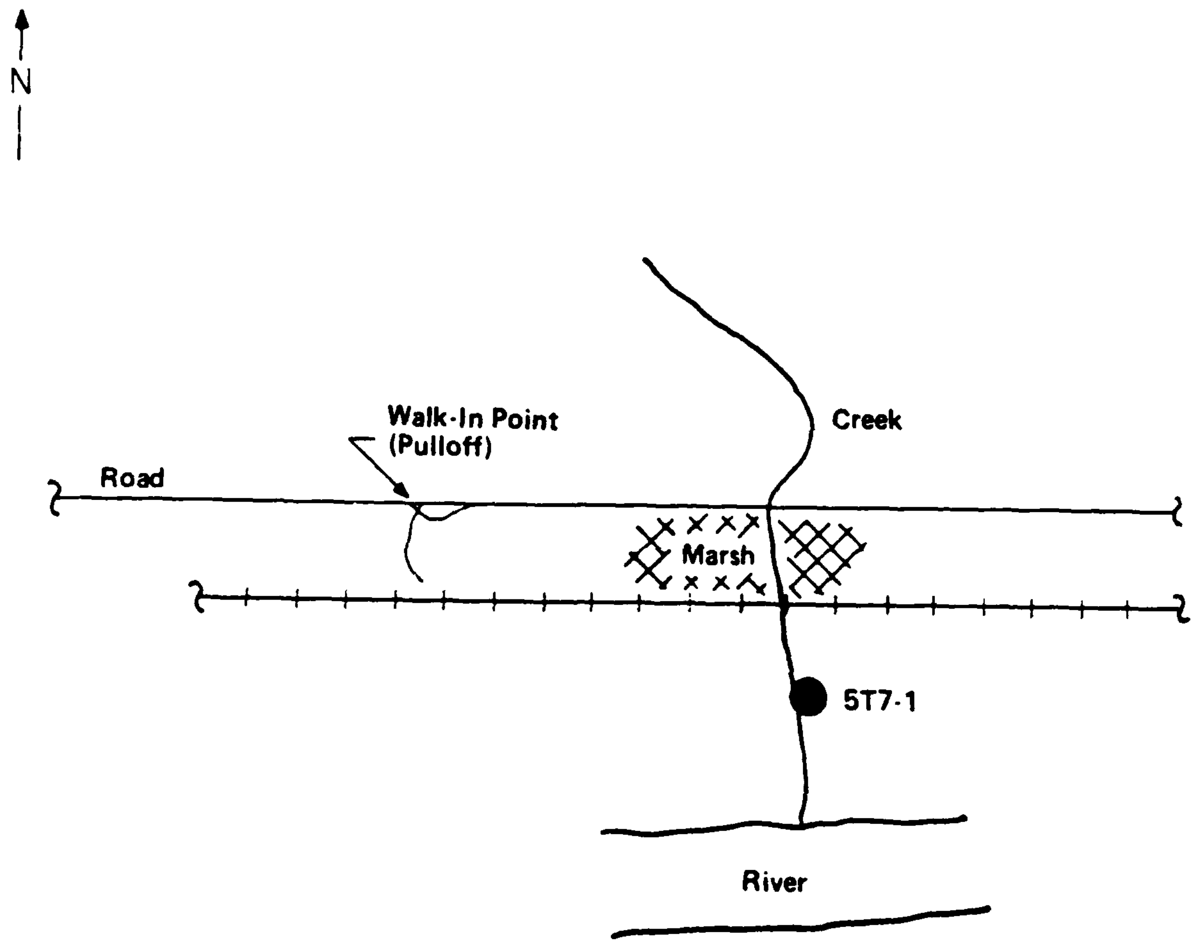


FIGURE E-6. MEASUREMENT POINTS AT FEX 1, FEX 2, FEX 4, FEX 6; 5T1-1, 2; 5T2-1, 2, 3; 5T3-1; 5T4-1, 2; 5T6-1.



Not to Scale

FIGURE E-7. MEASUREMENT POINT AT FEX 7; 5T7-1.

60297/189

TABLE E-2. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITES (V/m)
Aquatic Ecosystems Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
5C1-1	0.002	<0.001	-	-	-	-
5C1-2	<0.001	/	/	-	-	-
5C1-3	<0.001	/	/	-	-	-
5C1-4	-	<0.001	-	-	-	-
5C1-5	-	-	-	-	-	-
5C3-2	<0.001	0.003	-	-	-	-
5C5-1	0.001	<0.001	-	-	-	-
5C14-1	-	0.033	-	-	-	-
5T1-1	-	/	/	-	-	-
5T1-2	<0.001	-	-	-	-	-
5T2-1	-	-	-	-	-	-
5T2-2	-	-	-	-	<0.001	0.002
5T2-3	-	-	-	-	-	<0.001
5T3-1	-	-	-	-	0.001	<0.001
5T4-1	-	-	/	-	-	-
5T4-2	-	-	-	-	-	-
5T6-1	-	<0.001	-	-	-	<0.001
5T7-1	-	-	-	-	-	<0.001

[a] = prior to antenna construction.
[b] = antenna elements grounded at transmitter (condition 2).
[c] = antenna elements connected to transmitter, transmitter off (condition 9).
- = site measurement point not established.
- = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.
/ = data not taken.

TABLE E-3. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Aquatic Ecosystems Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
5C1-1	1.47, 1.73	2.7	2.6	0.22	0.26	0.32
5C1-2	1.8	/	/	0.155	0.160	0.21
5C1-3	1.3	/	/	0.126	0.148	0.179
5C1-4	-	2.5, 2.7	2.2	0.174	0.25	0.21
5C1-5	-	-	-	-	-	0.27
5C3-2	0.049	0.045	0.060	0.119	0.079	0.110
5C5-1	0.076	0.062	0.059	0.077	0.118	0.140
5C14-1	-	0.174, 0.24	0.22	0.187	0.31	0.41
5T1-1	0.38	0.38	/	0.125	0.062	0.093
5T1-2	0.184	0.154, 0.22	0.175	0.037	0.032	0.044
5T2-1	-	0.22, 0.31	0.23	0.057	0.061	0.126
5T2-2	-	0.26	0.165	0.082	0.076	0.198
5T2-3	-	-	-	0.050	0.056	0.063
5T3-1	-	0.22, 0.26	0.23	0.046	0.053	0.115
5T4-1	-	0.170, 0.195	/	0.032	0.028	0.035
5T4-2	-	-	-	0.073	0.048	0.064
5T6-1	-	0.37, 0.42	0.34	0.047	0.043	0.116
5T7-1	-	-	-	0.040	0.012	0.053

[a] = prior to antenna construction.
[b] = antenna elements grounded at transmitter (condition 2).
[c] = antenna elements connected to transmitter, transmitter off (condition 9).
- = site measurement point not established.
/ = data not taken.

TABLE E-4. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Aquatic Ecosystems Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
5C1-1	0.008	0.008	0.003	0.001	0.001	0.001
5C1-2	0.006	/	/	0.001	0.001	<0.001
5C1-3	0.004	/	/	0.001	0.001	0.001
5C1-4	-	0.007, 0.008	0.007	0.001	0.001	0.001
5C1-5	-	-	-	-	-	<0.001
5C3-2	0.003	0.003	0.003	0.005	0.004	0.009
5C5-1	0.002	0.002	0.002	0.001	0.001	0.002
5C14-1	-	0.013, 0.021	0.020	0.017	0.094	0.034
5T1-1	<0.001	<0.001	/	0.002	0.003	<0.001
5T1-2	<0.001	0.001	0.001	0.004	0.005	0.001
5T2-1	-	0.001, 0.002	0.001	0.005	0.009	0.015
5T2-2	-	0.002	0.001	0.014	0.021	0.047
5T2-3	-	-	-	0.004	0.007	0.007
5T3-1	-	0.001, 0.002	0.001	0.005	0.009	0.021
5T4-1	-	0.001	/	<0.001	0.002	<0.001
5T4-2	-	-	-	0.001	0.002	<0.001
5T6-1	-	0.001	0.001	0.001	0.002	0.003
5T7-1	-	-	-	0.001	0.001	0.005

[a] = prior to antenna construction.
[b] = antenna elements grounded at transmitter (condition 2).
[c] = antenna elements connected to transmitter, transmitter off (condition 9).
- = site measurement point not established.
/ = data not taken.

TABLE E-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Aquatic Ecosystems Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps) NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	1987 Exposures; Antenna Element, Current (Amps) NS(15) M	EW(15) M	1988 Exposures; Antenna Element, Current (Amps) NS(75) M	EW(75) M
5C1-1	~	~	~	~~	~	~	~	~
5C1-2	~	~	~	~~	~	~	~	~
5C1-3	~	~	~	~~	~	~	~	~
5C1-4	~	~	~	~~	~	~	~	~
5C1-5	-	-	-	-	-	-	~	~
5C3-2	~	~	~	~~	~	~	~	~
5C5-1	~	~	~	~~	~	~	~	~
5C14-1	~	~	~	~~	~	~	~	~
5T1-1	~	~	~	~~	0.009	~	0.037	0.001
5T1-2	~	~	~	~~	<0.001	~	0.014	0.002
5T2-1	0.001	~	~	~~	0.005	~	0.026	0.002
5T2-2	0.011	~	~	~~	0.022	<0.001	0.130	<0.001
5T2-3	~	~	~	~~	0.005	~	0.030	<0.001
5T3-1	0.008	~	~	~~	0.020	~	0.104	<0.001
5T4-1	~	~	~	~~	0.003	~	0.014	<0.001
5T4-2	~	~	~	~~	0.007	~	0.054	<0.001
5T6-1	~	~	~	~~	0.006	~	0.035	0.002
5T7-1	~	~	~	~~	/	~	0.014	<0.001

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).

\- = site measurement point not established.
~ = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.
~~ = data cannot be extrapolated.
/ = data not taken.

TABLE E-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Aquatic Ecosystems Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps) NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	1987 Exposures; Antenna Element, Current (Amps) NS(15) M	EW(15) M	1988 Exposures; Antenna Element, Current (Amps) NS(75) M	EW(75) M
5C1-1	0.33	0.020	0.052	0.087	1.33	0.158	6.8	0.81
5C1-2	0.24	0.016	0.053	0.088	1.07	0.186	4.9	0.76
5C1-3	0.191	0.013	0.047	0.078	0.85	0.130	4.1	0.73
5C1-4	0.26	0.014	0.075	0.125	1.02	0.160	4.6	0.64
5C1-5	-	-	-	-	-	-	7.1	0.83
5C3-2	0.013	0.002	0.007	0.012	0.067	0.023	0.26	0.091
5C5-1	0.034	0.002	0.009	0.015	0.138	0.035	0.68	0.150
5C14-1	0.042	0.004	0.015	0.025	0.183	0.055	0.81	0.25
5T1-1	2.5	0.080	0.108	0.180	7.5	0.33	46	1.47
5T1-2	0.77	0.034	0.097	0.162	2.9	0.30	16.1	1.61
5T2-1	1.33	0.045	0.077	0.128	5.4	0.22	25	1.16
5T2-2	1.62	0.052	0.067	0.112	6.1	0.184	31	0.100
5T2-3	1.17	0.042	0.079	0.132	4.9	0.23	21	1.18
5T3-1	1.22	0.045	0.082	0.137	4.8	0.27	18.8	1.07
5T4-1	0.75	0.026	0.061	0.102	3.0	0.182	17.3	1.06
5T4-2	1.91	0.056	0.077	0.128	5.3	0.21	37	1.06
5T6-1	1.21	0.030	0.066	0.110	4.5	0.20	24	0.96
5T7-1	0.76	0.033	0.072	0.120	2.6	0.189	15.3	1.09

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
\- = site measurement point not established.

TABLE E-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Aquatic Ecosystems Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)		1988 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M	NS(75) M	EW(75) M
5C1-1	0.001	<0.001	<0.001	~~	0.005	0.001	0.022	0.005
5C1-2	0.001	<0.001	<0.001	~~	0.005	0.001	0.022	0.005
5C1-3	0.001	<0.001	<0.001	~~	0.005	0.001	0.022	0.005
5C1-4	0.001	<0.001	<0.001	~~	0.005	0.001	0.022	0.005
5C1-5	-	-	-	-	-	-	0.022	0.005
5C3-2	0.001	<0.001	<0.001	~~	0.003	0.001	0.016	0.004
5C5-1	0.003	<0.001	0.001	0.002	0.013	0.002	0.061	0.007
5C14-1	0.001	<0.001	<0.001	~~	0.005	0.001	0.024	0.004
5T1-1	0.045	0.001	<0.001	~~	0.170	0.002	0.81	0.006
5T1-2	0.063	0.002	<0.001	~~	0.25	0.002	1.19	0.006
5T2-1	0.129	0.004	0.001	0.002	0.50	0.002	2.3	0.008
5T2-2	0.31	0.009	0.001	0.002	1.20	0.003	5.5	0.018
5T2-3	0.110	0.003	~	~~	0.41	0.002	1.90	0.007
5T3-1	0.137	0.004	0.001	0.002	0.51	0.001	2.6	0.014
5T4-1	0.028	0.001	<0.001	~~	0.118	0.002	0.58	0.007
5T4-2	0.033	0.001	<0.001	~~	0.123	0.002	0.60	0.006
5T6-1	0.029	0.001	0.001	0.002	0.109	0.002	0.51	0.008
5T7-1	0.011	<0.001	0.001	0.002	0.040	0.002	0.20	0.008

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).

- = site measurement point not established.
~~ = data cannot be extrapolated.

TABLE E-8. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Aquatic Ecosystems Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations		1988 Extrapolations	
	NS	NEW	SEW	NS	EW	NS	EW
5C1-1	--	--	--	--	--	--	--
5C1-2	--	--	--	--	--	--	--
5C1-3	--	--	--	--	--	--	--
5C1-4	--	--	--	--	--	--	--
5C1-5	-	-	-	-	-	--	--
5C3-2	--	--	--	--	--	--	--
5C5-1	--	--	--	--	--	--	--
5C14-1	--	--	--	--	--	--	--
5T1-1	--	--	--	0.090	--	0.074	0.002
5T1-2	--	--	--	--	--	0.028	0.004
5T2-1	0.038	--	--	0.050	--	0.052	0.004
5T2-2	0.41	--	--	0.22	--	0.26	--
5T2-3	--	--	--	0.050	--	0.060	--
5T3-1	0.30	--	--	0.20	--	0.21	--
5T4-1	--	--	--	0.030	--	0.028	--
5T4-2	--	--	--	0.070	--	0.108	--
5T6-1	--	--	--	0.060	--	0.070	0.004
5T7-1	--	--	--	/	--	0.028	--

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
- = site measurement point not established.
-- = data cannot be extrapolated.
/ = data not taken.

TABLE E-9. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Aquatic Ecosystems Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations		1988 Extrapolations	
	NS	NEW	SEW	NS	EW	NS	EW
5C1-1	12.4	0.50	1.30	13.3	1.58	13.6	1.62
5C1-2	9.0	0.40	1.33	10.7	1.86	9.8	1.52
5C1-3	7.2	0.33	1.18	8.5	1.30	8.1	1.46
5C1-4	9.8	0.35	1.88	10.2	1.60	9.2	1.28
5C1-5	-	-	-	-	-	14.1	1.66
5C3-2	0.49	0.050	0.175	0.67	0.23	0.52	0.182
5C5-1	1.28	0.050	0.23	1.38	0.35	1.36	0.30
5C14-1	1.58	0.100	0.38	1.83	0.55	1.62	0.50
5T1-1	94	2.0	2.7	75	3.3	92	2.9
5T1-2	29	0.85	2.4	29	3.0	32	3.2
5T2-1	50	1.13	1.93	54	2.2	50	2.3
5T2-2	61	1.30	1.68	61	1.84	62	0.20
5T2-3	44	1.05	1.98	49	2.3	42	2.4
5T3-1	46	1.13	2.1	48	2.7	38	2.1
5T4-1	28	0.65	1.53	30	1.82	35	2.1
5T4-2	72	1.40	1.93	53	2.1	74	2.1
5T6-1	45	0.75	1.65	45	2.0	48	1.92
5T7-1	29	0.83	1.80	26	1.89	31	2.2

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
\- = site measurement point not established.

TABLE E-10. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Aquatic Ecosystems Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations		1988 Extrapolations	
	NS	NEW	SEW	NS	EW	NS	EW
5C1-1	0.038	--	--	0.050	0.010	0.044	0.010
5C1-2	0.038	--	--	0.050	0.010	0.044	0.010
5C1-3	0.038	--	--	0.050	0.010	0.044	0.010
5C1-4	0.038	--	--	0.050	0.010	0.044	0.010
5C1-5	-	-	-	-	-	0.044	0.010
5C3-2	0.038	--	--	0.030	0.010	0.032	0.008
5C5-1	0.113	--	0.025	0.130	0.020	0.122	0.014
5C14-1	0.038	--	--	0.050	0.010	0.048	0.008
5T1-1	1.69	0.025	--	1.70	0.020	1.62	0.012
5T1-2	2.4	0.050	--	2.5	0.020	2.4	0.012
5T2-1	4.8	0.100	0.025	5.0	0.020	4.6	0.016
5T2-2	11.6	0.23	0.025	12.0	0.030	11.0	0.036
5T2-3	4.1	0.075	--	4.1	0.020	3.8	0.014
5T3-1	5.1	0.100	0.025	5.1	0.010	5.2	0.028
5T4-1	1.05	0.025	--	1.18	0.020	1.16	0.014
5T4-2	1.24	0.025	--	1.23	0.020	1.20	0.012
5T6-1	1.09	0.025	0.025	1.09	0.020	1.02	0.016
5T7-1	0.41	--	0.025	0.40	0.020	0.40	0.016

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
\- = site measurement point not established.
-- = data cannot be extrapolated.

The 1988 60 Hz measurements showed the same trends in EM field magnitudes as were reported in 1986 and 1987. That is, the 60 Hz magnetic flux densities increased and the longitudinal electric fields decreased near the antenna wire(s) in comparison to measurements made at these sites prior to antenna construction. This is the result of 60 Hz currents from power lines coupled to the ELF antenna elements, which then reradiate 60 Hz EM fields. Because of this coupling, year-to-year variations in the 60 Hz EM field levels at the test sites are effected by and are generally consistent with expected fluctuations in regional power line load currents.

The EM fields generated by the 60 Hz currents on the antenna wires are localized near the antennas and do not affect the 60 Hz EM fields at the control sites. However, the 60 Hz EM field levels at these locations can be influenced by 60 Hz currents coupled to, and EM fields reradiated from, nearby railroads or pipelines, as well as by EM fields directly generated by local power lines. In any event, the 60 Hz EM fields measured at the control sites in 1988 were consistent with measurements from previous years.

76 Hz measurements were made in 1988 with 75 ampere antenna currents, the predominant MTF operating mode from July through December. The EM field exposures at the study sites for the period prior to July can be estimated either by using the 15 ampere antenna current measurement data from 1987 or more accurately by using one-fifth the value of the 1988 75 ampere data.

The measured EM field magnitudes for each antenna element for 1986-1988 have been linearly extrapolated to the planned operational antenna current of 150 amperes. Extrapolations were not performed when the measurements indicated that the EM field magnitudes were below the minimum sensitivity of the EM field sensors.

The 1988 extrapolations are the most accurate predictions of the EM field levels at the planned operational antenna current because the 1988 half-power EM field measurements are more accurate than those made at lower antenna currents in previous years. The 1988 extrapolations also reflect the operational configuration and tuning of the antenna elements with the new power amplifiers.

The maximum 76 Hz EM field intensities that can occur during simultaneous operation of both antennas at any antenna phasing can be estimated by calculating the algebraic sum of the levels from the individual antenna element extrapolations; minimum intensities can be estimated by calculating the algebraic difference.

APPENDIX F

SOIL AMOEBAE STUDIES

SOIL AMOEBAE STUDIES

On 20, 23, and 27 September 1988, IITRI field crews made ELF electromagnetic (EM) field measurements at nine measurement points at a total of two test sites and one control site for the soil amoebae studies. The study sites and the measurement points within those sites were unchanged from 1987.

The positions of the study sites relative to the MTF are shown on the composite map in Figure F-1. The site numbers listed on the map are those used by IITRI. Table F-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are shown in Figures F-2 through F-4.

The objectives of these studies are to monitor population and species characteristics, cell cycle, cropping efficiency, and distribution in the soil. The electric and magnetic fields in the earth are considered the most important EM factors to be examined. The electric field in the air is not expected to have a significant impact on the objectives of these studies.

EM field measurements for 1988 and previous years are found in Tables F-2 through F-10. Tables F-2, F-3, and F-4 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables F-5, F-6, and F-7 present 76 Hz data for these three fields at 1986, 1987, and 1988 MTF operating currents. Tables F-8, F-9, and F-10 present 76 Hz data extrapolated to a full-power condition of 150 amperes.

TABLE F-1. SITE NO. CROSS-REFERENCE
Soil Amoebae Studies

IITRI Site No.	Investigator's Site Name	Location		
		Township	Range	Section(s)
6T3	Leeman's Road	T43N	R29W	23
6T4	Wells Grade Ground	T42N	R29W	2
6C2	Merriman Truck Trail Control	T41N	R29W	21

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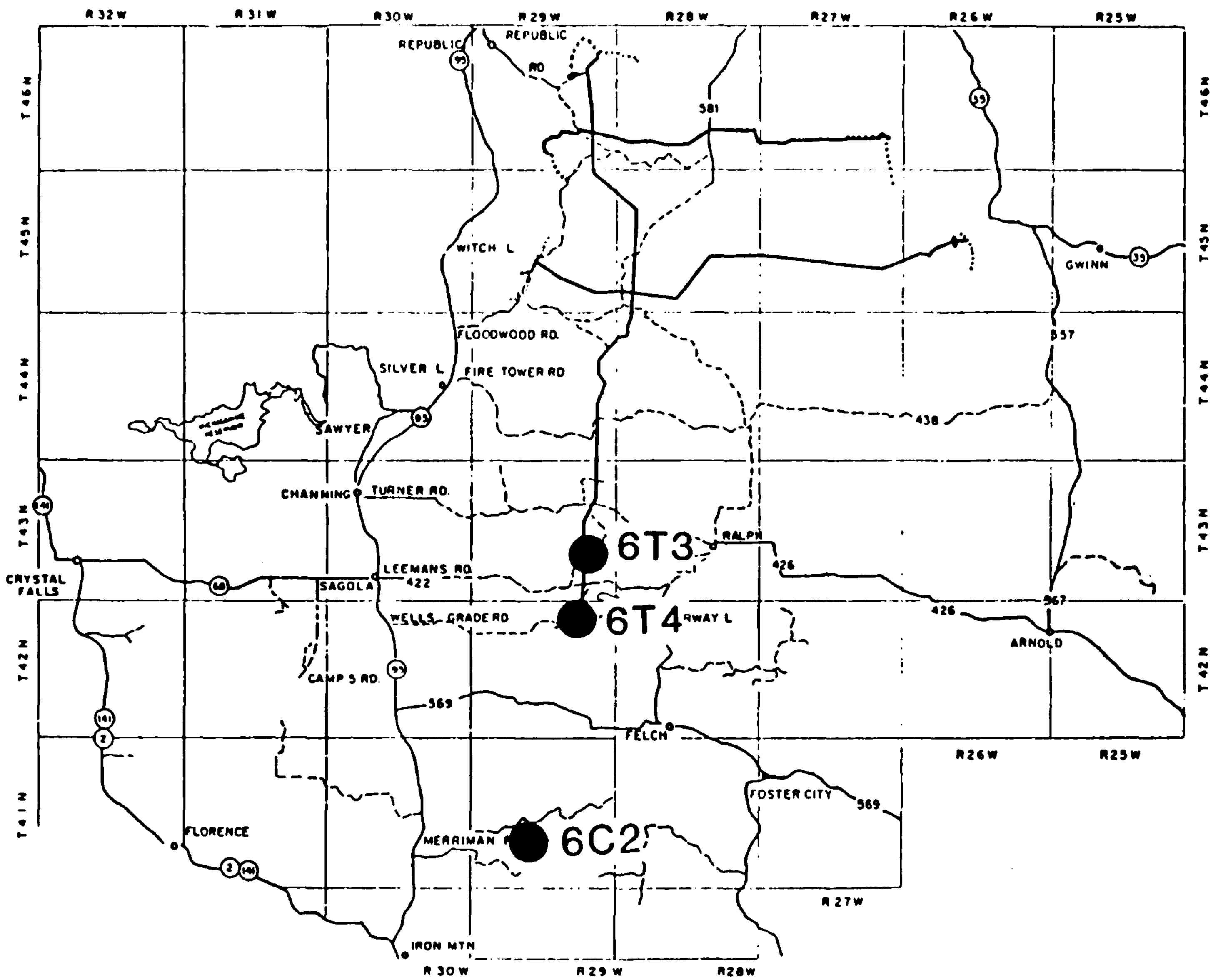

FIGURE F-1. POSITIONS OF SOIL AMOEBAE STUDY SITES RELATIVE TO MICHIGAN TRANSITTING FACILITY ANTENNA ELEMENTS.

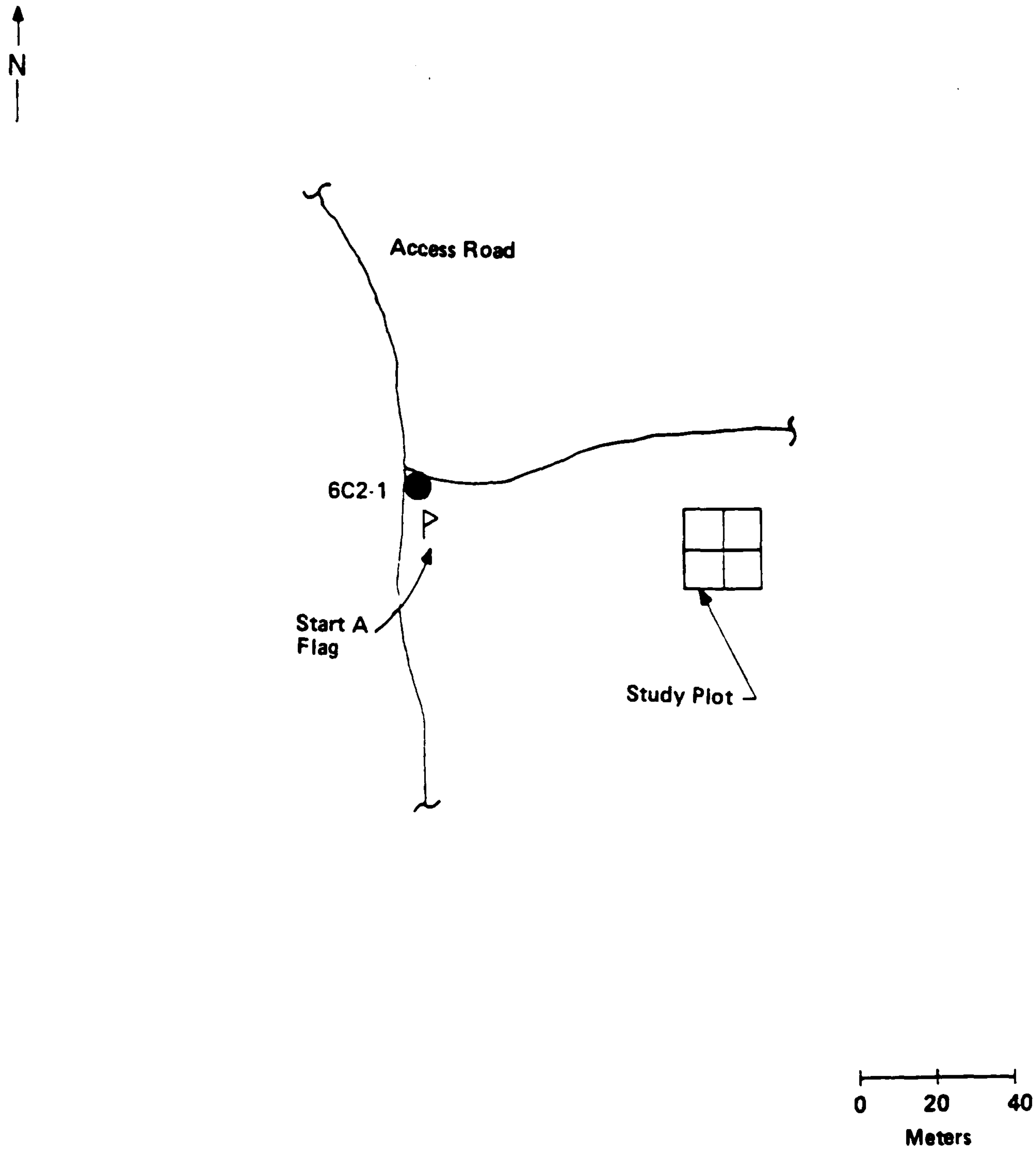

FIGURE F-2. MEASUREMENT POINT AT MERRIMAN TRUCK TRAIL CONTROL; 6C2-1.

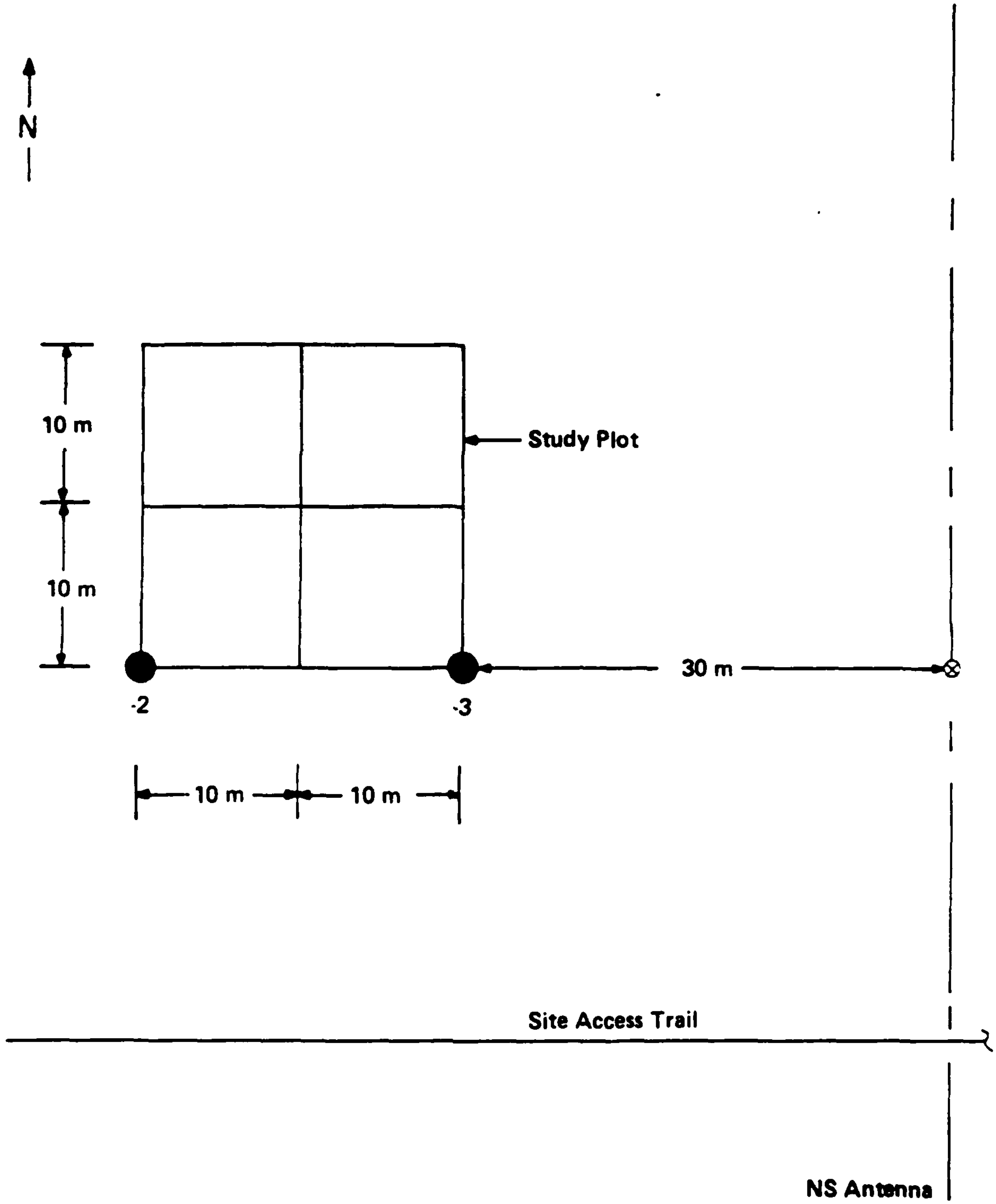

FIGURE F-3. MEASUREMENT POINTS AT LEEMAN'S ROAD; 6T3-2, 3.

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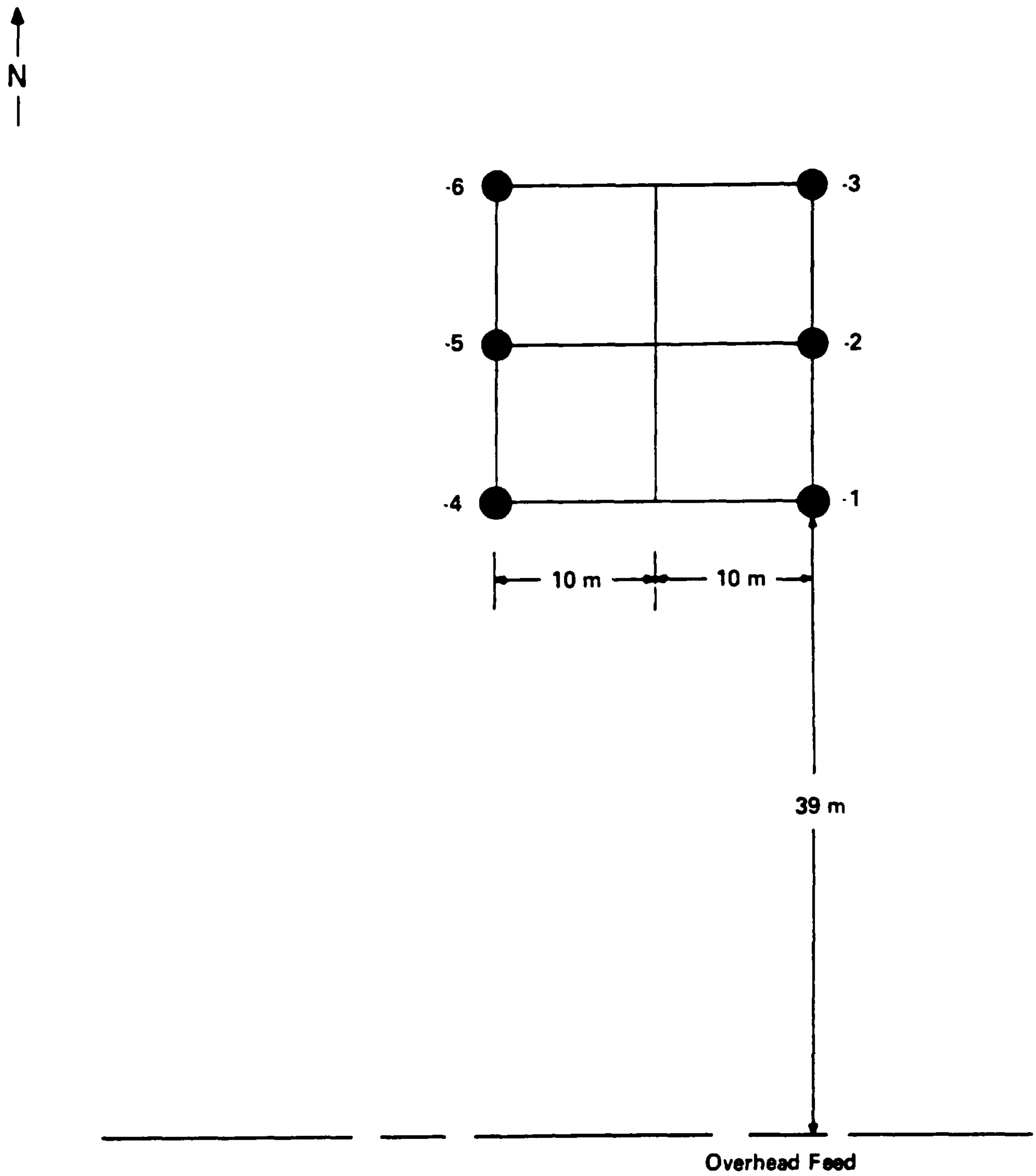


FIGURE F-4. MEASUREMENT POINTS AT WELLS GRADE GROUND; 6T4-1 THROUGH 6.

TABLE F-2. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITES (V/m)
Soil Amoebae Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
6C2-1	<0.001	~	~	~	~	~
6T3-2	-	~	~	~	~	~
6T3-3	-	-	~	~	~	~
6T4-1	-	~	~	~	~	~
6T4-2	-	-	-	~	~	<0.001
6T4-3	-	-	-	~	~	~
6T4-4	-	-	-	~	~	~
6T4-5	-	-	-	~	~	~
6T4-6	-	-	-	~	~	~

[a] = prior to antenna construction.
[b] = antenna elements grounded at transmitter (condition 2).
[c] = antenna elements connected to transmitter, transmitter off (condition 9).
- = site measurement point not established.
~ = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.

TABLE F-3. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Soil Amoebae Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
6C2-1	0.32	0.61	0.194, 0.28	0.058	0.256	0.98
6T3-2	0.087	0.130	/	0.085	0.125	0.35
6T3-3	-	-	0.134	0.078	0.130	0.41
6T4-1	-	0.48, 0.52	/	0.072	0.32	0.18
6T4-2	-	-	-	0.046	0.162	0.145
6T4-3	-	-	-	0.065	0.082	0.24
6T4-4	-	-	-	0.037	0.24	0.27
6T4-5	-	-	-	0.053	0.182	0.18
6T4-6	-	-	-	0.098	0.084	0.33

[a] = prior to antenna construction.
[b] = antenna elements grounded at transmitter (condition 2).
[c] = antenna elements connected to transmitter, transmitter off (condition 9).
- = site measurement point not established.
/ = data not taken.

TABLE F-4. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Amoebae Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
6C2-1	0.004	0.008	0.001, 0.003	0.002	0.003	0.011
6T3-2	-	0.002	/	0.020	0.023	0.065
6T3-3	-	-	0.003	0.013	0.033	0.103
6T4-1	-	0.005, 0.007	/	0.005	0.006	0.019
6T4-2	-	-	-	0.005	0.006	0.016
6T4-3	-	-	-	0.004	0.005	0.014
6T4-4	-	-	-	0.002	0.006	0.018
6T4-5	-	-	-	0.003	0.006	0.017
6T4-6	-	-	-	0.005	0.005	0.015

[a] = prior to antenna construction.
[b] = antenna elements grounded at transmitter (condition 2).
[c] = antenna elements connected to transmitter, transmitter off (condition 9).
- = site measurement point not established.
/ = data not taken.

TABLE F-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Soil Amoebae Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps) NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	1987 Exposures; Antenna Element, Current (Amps) NS(15) M	EW(15) M	1988 Exposures; Antenna Element, Current (Amps) NS(75) M	EW(75) M
6C2-1	~	~	~	~~	~	~	~	~
6T3-2	~	~	~	~~	0.005	~	0.027	~
6T3-3	~	~	~	~~	0.005	~	0.028	~
6T4-1	~	~	~	~~	0.020	~	0.047	~
6T4-2	~	~	~	~~	0.007	~	0.022	<0.001
6T4-3	~	~	~	~~	0.004	~	0.030	~
6T4-4	~	~	~	~~	0.014	~	0.035	~
6T4-5	~	~	~	~~	0.007	~	0.036	<0.001
6T4-6	~	~	~	~~	0.004	~	0.043	~

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
~ = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.
~~ = data cannot be extrapolated.

TABLE F-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Soil Amoebae Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)		1988 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M	NS(75) M	EW(75) M
6C2-1	0.028	0.010	0.011	0.018	0.068	0.028	0.36	0.140
6T3-2	1.34	0.041	0.030	0.050	5.4	0.087	21	0.47
6T3-3	1.45	0.046	0.040	0.067	5.9	0.110	25	0.46
6T4-1	1.73	0.059	0.007	0.012	18.9	0.056	25	0.22
6T4-2	0.72	0.023	0.009	0.015	8.5	0.038	12.4	0.150
6T4-3	1.14	0.035	0.018	0.030	4.3	0.031	21	0.191
6T4-4	1.31	0.042	0.006	0.010	12.8	0.040	21	0.174
6T4-5	0.78	0.027	0.012	0.020	10.2	0.045	15.5	0.194
6T4-6	1.27	0.040	0.015	0.025	4.4	0.034	26	0.22

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).

TABLE F-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Amoebae Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps) NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	1987 Exposures; Antenna Element, Current (Amps) NS(15) M	EW(15) M	1988 Exposures; Antenna Element, Current (Amps) NS(75) M	EW(75) M
6C2-1	<0.001	<0.001	<0.001	--	<0.001	<0.001	0.002	0.001
6T3-2	0.170	0.006	0.001	0.002	0.64	0.003	3.1	0.007
6T3-3	0.28	0.009	0.001	0.002	1.03	0.004	4.9	0.011
6T4-1	0.100	0.003	0.001	0.002	0.35	0.001	1.82	0.007
6T4-2	0.082	0.003	0.001	0.002	0.29	0.001	1.50	0.006
6T4-3	0.071	0.002	<0.001	--	0.26	0.001	1.30	0.005
6T4-4	0.090	0.003	0.001	0.002	0.38	0.001	1.64	0.006
6T4-5	0.078	0.002	<0.001	--	0.27	<0.001	1.41	0.006
6T4-6	0.067	0.002	<0.001	--	0.24	0.001	1.22	0.005

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
-- = data cannot be extrapolated.

TABLE F-8. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Soil Amoebae Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations		1988 Extrapolations	
	NS	NEW	SEW	NS	EW	NS	EW
6C2-1	--	--	--	--	--	--	--
6T3-2	--	--	--	0.050	--	0.054	--
6T3-3	--	--	--	0.050	--	0.056	--
6T4-1	--	--	--	0.20	--	0.094	--
6T4-2	--	--	--	0.070	--	0.044	--
6T4-3	--	--	--	0.040	--	0.060	--
6T4-4	--	--	--	0.140	--	0.070	--
6T4-5	--	--	--	0.070	--	0.072	--
6T4-6	--	--	--	0.040	--	0.086	--

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
-- = data cannot be extrapolated.

TABLE F-9. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Soil Amoebae Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations		1988 Extrapolations	
	NS	NEW	SEW	NS	EW	NS	EW
6C2-1	1.05	0.25	0.28	0.68	0.28	0.72	0.28
6T3-2	50	1.03	0.75	54	0.87	42	0.94
6T3-3	54	1.15	1.00	59	1.10	50	0.92
6T4-1	65	1.48	0.175	189	0.56	50	0.44
6T4-2	27	0.58	0.23	85	0.38	25	0.30
6T4-3	43	0.88	0.45	43	0.31	42	0.38
6T4-4	49	1.05	0.150	128	0.40	42	0.35
6T4-5	29	0.68	0.30	102	0.45	31	0.39
6T4-6	48	1.00	0.38	44	0.34	52	0.44

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).

TABLE F-10. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Amoebae Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations		1988 Extrapolations	
	NS	NEW	SEW	NS	EW	NS	EW
6C2-1	--	--	--	--	--	0.004	0.002
6T3-2	6.4	0.150	0.025	6.4	0.030	6.2	0.014
6T3-3	10.5	0.23	0.025	10.3	0.040	9.8	0.022
6T4-1	3.8	0.075	0.025	3.5	0.010	3.6	0.014
6T4-2	3.1	0.075	0.025	2.9	0.010	3.0	0.012
6T4-3	2.7	0.050	--	2.6	0.010	2.6	0.010
6T4-4	3.4	0.075	0.025	3.8	0.010	3.3	0.012
6T4-5	2.9	0.050	--	2.7	--	2.8	0.012
6T4-6	2.5	0.050	--	2.4	0.010	2.4	0.010

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
-- = data cannot be extrapolated.

The 1988 60 Hz measurements showed the same trends in EM field magnitudes as were reported in 1986 and 1987. That is, the 60 Hz magnetic flux densities increased and the longitudinal electric fields decreased near the antenna wire(s) in comparison to measurements made at these sites prior to antenna construction. This is the result of 60 Hz currents from power lines coupled to the ELF antenna elements, which then reradiate 60 Hz EM fields. Because of this coupling, year-to-year variations in the 60 Hz EM field levels at the test sites are effected by and are generally consistent with expected fluctuations in regional power line load currents.

The EM fields generated by the 60 Hz currents on the antenna wires are localized near the antennas and do not affect the 60 Hz EM fields at the control site. However, the 60 Hz EM field levels at this location can be influenced directly by local power lines. The 60 Hz EM fields measured at the control site in 1988 were consistent with measurements from previous years.

76 Hz measurements were made in 1988 with 75 ampere antenna currents, the predominant MTF operating mode from July through December. The EM field exposures at the study sites for the period prior to July can be estimated either by using the 15 ampere antenna current measurement data from 1987 or more accurately by using one-fifth the value of the 1988 75 ampere data. This ratio is quite accurate for all EM fields and sites with the exception of the longitudinal electric field at the ground site. Here, the electric field behaves more erratically, most likely because of local variations in soil conductivity. Variations in soil conductivity are expected to affect the longitudinal electric field near ground terminals to a greater degree than other fields for reasons discussed in Section 4.5 of this report.

The measured EM field magnitudes for each antenna element for 1986-1988 have been linearly extrapolated to the planned operational antenna current of 150 amperes. Extrapolations were not performed when the measurements indicated that the EM field magnitudes were below the minimum sensitivity of the EM field sensors.

The 1988 extrapolations are the most accurate predictions of the EM field levels at the planned operational antenna current because the 1988 half-power EM field measurements are more accurate than those made at lower antenna currents in previous years. The 1988 extrapolations also reflect the operational configuration and tuning of the antenna elements with the new power amplifiers.

The maximum 76 Hz EM field intensities that can occur during simultaneous operation of both antennas at any antenna phasing can be estimated by calculating the algebraic sum of the levels from the individual antenna element extrapolations; minimum intensities can be estimated by calculating the algebraic difference.

APPENDIX G

BIRD SPECIES AND COMMUNITIES STUDIES

BIRD SPECIES AND COMMUNITIES STUDIES

On 15-19 August 1988, IITRI field crews made ELF electromagnetic (EM) field measurements at 22 measurement points at a total of five test and five control transects for the bird species and communities studies in Wisconsin. Measurements at 24 points at the five test and five control transects in Michigan were conducted on 21, 23, 29, and 30 September and 4-6 October. The study transects and the measurement points within those transects were unchanged from 1987. In addition, randomly chosen test and control transects in Wisconsin (10C7 and 10T8) were examined in more detail; measurements were taken along these transects at their start and finish, and between the eight subsegments at each "X" flag. These data were taken to determine typical EM field variability along study transects. Measurements were also taken on a line perpendicular to the WTF NS antenna and to study transect 10T8 to characterize EM field gradients as a function of distance from the antenna wire.

The positions of the 10 Wisconsin transects and 10 Michigan transects relative to the WTF and MTF, respectively, are shown on the composite maps in Figures G-1 and G-2. The transect numbers listed on the map are those used by IITRI. Table G-1 provides a cross-reference of IITRI transect numbers, investigator transect names, and township, range, and section numbers for the transects in both Wisconsin and Michigan.

The bird species and communities studies monitor migrating bird population using a census technique that involves variable-width transects. The study involves monitoring the total population of migrating birds in an area both as a whole and as individual species. The electric and magnetic fields in the air are considered the most important EM factors influencing migrating birds; however, the electric field in the earth may also have an influence.

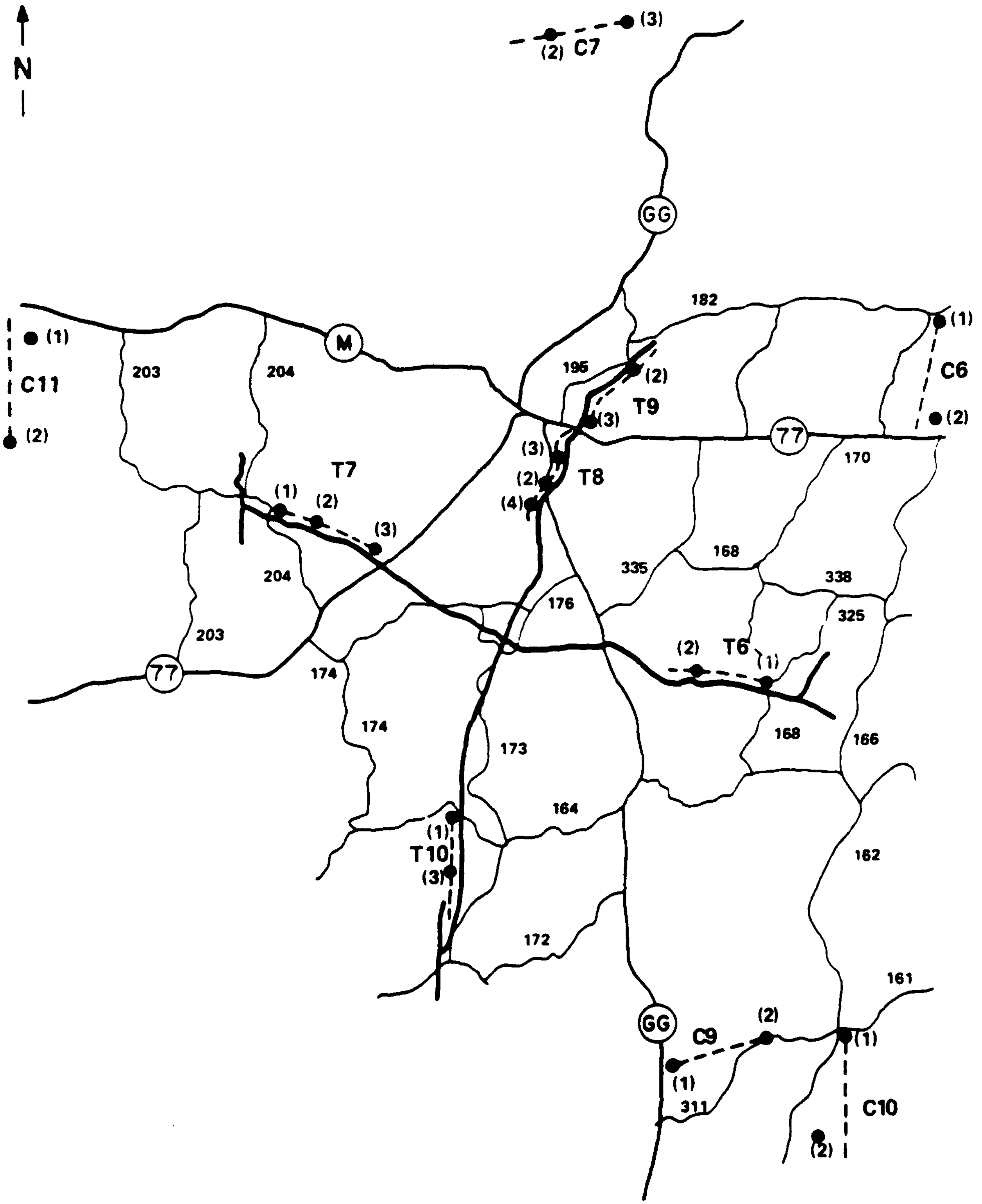


FIGURE G-1. POSITIONS OF BIRD SPECIES AND COMMUNITIES STUDY TRANSECTS RELATIVE TO WISCONSIN TRANSMITTING FACILITY ANTENNA ELEMENTS.

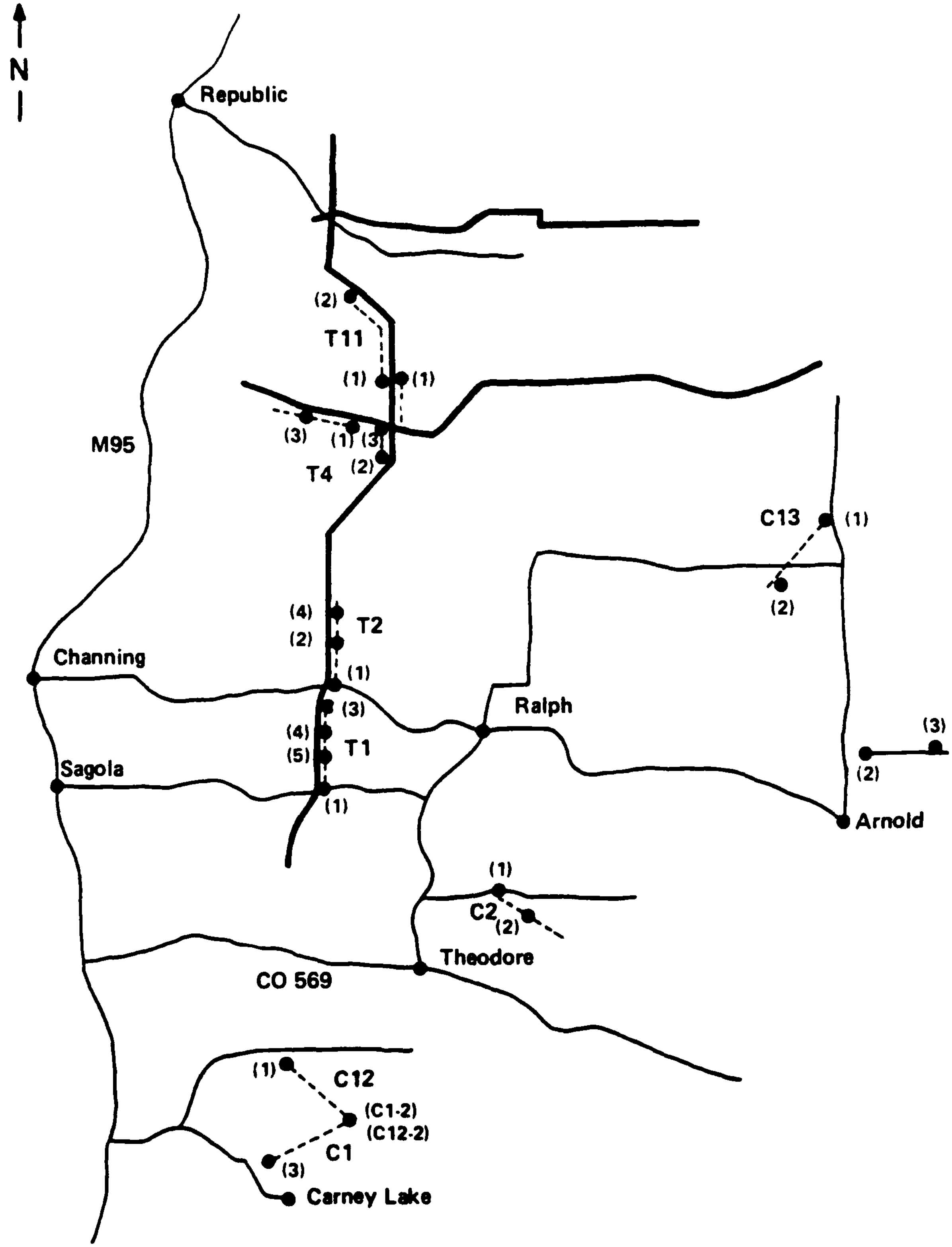


FIGURE G-2. POSITIONS OF BIRD SPECIES AND COMMUNITIES STUDY TRANSECTS RELATIVE TO MICHIGAN TRANSMITTING FACILITY ANTENNA ELEMENTS.

TABLE G-1. TRANSECT NO. CROSS-REFERENCE
Bird Species and Communities Studies

IITRI Transect No.	Investigator's Transect Name	Location				
		Township	:	Range	:	Section(s)
Wisconsin						
10C6	Spillerberg Lake	T43N	:	R3W	:	23, 26, 35
10C7	Mineral Lake	T44N	:	R4W	:	15, 16, 17, 18
10C9	Blaisdell Lake	T40N	:	R3W	:	18
		T40N	:	R4W	:	13, 14, 22, 23
10C10	Brunet River	T40N	:	R3W	:	16, 21, 28
10C11	Rock Lake	T42N	:	R6W	:	6
		T43N	:	R6W	:	19, 30, 31
10T6	Moose River	T42N	:	R3W	:	31
		T42N	:	R4W	:	35, 36
10T7	Christy Lake	T42N	:	R5W	:	7, 8, 15, 16, 17
10T8	Little Clam Lake	T42N	:	R4W	:	5, 8, 17
10T9	Woodtick Lake	T43N	:	R4W	:	22, 23, 27, 28, 33
10T10	Black Lake	T41N	:	R5W	:	24, 25, 36
Michigan						
10C1	Carney Lake	T41N	:	R29W	:	33, 34, 35, 36
10C2	Skunk Creek	T42N	:	R27W	:	19, 30
		T42N	:	R28W	:	14, 23, 24
10C5	Arnold	T43N	:	R25W	:	31, 32, 33, 34
10C12	Lost Lake	T41N	:	R29W	:	21, 26, 27, 28, 35
10C13	Bob's Creek	T44N	:	R26W	:	13, 23, 24, 26
10T1	Leeman's Road	T43N	:	R29W	:	14, 23, 26, 35
10T2	Turner Road	T43N	:	R29W	:	1, 12
		T44N	:	R29W	:	36
10T3	Flat Rock Creek	T45N	:	R28W	:	19, 30, 31
10T4	Schwartz Creek	T45N	:	R28W	:	31
		T45N	:	R29W	:	26, 27, 35, 36
10T11	Heart Lake	T45N	:	R28W	:	7, 18, 19
		T45N	:	R29W	:	1, 12

Wisconsin Measurements

Historical Measurements

EM field measurements for Wisconsin for 1988 and previous years are found in Tables G-2, G-3, and G-4, which present 76 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Since 1986, all measurements have been made during simultaneous phased operation of both antenna elements; prior to 1986, control of antenna conditions was possible, and EM field measurements were made under individual antenna operation modes. These data are included in the tables. There were no significant changes in the 76 Hz EM field intensities in Wisconsin in 1988. Some year-to-year variations in the longitudinal electric field intensities are indicated, which were likely caused by annual and seasonal variations in soil conductivity.

Since mid-1985, measurement of 60 Hz ambient EM fields has not been possible at the WTF because of its full-time operating status and modulated signal. 60 Hz measurement data from 1984 and early 1985 are given in Table G-5.

EM Gradients Perpendicular to Antenna

Measurements made at regular intervals on a line perpendicular to the WTF NS antenna and to study transect 10T8 are shown in Table G-6. These data define typical gradients of 76 Hz longitudinal electric field intensity and magnetic flux density across the study transect. Graphs of these data are presented and discussed in Section 4.4 of this report.

EM Field Variations Along Study Transects

Data for electric and magnetic fields along transects 10C7 and 10T8 are shown in Table G-7. Measurements were taken at the start and finish of each transect, as well as between transect subsegments at each "X" flag. Table G-7 also includes data from applicable historical measurement locations. The EM field intensities along transects 10C7 and 10T8 are presented graphically and discussed in Section 4.4 of this report.

TABLE G-2. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Bird Species and Communities Studies
Wisconsin Transects

Site No.	1984		1985			1986	1987	1988
Meas. Pt.	NS	EW	NS	EW	B(-75)	B(-75)	B(-75)	B(-75)
10C6-1	-	-	/	/	-	-	-	-
10C6-2	-	-	/	/	-	-	-	-
10C7-2	-	-	-	/	-	-	-	-
10C7-3	-	-	-	-	-	-	-	-
10C9-1	-	-	/	/	-	-	-	-
10C9-2	-	-	/	/	-	-	-	-
10C10-1	-	-	/	/	-	-	-	-
10C10-2	-	-	/	/	-	-	--	--
10C10-3	-	-	-	-	-	-	-	-
10C11-1	-	-	-	-	-	-	-	-
10C11-2	-	-	-	-	-	-	-	-
10T6-1	0.006	0.195	/	/	/	0.166	0.22	0.22
10T6-2	0.014	0.107	/	/	/	0.090	0.077	0.135
10T7-1	/	/	/	/	/	0.20	0.136	0.182
10T7-2	0.014	0.156	/	/	/	0.117	0.116	0.129
10T7-3	0.015	0.183	/	/	/	0.129	0.110	0.121
10T8-2	0.089	0.013	/	/	/	0.067	0.094	0.078
10T8-3	-	-	/	/	/	0.107	0.121	0.129
10T8-4	-	-	/	/	/	0.078	0.087	0.072
10T9-2	0.47	0.004	/	/	0.48	0.41	0.45	0.43
10T9-3	-	-	/	/	/	0.092	0.106	0.092
10T10-1	0.094	0.007	/	/	0.146	0.07	0.101	0.082
10T10-2	0.195	0.006	/	/	0.163	0.091	0.082	0.087

NS = north-south antenna.
EW = east-west antenna.
B = both antennas.
- = site measurement point not established.
-- = site measurement point dropped.
/ = data not taken.
- = measurement expected to be <0.002 V/m based on the longitudinal electric field measurements.

TABLE G-3. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Bird Species and Communities Studies
Wisconsin Transects

Site No. Meas. Pt.	1984		1985			1986	1987	1988
	NS	EW	NS	EW	B(-75)	B(-75)	B(-75)	B(-75)
10C6-1	1.60	1.08	/	/	1.20	1.12	1.32	0.86
10C6-2	1.89	1.61	/	/	2.7	2.3	2.9	2.9
10C7-2	0.47	0.43	0.48	/	0.64	0.59	0.67	0.61
10C7-3	-	-	0.25, 0.34	0.36	0.59	0.62	0.54	0.64
10C9-1	1.16	0.44	/	/	0.95	1.12	1.05	1.04
10C9-2	1.44	1.08	/	/	1.77	2.0	2.12	2.3
10C10-1	1.40	1.12	/	/	1.98	1.55	1.83	1.55
10C10-2	0.30	0.31	/	/	0.48	0.55	--	--
10C10-3	-	-	-	-	-	-	0.37	0.32
10C11-1	-	-	0.67	0.59	1.44	1.63	1.10	1.23
10C11-2	-	-	0.98	0.91	2.0	1.91	0.81	1.42
10T6-1	6.0	130	/	/	157	184	260	250
10T6-2	12.8	88	14.1	95	77	82	76	56
10T7-1	20	180	/	/	210	210	145	194
10T7-2	13.2	142	/	/	137	99	119	121
10T7-3	18.7	159	/	/	104	101	121	97
10T8-2	102	15.2	/	/	81	90	84	115
10T8-3	-	-	150	13.2	121	114	128	125
10T8-4	-	-	73, 85	23, 24	71	63	70	86
10T9-2	470	3.5	/	/	350	470	470	566
10T9-3	-	-	81	7.8	71	88	114	89
10T10-1	73	11.0	77	10.5	109	96	90	98
10T10-2	150	6.5	130	11.2	158	94	92	88

NS = north-south antenna.
EW = east-west antenna.
B = both antennas.
- = site measurement point not established.
-- = site measurement point dropped.
/ = data not taken.

TABLE G-4. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Bird Species and Communities Studies
Wisconsin Transects

Site No.	1984		1985			1986	1987	1988
Meas. Pt.	NS	EW	NS	EW	B(-75)	B(-75)	B(-75)	B(-75)
10C6-1	0.011	0.010	/	/	0.012	0.013	0.013	0.014
10C6-2	0.012	0.014	/	/	0.016	0.017	0.018	0.019
10C7-2	0.005	0.005	0.005	/	0.007	0.007	0.008	0.007
10C7-3	-	-	0.004, 0.005	0.005	0.007	0.006	0.007	0.007
10C9-1	0.030	0.017	/	/	0.035	0.037	0.037	0.040
10C9-2	0.022	0.015	/	/	0.027	0.027	0.027	0.027
10C10-1	0.017	0.014	/	/	0.023	0.023	0.025	0.024
10C10-2	0.008	0.007	/	/	0.011	0.011	--	--
10C10-3	-	-	-	-	-	-	0.012	0.012
10C11-1	-	-	/	/	0.011	0.011	0.011	0.011
10C11-2	-	-	0.009	<0.001	0.014	0.014	0.014	0.015
10T6-1	0.041	3.6	/	/	8.8	9.0	9.0	10.2
10T6-2	0.069	7.5	0.082	7.8	7.1	9.6	7.7	8.2
10T7-1	0.061	4.7	/	/	4.4	4.2	5.2	4.8
10T7-2	0.059	2.3	/	/	2.2	2.2	2.3	2.3
10T7-3	0.094	4.9	/	/	4.7	4.6	4.8	5.1
10T8-2	4.9	0.136	/	/	4.8	4.9	5.0	5.2
10T8-3	-	-	9.9	0.127	8.1	8.4	8.5	8.5
10T8-4	-	-	3.4, 6.6	0.192	3.4	3.4	3.6	3.6
10T9-2	1.58	0.033	/	/	2.4	2.2	2.2	2.1
10T9-3	-	-	4.1	0.072	3.4	3.7	3.9	3.8
10T10-1	4.5	0.063	4.5	0.066	5.7	4.3	4.5	4.5
10T10-2	4.9	0.050	3.7	0.042	4.7	3.9	3.9	4.0

NS = north-south antenna.
EW = east-west antenna.
B = both antennas.
\- = site measurement point not established.
-- = site measurement point dropped.
/ = data not taken.

TABLE G-5. 60 Hz EM FIELD MEASUREMENTS--1984 and 1985
Bird Species and Communities Studies
Wisconsin Transects

Trans. No., Meas. Pt.	Transverse Electric Field Intensity (V/m) 1984	1985	Longitudinal Electric Field Intensity (mV/m) 1984	1985	Magnetic Flux Density (mG) 1984	1985
10C6-1	/	/	0.063	0.098	0.001	0.001
10C6-2	/	/	0.100	0.089	0.001	<0.001
10C7-2	/	/	0.053	0.051, 0.055	<0.001	<0.001
10C7-3	-	/	-	0.074, 0.93 0.104, 0.27	-	<0.001, 0.001
10C9-1	/	/	0.098	0.21	0.001	0.002
10C9-2	/	/	0.013	0.065	<0.001	<0.001
10C10-1	/	/	0.016	0.055	<0.001	<0.001
10C10-2	/	/	0.024	0.053	0.001	0.001
10C11-1	-	/	-	0.23, 0.32	-	0.002
10C11-2	-	/	-	0.038, 0.040, 0.071	-	<0.001, 0.001
10T6-1	<0.001	/	0.044	0.033	<0.001	0.001
10T6-2	<0.001	/	0.022	0.020	0.001	0.001
10T7-1	/	/	0.040	0.047	0.001	0.001
10T7-2	<0.001	/	0.104	0.087	<0.001	0.001
10T7-3	<0.001	/	0.096	0.066	0.001	0.001
10T8-2	<0.001	/	0.045	0.040	0.001	0.002
10T8-3	-	/	-	0.100, 0.110	-	0.002, 0.003
10T8-4	-	/	-	0.032, 0.038	-	0.001, 0.002
10T9-2	<0.001	/	0.129	0.071	<0.001	<0.001
10T9-3	-	/	-	0.028, 0.036	-	0.001, 0.002
10T10-1	<0.001	/	0.040	0.074	0.001	0.001
10T10-2	<0.001	/	0.091	0.126	0.001	0.001

/ = data not taken.

- = site measurement point not established.

TABLE G-6. EM FIELD GRADIENT PERPENDICULAR TO TRANSECT 10T8
Bird Species and Communities Studies

Distance from Antenna (meters)		Magnetic Flux Density (mG)	Electric Field Intensity (mV/m)
0	under wire	109	197
19	edge of ROW	32	151
25		23	126
50		11.7	109
75		8.3	91
86	transect 10T8	7.3	119
100		6.2	106
125		5.1	96
150		4.3	76
200		3.2	76
250	east side of GG	2.6	69
300	west side of GG	2.2	95

Notes: Measurement transect begins 41 m south of pole PIN66 and bears nominally to the west. It crosses study transect 10T8 between the E and F transect segments. Antenna conditions: 300 amperes, 76 Hz modulated, -75° phasing.

TABLE G-7. EM FIELD VARIATIONS ALONG STUDY TRANSECTS 10C7 AND 10T8
Bird Species and Communities Studies

Study Transect	Subsegment Location	Magnetic Flux Density (mG)	Electric Field Intensity (mV/m)
10C7-3	Start A	0.0066	0.64
10C7	A-X-B	0.0061	1.13
10C7	B-X-C	0.0063	1.35
10C7	C-X-D	0.0064	0.83
10C7	D-X-E	0.0068	0.40
10C7	E-X-F	0.0070	0.45
10C7-2	F-14	0.0074	0.61
10C7	F-X-G	0.0077	0.97
10C7	G-X-H	0.0079	0.99
10C7	End H	0.0084	1.29
10T8	Start B	6.7	80
10T8-3	B-X-C	8.5	125
10T8	C-X-D	7.6	88
10T8	D-X-E	6.9	166
10T8	E-X-F	7.5	96
10T8-2	Hwy GG	5.2	115
10T8	F-X-G	12.1	162
10T8	G-X-H	5.9	119
10T8	H-X-I	3.5	216
10T8-4	I-13	3.6	90
10T8	I-X-J	4.0	105
10T8	End J	3.1	73

Notes: Measurements taken at "X" flag between transect subsegments except as noted. Antenna conditions: 300 amperes, 76 Hz modulated, -75° phasing.

Michigan Measurements

EM field measurements for Michigan for 1988 and previous years are found in Tables G-8 through G-16. Tables G-8, G-9, and G-10 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables G-11, G-12, and G-13 present 76 Hz data for these three fields at 1986, 1987, and 1988 MTF operating currents. Tables G-14, G-15, and G-16 present 76 Hz data extrapolated to a full-power condition of 150 amperes.

The 1988 60 Hz measurements showed the same trends in EM field magnitudes as were reported in 1986 and 1987. That is, the 60 Hz magnetic flux densities increased near the antenna wire(s) in comparison to measurements made at these sites prior to antenna construction. The longitudinal electric field intensities also increased significantly at many test sites. Both are the result of 60 Hz currents from power lines coupled to the ELF antenna elements, which then reradiate 60 Hz EM fields.

Because of this coupling, year-to-year variations in the 60 Hz EM field levels at the test sites are effected by fluctuations in regional power line load currents. 60 Hz coupling to the NS antenna appears to have increased substantially in 1988. This correlates with large load increases on a transmission line that parallels the NS antenna. The purchase of the Presque Isle power plant by Wisconsin Electric Power Co. in January 1988 and its subsequent operation as a major producer of electrical energy in the region suggests that this line will remain heavily loaded.

The EM fields generated by the 60 Hz currents on the antenna wires are localized near the antennas and do not affect the 60 Hz EM fields at the control transects. However, the 60 Hz EM field levels at these transects can be influenced directly by local power lines. The 60 Hz EM fields measured at the control transects in 1988 were generally consistent with measurements from previous years, with one exception: at transect 10C12-3, the 60 Hz EM fields increased considerably in 1988, presumably because of the proximity of this transect to the transmission line mentioned above.

TABLE G-8. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Bird Species and Communities Studies
Michigan Transects

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
10C1-2	-	~	~	~	~	~
10C1-3	-	-	~	~	~	~
10C2-1	-	~	~	~	~	~
10C2-2	-	~	~	~	~	~
10C5-2	-	~	~	~	~	~
10C5-3	-	~	~	~	~	~
10C12-1	-	-	~	~	~	~
10C12-2	-	-	~	~	~	~
10C13-1	-	-	~	~	~	~
10C13-2	-	-	~	~	~	~
10T1-1	-	~	~	~	~	~
10T1-3	-	-	~	~	~	~
10T1-4	-	-	-	~	~	~
10T1-5	-	-	-	~	~	~
10T2-1	-	<0.001	~	~	~	~
10T2-2	-	-	-	~	~	~
10T2-4	-	-	~	~	~	0.008
10T3-1	-	~	~	~	~	~
10T3-2	-	~	~	~	~	~
10T3-3	-	-	-	~	~	<0.001
10T4-1	-	~	~	~	~	~
10T4-3	-	-	-	~	~	~
10T11-1	-	-	~	~	~	<0.001
10T11-2	-	-	~	~	0.011	<0.001

[a] = prior to antenna construction.
[b] = antenna elements grounded at transmitter (condition 2).
[c] = antenna elements connected to transmitter, transmitter off (condition 9).
\- = site measurement point not established.
~ = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.

TABLE G-9. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Bird Species and Communities Studies
Michigan Transects

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
10C1-2	-	0.62	0.106, 0.141	0.101	0.059	0.20
10C1-3	-	-	0.26, 0.27	0.055	0.21	0.32
10C2-1	-	0.98	0.138	0.041	0.038	0.087
10C2-2	-	0.35	0.21	0.055	0.048	0.047
10C5-2	-	0.35	0.45	0.193	0.116	0.23
10C5-3	-	0.111	0.23	0.25	0.103	0.126
10C12-1	-	-	0.194, 0.28	0.058	0.256	0.98
10C12-2	-	-	0.106, 0.141	0.101	0.059	0.20
10C13-1	-	-	0.34, 0.52	0.30	0.40	0.37
10C13-2	-	-	0.143, 0.31	0.139	0.157	0.121
10T1-1	-	0.076	0.061	0.034	0.099	0.21
10T1-3	-	-	0.38	0.120	0.20	0.51
10T1-4	-	-	-	0.111	0.085	0.30
10T1-5	-	-	-	0.040	0.052	0.116
10T2-1	-	0.42	0.194	0.050	0.058	0.23
10T2-2	-	-	-	0.058	0.052	0.24
10T2-4	-	-	0.158	0.054	0.029	0.166
10T3-1	-	0.30	0.23	0.145	0.164	0.070
10T3-2	-	0.26	0.117	0.069	0.103	0.075
10T3-3	-	-	-	0.094	0.120	0.132
10T4-1	-	0.29	0.132	0.129	0.093	0.087
10T4-3	-	-	-	0.112	0.22	0.166
10T11-1	-	-	0.23	0.172	0.106	0.095
10T11-2	-	-	0.26, 0.50	0.58	0.45	0.196

[a] = prior to antenna construction.
[b] = antenna elements grounded at transmitter (condition 2).
[c] = antenna elements connected to transmitter, transmitter off (condition 9).
- = site measurement point not established.

TABLE G-10. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Bird Species and Communities Studies
Michigan Transects

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]
10C1-2	-	0.001	0.001	<0.001	<0.001	0.001
10C1-3	-	-	0.001, 0.003	<0.001	0.003	0.002
10C2-1	-	0.005	0.004	<0.001	<0.001	<0.001
10C2-2	-	0.003	0.003	<0.001	0.001	0.001
10C5-2	-	0.008	0.009	0.006	0.005	0.006
10C5-3	-	0.001	0.002	0.002	0.001	0.001
10C12-1	-	-	0.001, 0.003	0.002	0.003	0.011
10C12-2	-	-	0.001	<0.001	<0.001	0.001
10C13-1	-	-	0.007, 0.010	0.007	0.005	0.003
10C13-2	-	-	0.001, <0.001	0.001	0.001	0.001
10T1-1	-	0.006	0.004	0.002	0.005	0.016
10T1-3	-	-	0.002	0.003	0.005	0.017
10T1-4	-	-	-	0.003	0.003	0.009
10T1-5	-	-	-	0.003	0.016	0.012
10T2-1	-	0.002	0.002	0.003	0.005	0.012
10T2-2	-	-	-	<0.001	0.002	0.008
10T2-4	-	-	0.001	0.002	0.001	0.004
10T3-1	-	0.001	0.001	0.006	0.003	0.004
10T3-2	-	0.001	<0.001	0.008	0.005	0.004
10T3-3	-	-	-	0.012	0.007	0.017
10T4-1	-	0.001	<0.001	0.002	0.002	0.003
10T4-3	-	-	-	0.001	0.003	0.004
10T11-1	-	-	<0.001	0.006	0.006	0.003
10T11-2	-	-	0.001, <0.001	0.008	0.005	0.004

[a] = prior to antenna construction.
[b] = antenna elements grounded at transmitter (condition 2).
[c] = antenna elements connected to transmitter, transmitter off (condition 9).
\- = site measurement point not established.

TABLE G-11. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Bird Species and Communities Studies
Measured (M) and Extrapolated (Ex) Data
Michigan Transects (page 1 of 2)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps) NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	1987 Exposures; Antenna Element, Current (Amps) NS(15) M	EW(15) M	1988 Exposures; Antenna Element, Current (Amps) NS(75) M	EW(75) M
10C1-2	-	-	-	--	-	-	-	-
10C1-3	-	-	-	--	-	-	-	-
10C2-1	-	-	-	--	-	-	-	-
10C2-2	-	-	-	--	-	-	-	-
10C5-2	-	-	-	--	-	-	-	-
10C5-3	-	-	-	--	-	-	-	-
10C12-1	-	-	-	--	-	-	-	-
10C12-2	-	-	-	--	-	-	-	-
10C13-1	-	-	-	--	-	-	-	-
10C13-2	-	-	-	--	-	-	-	-
10T1-1	-	-	-	--	0.005	-	0.022	-
10T1-3	0.002	-	-	--	0.007	-	0.038	<0.001
10T1-4	-	-	-	--	0.004	-	0.024	-
10T1-5	-	-	-	--	0.003	-	0.010	-
10T2-1	0.002	-	-	--	0.006	-	0.033	<0.001
10T2-2	0.002	-	-	--	0.007	-	0.047	0.003
10T2-4	0.002	-	-	--	0.007	-	0.028	0.007
10T3-1	0.004	-	-	--	0.005	0.003	0.016	0.019
10T3-2	0.004	-	0.001	0.002	0.006	0.003	0.048	0.034
10T3-3	0.005	-	0.017	0.028	0.005	0.009	0.046	0.120

TABLE G-11. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Bird Species and Communities Studies
Measured (M) and Extrapolated (Ex) Data
Michigan Transects (page 2 of 2)

	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)		1988 Exposures; Antenna Element, Current (Amps)	
Site No., Meas. Pt.	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M	NS(75) M	EW(75) M
10T4-1	0.002	~	0.003	0.005	0.003	0.006	0.042	0.038
10T4-3	~	~	0.003	0.005	0.001	0.008	0.018	0.054
10T11-1	~	~	~	~~	0.004	0.002	0.019	0.014
10T11-2	~	~	~	~~	0.038	0.009	0.059	0.017

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
~ = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.
~~ = data cannot be extrapolated.

TABLE G-12. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Bird Species and Communities Studies
Measured (M) and Extrapolated (Ex) Data
Michigan Transects (page 1 of 2)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps) NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	1987 Exposures; Antenna Element, Current (Amps) NS(15) M	EW(15) M	1988 Exposures; Antenna Element, Current (Amps) NS(75) M	EW(75) M
10C1-2	0.004	0.003	0.004	0.007	0.015	0.012	0.074	0.058
10C1-3	0.013	0.004	0.002	0.003	0.049	0.011	0.26	0.060
10C2-1	0.017	0.002	0.007	0.012	0.073	0.021	0.30	0.095
10C2-2	0.011	0.003	0.007	0.012	0.037	0.020	0.176	0.100
10C5-2	0.001	0.003	0.007	0.012	0.014	0.023	0.073	0.119
10C5-3	0.005	0.003	0.009	0.015	0.017	0.027	0.091	0.143
10C12-1	0.028	0.010	0.011	0.018	0.068	0.028	0.36	0.140
10C12-2	0.004	0.003	0.004	0.007	0.015	0.012	0.074	0.058
10C13-1	0.024	0.027	0.104	0.173	0.057	0.24	0.32	1.39
10C13-2	0.024	0.023	0.098	0.163	0.089	0.29	0.34	1.07
10T1-1	0.85	0.028	0.008	0.013	2.8	0.015	13.0	0.115
10T1-3	2.2	0.068	0.077	0.128	7.1	0.147	33	0.86
10T1-4	0.96	0.030	0.031	0.052	4.1	0.087	19.8	0.46
10T1-5	0.65	0.020	0.006	0.010	2.3	0.015	10.9	0.098
10T2-1	1.42	0.043	0.077	0.128	5.3	0.25	31	1.05
10T2-2	1.69	0.056	0.107	0.178	7.0	0.34	33	1.77
10T2-4	0.59	0.056	0.158	0.26	5.0	0.49	26	2.6
10T3-1	0.82	0.23	0.60	1.00	4.9	2.1	26	10.1
10T3-2	1.24	0.133	1.05	1.75	5.4	2.7	21	31
10T3-3	1.36	-	3.6	6.0	4.8	7.5	43	54

TABLE G-12. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Bird Species and Communities Studies
Measured (M) and Extrapolated (Ex) Data
Michigan Transects (page 2 of 2)

	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)		1988 Exposures; Antenna Element, Current (Amps)	
Site No., Meas. Pt.	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M	NS(75) M	EW(75) M
10T4-1	0.88	0.137	1.58	2.6	2.4	4.8	14.5	19.3
10T4-3	0.46	0.139	1.92	3.2	1.30	8.1	5.4	39
10T11-1	0.67	0.27	0.59	0.98	3.9	1.97	17.6	8.9
10T11-2	1.38	0.93	0.44	0.73	7.3	2.9	32	12.6

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).

TABLE G-13. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Bird Species and Communities Studies
Measured (M) and Extrapolated (Ex) Data
Michigan Transects (page 1 of 2)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps) NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	1987 Exposures; Antenna Element, Current (Amps) NS(15) M	EW(15) M	1988 Exposures; Antenna Element, Current (Amps) NS(75) M	EW(75) M
10C1-2	<0.001	<0.001	<0.001	--	<0.001	<0.001	<0.001	<0.001
10C1-3	<0.001	<0.001	<0.001	--	<0.001	<0.001	0.002	<0.001
10C2-1	<0.001	<0.001	<0.001	--	0.001	0.001	0.005	0.002
10C2-2	<0.001	<0.001	<0.001	--	0.001	<0.001	0.003	0.002
10C5-2	<0.001	<0.001	<0.001	--	<0.001	0.001	0.001	0.002
10C5-3	<0.001	<0.001	<0.001	--	<0.001	<0.001	0.001	0.001
10C12-1	<0.001	<0.001	<0.001	--	<0.001	<0.001	0.002	0.001
10C12-2	<0.001	<0.001	<0.001	--	<0.001	<0.001	<0.001	<0.001
10C13-1	<0.001	<0.001	<0.001	--	0.001	0.002	0.002	0.009
10C13-2	<0.001	<0.001	<0.001	--	<0.001	0.001	0.002	0.006
10T1-1	0.044	0.001	<0.001	--	0.179	0.001	0.84	0.005
10T1-3	0.047	0.001	0.007	0.012	0.176	0.001	0.84	0.010
10T1-4	0.026	0.001	0.001	0.002	0.103	0.002	0.49	0.014
10T1-5	0.034	0.001	0.001	0.002	0.49	0.002	0.61	0.008
10T2-1	0.066	0.002	0.001	0.002	0.25	0.001	1.21	0.010
10T2-2	0.043	0.001	0.001	0.002	0.165	0.002	0.80	0.010
10T2-4	0.026	0.001	0.001	0.002	0.097	0.002	0.46	0.005
10T3-1	0.029	0.003	0.007	0.012	0.188	0.015	0.96	0.078
10T3-2	0.081	0.002	0.013	0.022	0.29	0.031	1.61	0.161
10T3-3	0.116	0.40	0.58	0.97	0.196	0.89	1.11	7.7

TABLE G-13. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Bird Species and Communities Studies
Measured (M) and Extrapolated (Ex) Data
Michigan Transects (page 2 of 2)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)		1988 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M	NS(75) M	EW(75) M
10T4-1	0.025	0.001	0.081	0.135	0.038	0.191	0.20	1.00
10T4-3	0.025	0.001	0.119	0.198	0.011	0.32	0.051	1.42
10T11-1	0.033	0.002	0.006	0.010	0.24	0.015	1.09	0.072
10T11-2	0.042	0.003	0.003	0.005	0.31	0.006	1.42	0.033

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
-- = data cannot be extrapolated.

TABLE G-14. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Bird Species and Communities Studies
Data Extrapolated to 150 Ampere Current
Michigan Transects

Site No.,	1986 Extrapolations			1987 Extrapolations		1988 Extrapolations	
Meas. Pt.	NS	NEW	SEW	NS	EW	NS	EW
10C1-2	--	--	--	--	--	--	--
10C1-3	--	--	--	--	--	--	--
10C2-1	--	--	--	--	--	--	--
10C2-2	--	--	--	--	--	--	--
10C5-2	--	--	--	--	--	--	--
10C5-3	--	--	--	--	--	--	--
10C12-1	--	--	--	--	--	--	--
10C12-2	--	--	--	--	--	--	--
10C13-1	--	--	--	--	--	--	--
10C13-2	--	--	--	--	--	--	--
10T1-1	--	--	--	0.050	--	0.044	--
10T1-3	0.075	--	--	0.070	--	0.076	--
10T1-4	--	--	--	0.040	--	0.048	--
10T1-5	--	--	--	0.030	--	0.020	--
10T2-1	0.075	--	--	0.060	--	0.066	--
10T2-2	0.075	--	--	0.070	--	0.094	0.006
10T2-4	0.075	--	--	0.070	--	0.056	0.014
10T3-1	0.150	--	--	0.050	0.030	0.032	0.038
10T3-2	0.150	--	0.025	0.060	0.030	0.096	0.068
10T3-3	0.188	--	0.43	0.050	0.090	0.092	0.24
10T4-1	0.075	--	0.075	0.030	0.060	0.084	0.076
10T4-3	--	--	0.075	0.010	0.080	0.036	0.108
10T11-1	--	--	--	0.040	0.020	0.038	0.028
10T11-2	--	--	--	0.38	0.090	0.118	0.034

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
= data cannot be extrapolated.

TABLE G-15. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITES (mV/m)
Bird Species and Communities Studies
Data Extrapolated to 150 Ampere Current
Michigan Transects

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations		1988 Extrapolations	
	NS	NEW	SEW	NS	EW	NS	EW
10C1-2	0.150	0.075	0.100	0.150	0.120	0.148	0.116
10C1-3	0.49	0.100	0.050	0.49	0.110	0.52	0.120
10C2-1	0.64	0.050	0.175	0.73	0.21	0.60	0.190
10C2-2	0.41	0.075	0.175	0.37	0.20	0.35	0.20
10C5-2	0.038	0.075	0.175	0.140	0.23	0.146	0.24
10C5-3	0.188	0.075	0.23	0.170	0.27	0.182	0.29
10C12-1	1.05	0.25	0.28	0.68	0.28	0.72	0.28
10C12-2	0.150	0.075	0.100	0.150	0.120	0.148	0.116
10C13-1	0.90	0.68	2.6	0.57	2.4	0.64	2.8
10C13-2	0.90	0.58	2.5	0.89	2.9	0.68	2.1
10T1-1	32	0.70	0.20	28	0.150	26	0.23
10T1-3	83	1.70	1.93	71	1.47	66	1.72
10T1-4	36	0.75	0.78	41	0.87	40	0.92
10T1-5	24	0.50	0.150	23	0.150	22	0.196
10T2-1	53	1.08	1.93	53	2.5	62	2.1
10T2-2	63	1.40	2.7	70	3.4	66	3.5
10T2-4	22	1.40	4.0	50	4.9	52	5.2
10T3-1	31	5.8	15.0	49	21	52	20
10T3-2	47	3.3	26	54	27	42	62
10T3-3	51	--	90	48	75	86	108
10T4-1	33	3.4	40	24	48	29	39
10T4-3	17.3	3.5	48	13.0	81	10.8	78
10T11-1	25	6.8	14.8	39	19.7	35	17.8
10T11-2	52	23	11.0	73	29	64	25

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).

TABLE G-16. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Bird Species and Communities Studies
Data Extrapolated to 150 Ampere Current
Michigan Transects

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations		1988 Extrapolations	
	NS	NEW	SEW	NS	EW	NS	EW
10C1-2	--	--	--	--	--	--	--
10C1-3	--	--	--	--	--	0.004	--
10C2-1	--	--	--	0.010	0.010	0.010	0.004
10C2-2	--	--	--	0.010	--	0.006	0.004
10C5-2	--	--	--	--	0.010	0.002	0.004
10C5-3	--	--	--	--	--	0.002	0.002
10C12-1	--	--	--	--	--	0.004	0.002
10C12-2	--	--	--	--	--	--	--
10C13-1	--	--	--	0.010	0.020	0.004	0.018
10C13-2	--	--	--	--	0.010	0.004	0.012
10T1-1	1.65	0.025	--	1.79	0.010	1.68	0.010
10T1-3	1.76	0.025	0.175	1.76	0.010	1.68	0.020
10T1-4	0.98	0.025	0.025	1.03	0.020	0.98	0.028
10T1-5	1.28	0.025	0.025	4.9	0.020	1.22	0.016
10T2-1	2.5	0.050	0.025	2.5	0.010	2.4	0.020
10T2-2	1.61	0.025	0.025	1.65	0.020	1.60	0.020
10T2-4	0.98	0.025	0.025	0.97	0.020	0.92	0.010
10T3-1	1.09	0.075	0.175	1.88	0.150	1.92	0.156
10T3-2	3.0	0.050	0.33	2.9	0.31	3.2	0.32
10T3-3	4.4	10.0	14.5	1.96	8.9	2.2	15.4
10T4-1	0.94	0.025	2.0	0.38	1.91	0.40	2.0
10T4-3	0.94	0.025	3.0	0.110	3.2	0.102	2.8
10T11-1	1.24	0.050	0.150	2.4	0.150	2.2	0.144
10T11-2	1.58	0.075	0.075	3.1	0.060	2.8	0.066

NS = north-south antenna element.
NEW = northern east-west antenna element.
SEW = southern east-west antenna element.
EW = both east-west antenna elements (operational configuration).
-- = data cannot be extrapolated.

76 Hz measurements were made in 1988 with 75 ampere antenna currents, the predominant MTF operating mode from July through December. The EM field exposures at the study transects for the period prior to July can be estimated either by using the 15 ampere antenna current measurement data from 1987 or more accurately by using one-fifth the value of the 1988 75 ampere data.

The measured EM field magnitudes for each antenna element for 1986-1988 have been linearly extrapolated to the planned operational antenna current of 150 amperes. Extrapolations were not performed when the measurements indicated that the EM field magnitudes were below the minimum sensitivity of the EM field sensors.

The 1988 extrapolations are the most accurate predictions of the EM field levels at the planned operational antenna current because the 1988 half-power field measurements are more accurate than those made at lower antenna currents in previous years. The 1988 extrapolations also reflect the operational configuration and tuning of the antenna elements with the new power amplifiers.

The maximum 76 Hz EM field intensities that can occur during simultaneous operation of both antenna elements at any antenna phasing can be estimated by calculating the algebraic sum of the levels from the individual antenna element extrapolations; minimum intensities can be estimated by calculating the algebraic difference.

APPENDIX H

EM EXPOSURE CRITERIA

EM EXPOSURE CRITERIA

Because the electromagnetic (EM) intensity and operational characteristics required to produce a bioeffect are not known, EM exposure criteria were established to assist investigators in selecting study sites. The exposure criteria ensure that the 76 Hz EM fields at a test site are significantly larger than the 76 Hz EM fields at the control site, the 60 Hz EM fields at the test site, and the 60 Hz EM fields at the control site. In addition, the exposure criteria verify that there is not a substantial difference in the ambient 60 Hz EM field between the test and control sites.

The EM exposure criteria used in site selection are expressed in equation form as follows:

$$T\ (76\ \text{Hz}) \ /\ C\ (76\ \text{Hz}) > 10 \tag{1}$$

$$T\ (76\ \text{Hz}) \ /\ T\ (60\ \text{Hz}) > 10 \tag{2}$$

$$T\ (76\ \text{Hz}) \ /\ C\ (60\ \text{Hz}) > 10 \tag{3}$$

$$0.1 < T\ (60\ \text{Hz}) \ /\ C\ (60\ \text{Hz}) < 10 \tag{4}$$

where T (76 Hz) = test site exposure due to ELF Communications System
T (60 Hz) = test site exposure due to power lines
C (76 Hz) = control site exposure due to ELF Communications System
C (60 Hz) = control site exposure due to power lines

Based on the exposure assessment, each possible test and control site pairing was classified as acceptable, conditionally acceptable, or unacceptable. These categories are defined as follows:

> Acceptable. A test/control site pair was placed in this category if it satisfied all four EM exposure inequalities for each of the EM fields applicable to the study. For example, the small mammals and nesting birds studies would be concerned with both the soil and air electric fields as well as the magnetic fields. The soil arthropods and earthworms studies, however, would not be concerned with the electric field in the air, since this field terminates at the earth's surface and would not be expected to impact biota existing in the soil or litter layer.

Conditionally Acceptable. A test/control site pair was placed in this category if it approached, but did not meet, the criteria for acceptability. This category was established since the EM exposure criteria were not rigidly defined. The assumption that a difference of one order of magnitude or more would constitute a significant difference between test and control sites was chosen for these studies, but without knowing what effects will be experienced, if any. It is difficult to define this difference *a priori*. Furthermore, the EM field measurements themselves encompass a certain degree of error, as do any physical measurements.

Unacceptable. A test/control site pair was placed in this category if it neither satisfied the criteria for acceptability nor qualified for conditional acceptability.

APPENDIX I

EM MEASUREMENTS VS. WTF ANTENNA PHASE

EM MEASUREMENTS VS. WTF ANTENNA PHASE

Tables I-1 through I-3 document EM field measurements as a function of the Wisconsin Transmitting Facility (WTF) antenna current phase angle for study sites 10T6-2, 10T8-4, and 10T10-1, respectively.

These data can be used to relate measurements taken in previous years to measurements at any antenna current phase angle. They may also be used to estimate the EM field levels at phase angles for which measurements have not been made. For the longitudinal electric field, the data tables also give a correction factor that can be used to calculate the maximum EM field magnitude from the vector sum magnitude for the measured phase angles. Correction factors for other phase angles can be linearly extrapolated from those in the tables. This has already been done for -75°, the most commonly used WTF condition.

TABLE I-1. EM MEASUREMENTS VS. ANTENNA PHASE FOR 10T6-2

Site No., Meas. Pt.	Antenna Current Phase,* Degrees	Longitudinal Electric Field Intensity (mV/m)		Correction Factor:	Magnetic Flux Density (mG)	
		Vector Sum E_{VS}	Measured Max. E_{MAX}	E_{MAX}/E_{VS}	Vector Sum B_{VS}	Vertical Component $B_{Vert.}$
10T6-2	NS only	14.1	15.0	1.06	0.082	0.049
	EW only	95	95	1.00	7.8	7.7
	0	95	95	1.00	7.8	7.7
	-30	95	95	1.00	7.8	7.7
	-60	93	95	1.02	7.8	7.7
	-75			1.02		
	-90	93	95	1.02	7.8	7.7
	-120	93	95	1.02	7.8	7.7
	-150	92	95	1.03	7.8	7.7
	-180	95	95	1.00	7.8	7.7
	-210	95	95	1.00	7.8	7.7
	-240	97	95	0.98	7.8	7.7
	-270	97	95	0.98	7.8	7.7
	-300	97	95	0.98	7.8	7.7
	-330	96	95	0.99	7.8	7.7

*Defined as the phase of the NS antenna current with respect to the EW antenna current.

TABLE I-2. EM MEASUREMENTS VS. ANTENNA PHASE FOR 10T8-4

Site No., Meas. Pt.	Antenna Current Phase,* Degrees	Longitudinal Electric Field Intensity (mV/m)		Correction Factor: E_{MAX}/E_{VS}	Magnetic Flux Density (mG)	
		Vector Sum E_{VS}	Measured Max. E_{MAX}		Vector Sum B_{VS}	Vertical Component $B_{Vert.}$
10T8-4	NS only	85	82	0.96	3.4	3.4
	EW only	23	24	1.02	0.192	0.160
	0	88	84	0.95	3.7	3.6
	-30	84	82	0.98	3.7	3.6
	-60	84	80	0.95	3.7	3.6
	-75			0.95		
	-90	86	82	0.95	3.6	3.5
	-120	86	82	0.95	3.6	3.5
	-150	89	82	0.92	3.3	3.3
	-180	91	90	0.99	3.5	3.4
	-210	91	93	1.02	3.3	3.3
	-240	91	94	1.03	3.5	3.4
	-270	91	90	0.99	3.5	3.4
	-300	85	85	1.00	3.6	3.5
	-330	88	84	0.95	3.6	3.5

*Defined as the phase of the NS antenna current with respect to the EW antenna current.

TABLE I-3. EM MEASUREMENTS VS. ANTENNA PHASE FOR 10T10-1

Site No., Meas. Pt.	Antenna Current Phase,* Degrees	Longitudinal Electric Field Intensity (mV/m)		Correction Factor:	Magnetic Flux Density (mG)	
		Vector Sum E_{VS}	Measured Max. E_{MAX}	E_{MAX}/E_{VS}	Vector Sum B_{VS}	Vertical Component $B_{Vert.}$
10T10-1	NS only	77	82	1.06	4.5	4.5
	EW only	10.5	10.5	1.00	0.066	0.030
	0	79	80	1.01	4.5	4.5
	-30	80	83	1.04	4.5	4.5
	-60	80	84	1.05	4.5	4.5
	-75			1.05		
	-90	80	84	1.05	4.5	4.5
	-120	79	83	1.05	4.5	4.5
	-150	78	81	1.04	4.6	4.6
	-180	78	81	1.04	4.6	4.6
	-210	78	82	1.05	4.6	4.6
	-240	78	82	1.05	4.6	4.6
	-270	78	81	1.04	4.6	4.6
	-300	78	80	1.03	4.6	4.6
	-330	79	80	1.01	4.5	4.5

*Defined as the phase of the NS antenna current with respect to the EW antenna current.

APPENDIX J

EM EXPOSURE SETUP PROTOCOLS FOR SOIL AMOEBAE STUDIES

EM EXPOSURE SETUP PROTOCOLS FOR SOIL AMOEBAE STUDIES

This appendix documents the protocol written by IITRI to assist the soil amoebae study investigator in setting up his study sites using the culture cell exposure hardware fabricated by IITRI. This protocol also provides guidelines for proper adjustment of the EM exposures and monitoring of the exposure parameters using this equipment.

EXPOSURE SETUP PROTOCOLS
FOR SOIL AMOEBAE STUDIES

MATCHED ELECTRIC FIELD PROTOCOL

(1) Measure maximum electric field, E, in soil, using 1 meter probe.

(2) Multiply electric field value by 0.15 to determine the minimum required drive voltage, V_{DR} (min).

$$V_{DR}\ (\text{min}) = E \times 0.15\ (\text{volts})$$

(3) Locate collector electrodes in line with the maximum electric field in the earth, and spaced far enough apart to generate a voltage across 2000-ohm resistor that is greater than or equal to V_{DR} (min) (see Figure J-1).

(4) Measure and record electrode spacing and the open circuit (no load) electrode voltage, V_{OC}.

(5) Connect the test cell and control box to the electrodes (see Figure J-2). While monitoring the test cell voltage, V_{CL}, adjust the variable resistor so that V_{CL} is equal to the value given by the following formula:

$$V_{CL} = E \times 0.113\ (\text{volts})$$

(6) With the cell voltage set, measure and record the voltage across the 100 ohm series resistor, V_R. This allows calculation of the cell current and current density.

(7) Measure and record the electrode voltage, V_{DR}, with the test cell and monitoring box connected and adjusted as per Step 5.

MATCHED CURRENT DENSITY PROTOCOL

(1) Measure maximum electric field, E, in soil, using 1 meter probe.

(2) Locate collector electrodes in line with maximum electric field with a separation of 1 meter.

(3) Measure exact electrode spacing and open circuit (no load) electrode voltage, V_{OC}. Measured voltage should be within a few percent of that measured in Step 1. If not, correct electrode spacing as appropriate.

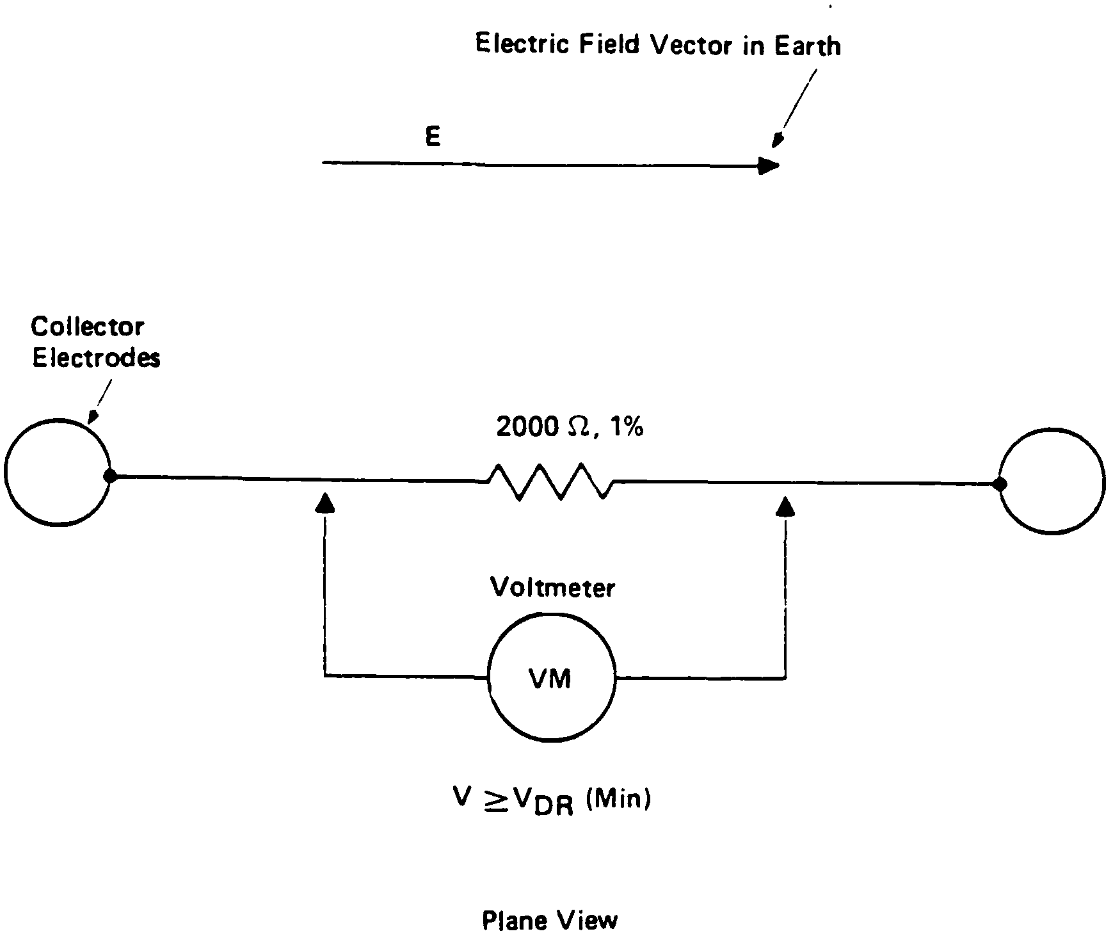
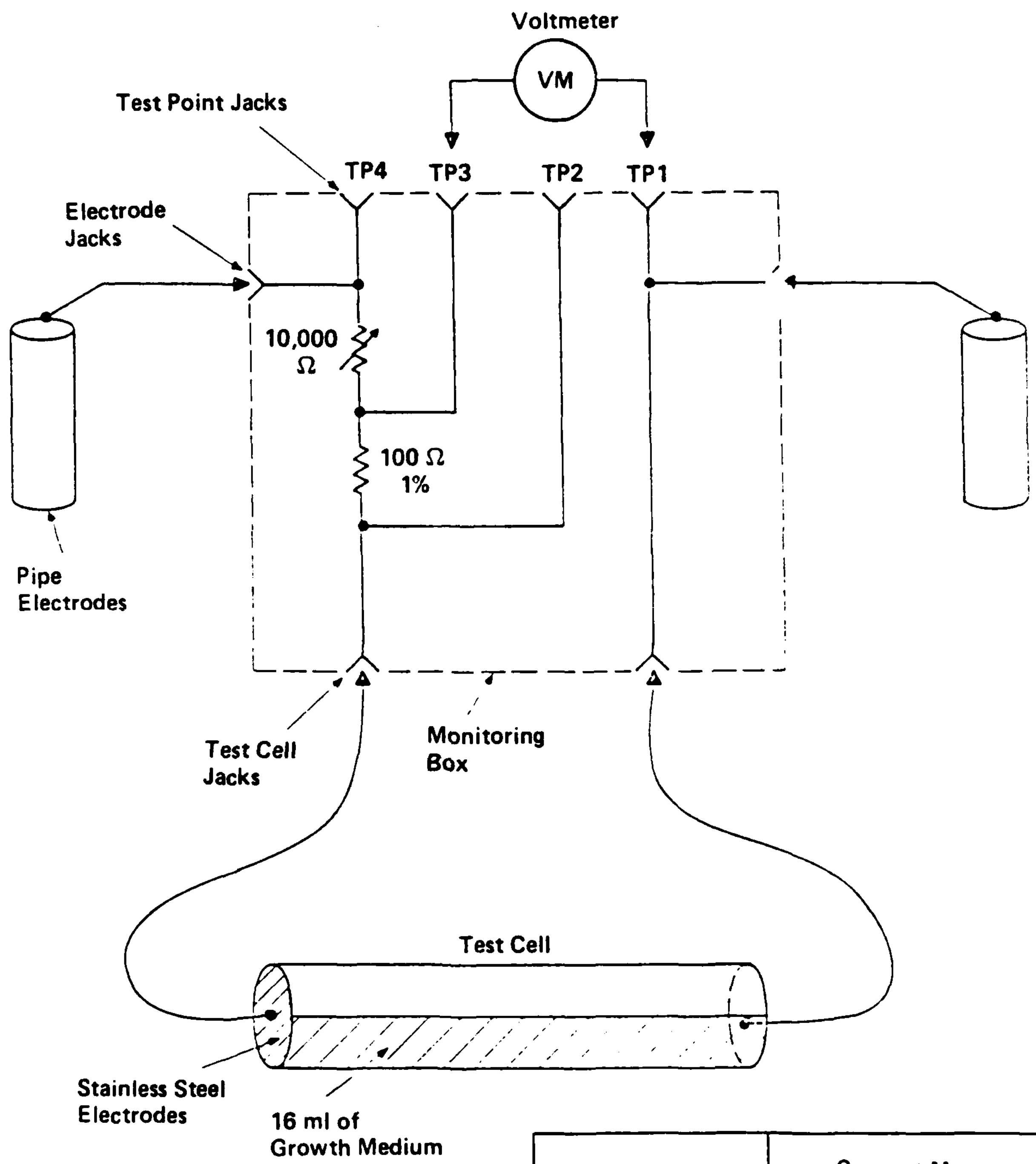


FIGURE J-1. DETERMINATION OF DRIVE VOLTAGE FOR THE SOIL AMOEBAE STUDIES MATCHED ELECTRIC FIELD PROTOCOL.



To Measure	Connect Meter Across
V_{CL}	TP1 – TP2
V_{R}	TP2 – TP3
V_{DR}	TP1 – TP4

FIGURE J-2. TEST CHAMBER HOOKUP FOR THE SOIL AMOEBAE STUDIES MATCHED ELECTRIC FIELD PROTOCOL.

(4) Connect current-limiting control box (see Figure J-3) to electrodes. Place the current limit select switch to the 2.5 megohm position (2.5 M).

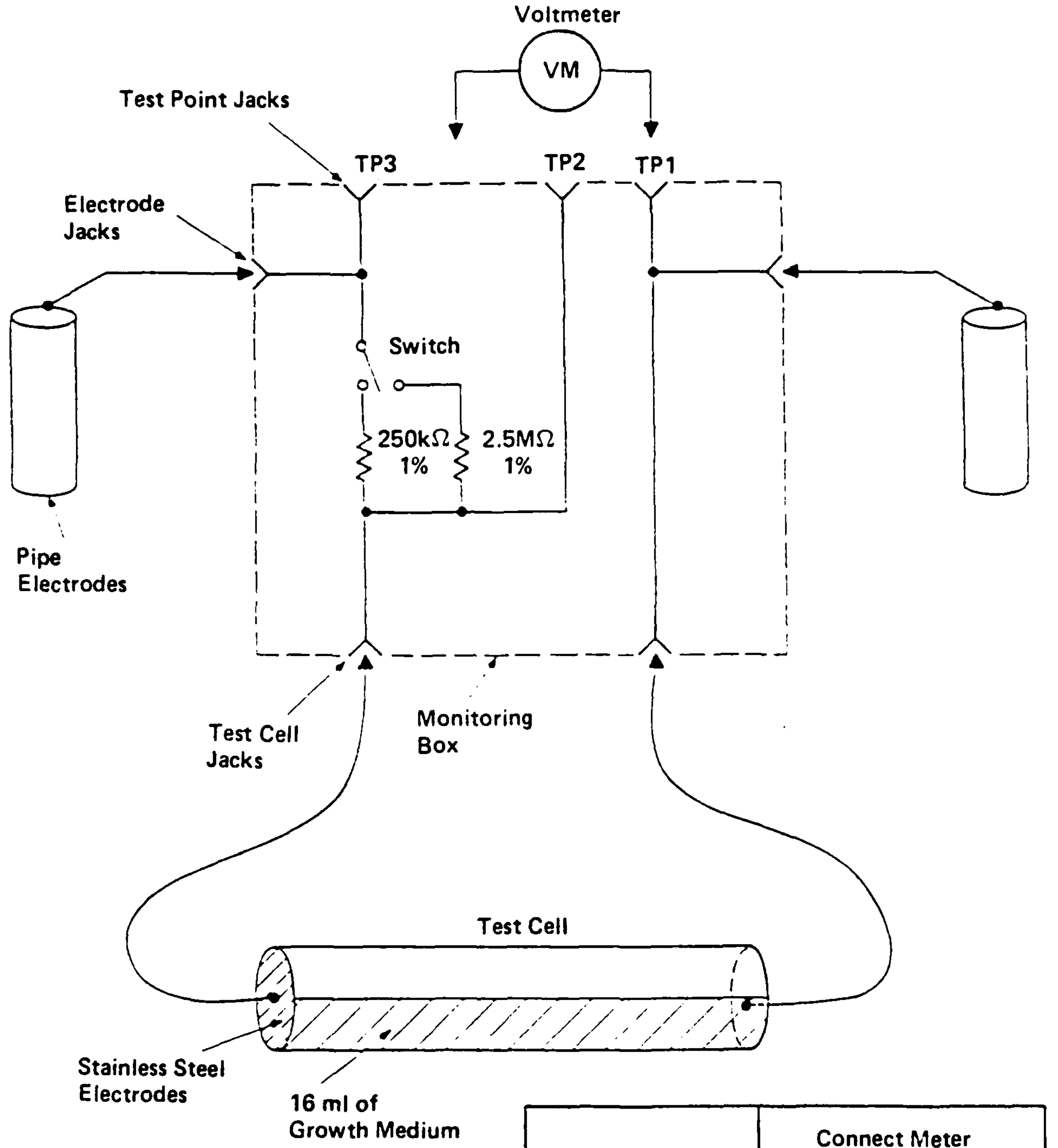
(5) Measure and record the voltages across the test cell, V_{CL}, the resistor, V_R, and the electrodes, V_{DR}, using the test point jacks (see Figure J-3 for test point numbering).

The voltages across the resistor and across the electrodes should be close in value to V_{OC} from Step 3.

$$V_R \simeq V_{DR} \simeq V_{OC}$$

The voltage across the test cell will be much lower, and can be estimated as:

$$V_{CL} \simeq 0.6 \times 10^{-3} \times V_{OC} \text{ (volts).}$$



To Measure	Connect Meter Across
V_{CL}	TP1 – TP2
V_R	TP2 – TP3
V_{DR}	TP1 – TP3

8C641RK

FIGURE J-3. TEST CHAMBER HOOKUP FOR THE SOIL AMOEBAE STUDIES MATCHED CURRENT DENSITY PROTOCOL.

APPENDIX K

SUMMARY OF WISCONSIN AND MICHIGAN TRANSMITTING FACILITY OPERATION

SUMMARY OF WISCONSIN AND MICHIGAN TRANSMITTING FACILITY OPERATION

The operations of the Wisconsin and Michigan Transmitting Facilities (WTF and MTF) during 1984-1988 have been summarized in response to requests from investigators for information on operating schedules. The summary is partitioned differently for the WTF and MTF because of differences in their operating modes. The WTF is partitioned according to antenna element, modulation, and frequency. The MTF is partitioned according to antenna element, modulation, antenna current, and, for 1988, frequency as well. Discussion and presentation of data from the WTF appear below, followed by the same for the MTF.

The WTF operating schedule has been broken down into three antenna conditions: north-south (NS) antenna element, east-west (EW) antenna element, and both (B) antenna elements. The NS antenna element data represent those times when the NS element was operating while the EW element was off; the EW antenna element data represent those times when the EW element was operating while the NS element was off; and the B antenna elements data represent only those times when the NS element and the EW element were operating simultaneously.

Tables K-1, K-2, and K-3 show the number of hours of operation per month in 1984 for the north-south, east-west, and both antenna elements, respectively. Equivalent data for 1985 through 1988 are presented in Tables K-4 through K-15. The columns on these tables, labeled with the calendar months, provide a breakdown of the WTF operation by frequency and signal type. Subtotals are given by signal type. A monthly total is also provided. Yearly total hours of operation by signal type and frequency are given in the "Annual Totals" column.

The bottom row of the tables gives the number of changes in operational mode of the antenna element(s) on a monthly and annual basis. These data represent any change in the transmitter facility operating condition. This would include an initial power up and changes in the antenna current, phase (when both antennas are powered), frequency, and modulation scheme. It does not include the powering down of antenna elements.

TABLE K-1. 1984 WTF OPERATIONS SUMMARY: NORTH-SOUTH ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
Mode: Modulated Signal[a]													
76	0.94	107.19	--	1.98	7.24	13.85	--	22.10	8.07	1.69	30.17	1.48	194.71
Mode: Unmodulated Signal													
44	--	1.69	0.05	0.55	0.66	--	0.58	--	1.75	0.08	--	--	5.36
72	0.64	8.65	--	--	0.52	0.30	0.07	16.40	1.50	0.28	0.32	--	28.68
76	3.91	0.21	0.30	4.46	10.35	6.09	11.44	158.38	116.88	9.29	2.28	--	323.59
80	0.81	3.12	1.79	1.06	--	--	0.01	1.97	2.69	2.40	2.91	--	16.76
Subtotals	5.36	13.67	2.14	6.07	11.53	6.39	12.10	176.75	122.82	12.05	5.51	--	374.39
Other[b]	--	0.34	0.21	0.62	0.59	--	--	--	0.05	1.38	0.13	--	3.32
Totals	6.30	121.20	2.35	8.67	19.36	20.24	12.10	198.85	130.94	15.12	35.81	1.48	572.42
Changes in Operational Mode	50	68	14	50	297	71	140	223	163	171	19	2	1268

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-2. 1984 WTF OPERATIONS SUMMARY: EAST-WEST ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
					Mode: Modulated Signal[a]								
44	--	--	--	--	0.82	--	--	--	--	--	--	--	0.82
76	0.64	13.94	18.81	0.92	7.90	0.05	1.45	0.02	2.41	0.33	0.22	0.04	46.73
Subtotals	0.64	13.94	18.81	0.92	8.72	0.05	1.45	0.02	2.41	0.33	0.22	0.04	47.55
					Mode: Unmodulated Signal								
44	5.11	--	--	3.45	--	--	0.53	--	--	0.03	--	--	9.12
72	10.45	2.81	0.18	0.01	0.45	--	0.05	--	--	--	--	--	13.95
76	47.97	5.75	0.77	5.53	18.28	4.20	9.76	1.20	2.78	5.88	--	--	102.12
80	--	--	0.07	17.20	1.19	--	1.36	--	--	--	0.31	--	20.13
Subtotals	63.53	8.56	1.02	26.19	19.92	4.20	11.70	1.20	2.78	5.91	0.31	--	145.32
Other[b]	--	--	3.10	--	0.93	--	--	--	--	0.15	--	--	4.18
Totals	**64.17**	**22.50**	**22.93**	**27.11**	**29.57**	**4.25**	**13.15**	**1.22**	**5.19**	**6.39**	**0.53**	**0.04**	**197.05**
Changes in Operational Mode	55	32	13	36	273	48	152	50	80	131	3	1	874

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-3. 1984 WTF OPERATIONS SUMMARY: NORTH-SOUTH AND EAST-WEST ANTENNA ELEMENTS SIMULTANEOUSLY
[Hours of Operation]

Frequency, Hz	Month: Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
						Mode: Modulated Signal[a]							
42	--	--	--	--	--	--	--	--	--	59.69	--	--	59.69
44	--	--	62.73	--	0.82	--	--	--	58.81	38.88	--	--	161.24
46	--	--	--	--	--	--	--	--	--	59.41	--	--	59.41
74	--	--	--	--	--	--	--	--	--	24.43	--	--	24.43
76	366.26	273.90	157.39	343.50	384.98	396.76	392.62	366.05	395.38	256.09	429.86	365.13	4127.92
78	--	--	--	--	--	--	--	--	43.37	--	--	--	43.37
Subtotals	366.26	273.90	220.12	343.50	385.80	396.76	392.62	366.05	497.56	438.50	429.86	365.13	4476.06
						Mode: Unmodulated Signal							
44	--	--	--	--	0.10	--	--	--	--	0.35	--	--	0.45
72	4.14	2.71	2.43	4.05	3.89	2.44	1.88	5.61	2.36	2.64	2.49	3.33	37.97
76	0.03	--	0.05	1.04	3.12	0.05	1.54	42.54	18.03	1.20	0.16	--	67.76
80	4.75	2.70	0.57	2.99	2.13	2.57	2.77	3.61	2.81	1.22	1.85	1.62	29.59
Subtotals	8.92	5.41	3.05	8.08	9.24	5.06	6.19	51.76	23.20	5.41	4.50	4.95	135.77
Other[b]	--	--	0.26	--	0.51	--	--	0.03	0.81	1.28	--	--	2.89
Totals	375.18	279.31	223.43	351.58	395.55	401.82	398.81	417.84	521.57	445.19	434.36	370.08	4614.72
Changes in Operational Mode	67	40	41	85	144	67	79	264	181	94	68	76	1206

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-4. 1985 WTF OPERATIONS SUMMARY: NORTH-SOUTH ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
Mode: Modulated Signal[a]													
44	--	--	3.41	0.86	0.50	--	--	--	--	--	--	--	4.77
76	0.15	--	3.83	3.21	3.15	3.09	--	1.98	76.31	27.12	--	--	118.84
78	--	--	--	0.33	--	--	--	--	1.87	--	--	--	2.20
Subtotals	0.15	--	7.24	4.40	3.65	3.09	--	1.98	78.18	27.12	--	--	125.81
Mode: Unmodulated Signal													
76	0.40	2.50	5.46	4.79	26.22	29.04	0.68	9.40	9.81	10.41	1.43	0.25	100.39
80	--	--	2.74	3.26	0.02	0.42	--	--	4.14	--	--	--	10.58
Subtotals	0.40	2.50	8.20	8.05	26.24	29.46	0.68	9.40	13.95	10.41	1.43	0.25	110.97
Other[b]	--	--	5.70	1.96	1.20	0.66	0.02	--	4.29	0.03	--	--	13.86
Totals	**0.55**	**2.50**	**21.14**	**14.41**	**31.09**	**33.21**	**0.70**	**11.38**	**96.42**	**37.56**	**1.43**	**0.25**	**250.64**
Changes in Operational Mode	18	2	32	56	126	115	15	51	42	15	3	1	476

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-5. 1985 WTF OPERATIONS SUMMARY: EAST-WEST ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Month Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
Mode: Modulated Signal[a]													
44	--	--	3.15	3.07	1.34	1.62	--	--	0.34	--	--	--	9.52
76	0.85	--	7.30	14.82	20.69	1.28	142.27	2.23	2.17	3.02	0.03	--	194.66
78	--	--	1.64	0.93	--	--	--	--	0.32	--	--	--	2.89
Subtotals	0.85	--	12.09	18.82	22.03	2.90	142.27	2.23	2.83	3.02	0.03	--	207.07
Mode: Unmodulated Signal													
76	1.08	2.06	8.94	0.61	40.81	12.87	37.19	10.98	4.76	28.76	3.31	--	151.37
80	--	--	1.50	2.55	3.77	6.55	--	--	1.86	0.13	--	--	16.36
Subtotals	1.08	2.06	10.44	3.16	44.58	19.42	37.19	10.98	6.62	28.89	3.31	--	167.73
Other[b]	0.10	--	5.86	3.94	0.90	5.26	19.13	0.19	1.16	--	--	--	36.54
Totals	**2.03**	**2.06**	**28.39**	**25.92**	**67.51**	**27.58**	**198.59**	**13.40**	**10.61**	**31.91**	**3.34**	--	**411.34**
Changes in Operational Mode	46	1	74	80	143	223	31	59	45	22	3	0	727

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-6. 1985 WTF OPERATIONS SUMMARY: NORTH-SOUTH AND EAST-WEST ANTENNA ELEMENTS SIMULTANEOUSLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
					Mode: Modulated Signal[a]								
44	0.23	--	--	1.97	0.46	0.05	29.73	--	--	--	--	--	32.44
76	0.70	--	7.62	15.01	45.98	261.68	118.66	74.91	161.36	451.69	657.61	730.96	2526.18
78	--	--	--	0.99	--	0.05	73.94	--	0.43	--	--	--	75.41
Subtotals	0.93	--	7.62	17.97	46.44	261.78	222.33	74.91	161.79	451.69	657.61	730.96	2634.03
					Mode: Unmodulated Signal								
76	0.34	--	10.16	90.06	10.35	10.70	--	1.63	4.82	3.40	0.61	--	132.07
80	--	--	--	9.80	--	0.98	--	--	--	1.72	--	--	12.50
Subtotals	0.34	--	10.16	99.86	10.35	11.68	--	1.63	4.82	5.12	0.61	--	144.57
Other[b]	0.13	--	25.48	43.63	0.31	0.22	10.87	--	0.03	--	--	--	80.67
Totals	**1.40**	--	**43.26**	**161.46**	57.10	273.68	233.20	**76.54**	**166.64**	**456.81**	**658.22**	**730.96**	**2859.27**
Changes in Operational Mode	13	0	14	60	55	69	15	48	20	54	38	38	424

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-7. 1986 WTF OPERATIONS SUMMARY: NORTH-SOUTH ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
76	40.51	11.81	1.37	3.13	0.16	21.20	7.65	3.33	1.88	0.01	0.05	0.94	92.04
Subtotal	40.51	11.81	1.37	3.13	0.16	21.20	7.65	3.33	1.88	0.01	0.05	0.94	92.04
						Mode: Unmodulated Signal							
72	0.00	0.00	0.00	0.29	1.86	0.00	0.00	0.00	0.15	0.00	0.00	0.00	2.30
76	0.00	0.00	0.00	1.22	0.30	0.00	0.00	0.00	0.17	3.28	0.00	0.00	4.97
80	0.00	0.00	0.00	0.42	1.33	0.00	0.00	0.12	0.08	0.00	0.00	0.00	1.95
Subtotals	0.00	0.00	0.00	1.93	3.49	0.00	0.00	0.12	0.40	3.28	0.00	0.00	9.22
Other[b]	0.00	0.00	0.00	0.00	1.46	0.00	0.00	0.00	0.19	0.00	0.00	0.00	1.65
Totals	40.51	11.81	1.37	5.06	5.11	21.20	7.65	3.45	2.47	3.29	0.05	0.94	102.91
Changes in Operational Mode	14	5	12	15	77	26	23	10	46	37	2	7	274

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-8. 1986 WTF OPERATIONS SUMMARY: EAST-WEST ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: Modulated Signal[a]													
76	0.05	2.81	2.32	0.34	1.86	1.00	2.91	2.58	4.37	2.59	1.65	0.09	22.57
Subtotals	0.05	2.81	2.32	0.34	1.86	1.00	2.91	2.58	4.37	2.59	1.65	0.09	22.57
Mode: Unmodulated Signal													
72	0.00	0.00	0.00	0.66	1.74	0.00	0.02	0.00	0.00	0.00	0.00	0.00	2.42
76	0.00	0.00	1.10	0.21	1.38	0.00	0.08	0.00	0.00	3.36	0.09	0.00	6.22
80	0.00	0.00	0.00	0.80	0.56	0.00	0.01	0.00	0.00	0.00	0.00	0.00	1.37
Subtotals	0.00	0.00	1.10	1.67	3.68	0.00	0.11	0.00	0.00	3.36	0.09	0.00	10.01
Other[b]	0.00	0.00	0.00	0.00	1.50	0.00	0.00	0.00	0.15	0.00	0.00	0.00	1.65
Totals	0.05	2.81	3.42	2.01	7.04	1.00	3.02	2.58	4.52	5.95	1.74	0.09	34.23
Changes in Operational Mode	47	6	14	24	65	32	20	5	8	18	2	4	245

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-9. 1986 WTF OPERATIONS SUMMARY: NORTH-SOUTH AND EAST-WEST ANTENNA ELEMENTS SIMULTANEOUSLY
[Hours of Operation]

Frequency, Hz	Month: Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
					Mode: Modulated Signal[a]								
76	672.44	633.09	600.27	595.68	656.56	641.07	689.94	633.20	675.58	688.85	696.57	679.21	7862.46
Subtotals	672.44	633.09	600.27	595.68	656.56	641.07	689.94	633.20	675.58	688.85	696.57	679.21	7862.46
					Mode: Unmodulated Signal								
72	0.00	0.00	0.00	0.00	0.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.89
76	0.15	0.07	7.54	0.00	0.25	0.00	0.00	0.00	0.00	1.80	0.44	0.00	10.25
80	0.00	0.00	0.00	0.00	0.51	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.58
Subtotals	0.15	0.07	7.54	0.00	1.65	0.00	0.00	0.00	0.00	1.87	0.44	0.00	11.72
Other[b]	0.00	0.00	0.00	0.00	1.48	0.00	0.00	0.00	0.33	0.00	0.00	0.34	2.15
Totals	672.59	633.16	607.81	595.68	659.69	641.07	689.94	633.20	675.91	690.72	697.01	679.55	7876.33
Changes in Operational Mode	45	54	69	61	112	72	66	42	63	62	45	61	752

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-10. 1987 WTF OPERATIONS SUMMARY: NORTH-SOUTH ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: Modulated Signal[a]													
76	11.03	0.07	0.00	0.09	0.38	0.40	1.88	0.24	0.00	2.13	1.09	0.00	17.31
Subtotals	11.03	0.07	0.00	0.09	0.38	0.40	1.88	0.24	0.00	2.13	1.09	0.00	17.31
Mode: Unmodulated Signal													
72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other[b]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totals	**11.03**	**0.07**	**0.00**	**0.09**	**0.38**	**0.40**	**1.88**	**0.24**	**0.00**	**2.13**	**1.09**	**0.00**	**17.31**
Changes in Operational Mode	19	0	2	0	6	8	32	1	1	5	5	1	80

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-11. 1987 WTF OPERATIONS SUMMARY: EAST-WEST ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
					Mode: Modulated Signal[a]								
76	0.10	0.00	0.00	0.00	11.18	7.30	4.72	0.10	3.27	0.00	1.13	24.60	52.40
Subtotals	0.10	0.00	0.00	0.00	11.18	7.30	4.72	0.10	3.27	0.00	1.13	24.60	52.40
					Mode: Unmodulated Signal								
72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.17
76	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.23
Subtotals	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.45
Other[b]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totals	**0.10**	**0.00**	**0.05**	**0.00**	**11.18**	**7.30**	**4.72**	**0.10**	**3.27**	**0.00**	**1.53**	**24.60**	**52.85**
Changes in Operational Mode	6	2	1	2	67	6	9	5	3	3	39	5	148

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-12. 1987 WTF OPERATIONS SUMMARY: NORTH-SOUTH AND EAST-WEST ANTENNA ELEMENTS SIMULTANEOUSLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
					Mode: Modulated Signal[a]								
76	712.70	651.08	658.35	697.30	715.76	691.87	700.54	584.40	697.31	724.71	703.15	695.82	8232.99
Subtotals	712.70	651.08	658.35	697.30	715.76	691.87	700.54	584.40	697.31	724.71	703.15	695.82	8232.99
					Mode: Unmodulated Signal								
72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76	1.77	0.00	0.00	0.00	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.53	2.76
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03
Subtotals	1.77	0.00	0.00	0.00	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.56	2.79
Other[b]	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38
Totals	**714.85**	**651.08**	**658.35**	**697.30**	**716.22**	**691.87**	**700.54**	**584.40**	**697.31**	**724.71**	**703.15**	**696.38**	**8236.16**
Changes in Operational Mode	32	10	11	10	13	14	24	23	13	10	12	12	184

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-13. 1988 WTF OPERATIONS SUMMARY: NORTH-SOUTH ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
76	0.00	0.00	0.25	0.55	0.26	27.08	2.71	1.04	0.00	0.02	0.17	0.01	32.09
Subtotal	0.00	0.00	0.25	0.55	0.26	27.08	2.71	1.04	0.00	0.02	0.17	0.01	32.09
						Mode: Unmodulated Signal							
44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00
72	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23
76	0.00	0.00	0.00	0.00	0.00	0.90	0.00	0.03	0.00	2.00	0.08	0.00	3.01
80	0.00	0.00	0.00	0.08	0.00	0.97	0.00	0.00	0.00	0.00	0.00	0.00	1.05
Subtotals	0.00	0.00	0.00	0.31	0.00	1.87	0.00	0.03	0.00	3.00	0.08	0.00	5.29
Other[b]	0.00	0.00	0.00	1.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.21
Totals	**0.00**	**0.00**	**0.25**	**2.07**	**0.26**	**28.95**	**2.71**	**1.07**	**0.00**	**3.02**	**0.25**	**0.01**	**38.59**
Changes in Operational Mode	3	4	0	18	4	21	12	10	9	1	5	2	89

[a]Frequencies listed refer to the center frequency of operation.

[b]Denotes small periods of time at other frequencies or undesignated operation.

TABLE K-14. 1988 WTF OPERATIONS SUMMARY: EAST-WEST ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
76	10.93	0.09	0.38	0.10	0.17	0.19	1.07	0.35	0.49	2.31	0.11	0.07	16.26
Subtotals	10.93	0.09	0.38	0.10	0.17	0.19	1.07	0.35	0.49	2.31	0.11	0.07	16.26
						Mode: Unmodulated Signal							
44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.10	0.00	2.10
72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.03	3.92	16.14	0.11	0.00	21.20
80	0.00	0.00	0.00	0.00	0.00	1.31	0.15	0.00	0.00	0.00	0.00	0.00	1.46
Subtotals	0.00	0.00	0.00	0.00	0.00	1.31	0.15	1.03	3.92	18.14	0.21	0.00	24.76
Other[b]	0.00	0.00	0.00	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.61
Totals	**10.93**	**0.09**	**0.38**	**0.71**	**0.17**	**1.50**	**1.22**	**1.38**	**4.41**	**20.45**	**0.32**	**0.07**	**41.63**
Changes in Operational Mode	0	4	5	11	8	9	13	10	2	6	5	34	107

[a]Frequencies listed refer to the center frequency of operation.

[b]Denotes small periods of time at other frequencies or undesignated operation.

TABLE K-15. 1988 WTF OPERATIONS SUMMARY: NORTH-SOUTH AND EAST-WEST ANTENNA ELEMENTS SIMULTANEOUSLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
76	716.72	680.73	721.26	699.90	716.52	654.48	685.32	714.15	691.24	660.47	690.78	720.02	8351.59
Subtotals	716.72	680.73	721.26	699.90	716.52	654.48	685.32	714.15	691.24	660.47	690.78	720.02	8351.59
						Mode: Unmodulated Signal							
44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.77	0.12	0.00	6.89
72	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40
76	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	14.75	0.07	0.00	14.88
80	0.00	0.00	0.00	0.25	0.00	0.00	1.03	0.00	0.00	0.00	0.00	0.00	21.28
Subtotals	0.00	0.00	0.00	0.71	0.00	0.00	21.03	0.00	0.00	21.52	0.19	0.00	43.45
Other[b]	0.00	0.00	0.00	1.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.17
Totals	716.72	680.73	721.26	701.78	716.52	654.48	706.35	714.15	691.24	681.99	690.97	720.02	8396.21
Changes in Operational Mode	10	10	21	23	11	16	20	19	14	17	19	9	189

[a]Frequencies listed refer to the center frequency of operation.

[b]Denotes small periods of time at other frequencies or undesignated operation.

The MTF operating schedule was broken down into three antenna conditions in 1986 and two antenna conditions in 1987 and 1988. The 1986 conditions were: north-south (NS) antenna element, north east-west (NEW) antenna element, and south east-west (SEW) antenna element. The 1987 and 1988 conditions were: north-south antenna element and east-west (EW) antenna elements. The NS antenna element data represent those times when the NS element was operating while the NEW and SEW elements were off; the NEW antenna element data represent those times when the NEW element was operating while the NS and SEW elements were off; the SEW antenna element data represent those times when the SEW element was operating while the NS and NEW elements were off; the EW antenna element data represent those times when the NEW and SEW elements were operated in parallel while the NS element was off.

Tables K-16, K-17, and K-18 show the number of hours of operation per month in 1986 for the NS, NEW, and SEW antenna elements, respectively. Tables K-19 through K-22 show the number of hours of operation per month in 1987 and 1988 for the NS and EW antenna elements, respectively. The columns of these tables, labeled with calendar months, provide a breakdown of the MTF operation by antenna current and signal type. Subtotals are given by signal type. A monthly total is also provided. Yearly total hours of operation by signal type and frequency are given in the "Annual Totals" column. The bottom row of the tables gives the number of on/off cycles of the antenna element on a monthly and annual basis.

Throughout 1986, 1987, and 1988 the MTF operated in such a manner as to permit measurement crews to perform field measurements. In this operating mode, the antenna elements were cycled on and off as needed to enable measurements to be made. In 1986 the cycling of the antenna elements was dictated primarily by measurement crews via radio communication with the transmitting site. As testing efforts grew in 1987 and 1988, the antenna elements were continuously cycled on and off during testing hours on a 15-minute rotational cycle as described in Section 4.6.3 of this report. This procedure permitted several measurement crews to perform measurements simultaneously.

TABLE K-16. 1986 MTF OPERATIONS SUMMARY: NORTH-SOUTH ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
Mode: Modulated Signal[a]													
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mode: Unmodulated Signal													
76 (4 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	24.43	16.74	10.71	11.49	0.00	0.00	63.37
76 (6 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.11
76 (10 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	24.43	16.74	10.82	11.49	0.00	0.00	63.48
Other[b]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.07
Totals	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**24.43**	**16.74**	**10.89**	**11.49**	**0.00**	**0.00**	**63.55**
Antenna On/Off Cycles	0	0	0	0	0	0	145	23	31	60	0	0	259

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-17. 1986 MTF OPERATIONS SUMMARY: NORTH EAST-WEST ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Month Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
						Mode: Modulated Signal[a]							
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
						Mode: Unmodulated Signal							
76 (4 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.11	0.00	0.00	0.00	0.16
76 (6 Amps)	0.00	0.00	0.00	0.00	0.00	18.87	13.80	0.36	2.46	9.15	0.00	0.00	44.64
76 (10 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	18.87	13.80	0.41	2.57	9.15	0.00	0.00	44.80
Other[b]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.06
Totals	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**18.87**	**13.80**	**0.41**	**2.63**	**9.15**	**0.00**	**0.00**	**44.86**
Antenna On/Off Cycles	0	0	0	0	0	55	10	2	26	83	0	0	176

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-18. 1986 MTF OPERATIONS SUMMARY: SOUTH EAST-WEST ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
Mode: Modulated Signal[a]													
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mode: Unmodulated Signal													
76 (4 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.00	0.00	0.00	0.05
76 (6 Amps)	0.00	0.00	0.00	0.00	0.00	11.72	0.00	0.00	5.26	5.76	0.00	0.00	22.74
76 (10 Amps)	0.00	0.00	3.87	18.64	6.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.66
Subtotals	0.00	0.00	3.87	18.64	6.15	11.72	0.00	0.04	5.27	5.76	0.00	0.00	51.45
Other[b]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.03
Totals	0.00	0.00	3.87	18.64	6.15	11.72	0.00	0.04	5.30	5.76	0.00	0.00	51.48
Antenna On/Off Cycles	0	0	27	39	5	6	0	2	30	78	0	0	187

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-19. 1987 MTF OPERATIONS SUMMARY: NORTH-SOUTH ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: Modulated Signal[a]													
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mode: Unmodulated Signal													
76 (15 Amps)	0.00	0.00	0.00	0.00	0.00	44.40	27.59	32.40	38.86	33.08	21.79	0.00	198.12
Subtotals	0.00	0.00	0.00	0.00	0.00	44.40	27.59	32.40	38.86	33.08	21.79	0.00	198.12
Other[b]	0.00	0.00	0.00	0.42	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.84
Totals	**0.00**	**0.00**	**0.00**	**0.42**	**0.42**	**44.40**	**27.59**	**32.40**	**38.86**	**33.08**	**21.79**	**0.00**	**198.96**
Antenna On/Off Cycles	0	0	0	1	1	533	331	389	466	397	262	0	2380

[a]Frequency listed refers to the center frequency of operation.

[b]Denotes small periods of time at other currents or undesignated operation.

TABLE K-20. 1987 MTF OPERATIONS SUMMARY: EAST-WEST ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
	Month												
Mode: Modulated Signal[a]													
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mode: Unmodulated Signal													
76 (15 Amps)	0.00	0.00	0.00	0.00	0.00	43.95	27.81	32.39	38.61	33.94	21.90	0.00	198.60
Subtotals	0.00	0.00	0.00	0.00	0.00	43.95	27.81	32.39	38.61	33.94	21.90	0.00	198.60
Other[b]	0.00	0.00	0.00	0.25	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67
Totals	**0.00**	**0.00**	**0.00**	**0.25**	**0.42**	**43.95**	**27.81**	**32.39**	**38.61**	**33.94**	**21.90**	**0.00**	**199.27**
Antenna On/Off Cycles	0	0	0	1	1	527	334	389	463	407	263	0	2385

[a]Frequency listed refers to the center frequency of operation.

[b]Denotes small periods of time at other currents or undesignated operation.

TABLE K-21. 1988 MTF OPERATIONS SUMMARY: NORTH-SOUTH ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
76 (75 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	3.27	0.14	0.00	0.00	0.00	0.00	3.41
Subtotal	0.00	0.00	0.00	0.00	0.00	0.00	3.27	0.14	0.00	0.00	0.00	0.00	3.41
						Mode: Unmodulated Signal							
76 (15 Amps)	27.13	26.36	27.14	34.14	41.23	43.27	0.19	0.00	0.00	0.00	0.00	0.00	199.46
76 (75 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	27.62	59.53	34.24	52.86	12.67	23.76	210.68
44 (75 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	1.27	0.00	26.16	2.61	31.20	15.68	76.92
Subtotals	27.13	26.36	27.14	34.14	41.23	43.27	29.08	59.53	60.40	55.47	43.87	39.44	487.06
Other[b]	0.00	0.00	0.00	0.00	0.00	0.00	8.09	0.00	0.00	0.00	0.00	0.00	8.09
Totals	27.13	26.36	27.14	34.14	41.23	43.27	40.44	59.67	60.40	55.47	43.87	39.44	498.56
Antenna On/Off Cycles	326	316	326	410	495	519	485	714	725	666	526	473	5981

[a]Frequency listed refers to the center frequency of operation.

[b]Denotes small periods of time at other currents or undesignated operation.

TABLE K-22. 1988 MTF OPERATIONS SUMMARY: EAST-WEST ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
					Mode: Modulated Signal[a]								
76 (15 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	3.32	0.14	0.00	0.00	0.00	0.00	3.46
Subtotal	0.00	0.00	0.00	0.00	0.00	0.00	3.32	0.14	0.00	0.00	0.00	0.00	3.46
					Mode: Unmodulated Signal								
76 (15 Amps)	27.14	30.95	31.48	34.34	41.33	43.13	0.22	0.00	0.00	0.00	0.00	0.00	208.59
76 (75 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	31.10	68.99	34.71	56.05	12.67	23.76	227.28
44 (75 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	1.06	0.00	26.38	2.52	31.29	15.58	76.83
Subtotals	27.14	30.95	31.48	34.34	41.33	43.13	32.38	68.99	61.09	58.57	43.96	39.34	512.70
Other[b]	0.00	0.00	0.00	0.25	0.42	0.00	7.20	0.00	0.00	0.00	0.00	0.00	7.20
Totals	27.14	30.95	31.48	34.34	41.33	43.13	42.90	69.13	61.09	58.57	43.96	39.34	523.36
Antenna On/Off Cycles	326	371	378	412	496	518	526	827	733	703	527	472	6289

[a]Frequency listed refers to the center frequency of operation.

[b]Denotes small periods of time at other currents or undesignated operation.

The last row in the MTF operations summary tables was changed from "changes in operational mode" used in previous years to "antenna on/off cycles." This new label more accurately describes the nature of the antenna operations. The number of on/off cycles in 1986 was determined by summing the cycle entries in the MTF log data sheets. In 1987 and 1988, the MTF operated primarily on a 15-minute rotational cycle broken into three 5-minute segments to accommodate several measurement crews. The summarized MTF log tables routinely provided to IITRI show the beginning and ending times of such cycles. Separate entries are not included for each change of antenna elements during this cycle, nor are deviations from the cycle accounted for, such as one field crew controlling the antenna condition for short time periods while other crews are not testing. Thus, the exact number of on/off cycles and duration of operating time for each antenna element cannot be determined directly from the summarized MTF log data sheets, but were estimated by the procedure described below for 1987 and 1988.

The total number of on/off cycles for the two elements was calculated by multiplying the time in hours between the start and finish of the rotational cycling of the antenna elements by 12, since on/off cycles were on a 5-minute (1/12-hour) basis. The total number of on/off cycles was then multiplied by 1/3 to give the number of cycles for either the NS or EW antenna element. This is because one of three cycles that occur in a single 15-minute cycle will involve the NS antenna element, and one of three will involve the EW antenna element. Note that this is the same formula used in the 1987 report* to calculate the number of changes in the operational mode of each antenna element in that year. Only the name of the row has been changed.

In the 1986** and 1987 reports the number of operational mode changes in 1986 were determined by summing the cycle entries in the MTF log data sheets

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* ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1987. IIT Research Institute Technical Report E06595-1, August 1988, 54 pp. plus appendixes.

**ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1986. IIT Research Institute Technical Report E06549-37, September 1987, 52 pp. plus appendixes.

and multiplying the sum by 2 to include the powering up and powering down of the antenna elements. In this report, the factor of 2 is omitted to give the number of on/off cycles. The powering down of antenna elements is not included in any count of on/off cycles or operational mode changes in this report.

The monthly operation times for each antenna element given in Tables K-19 through K-22 were calculated by multiplying the time period of the rotational cycles by one-third. This is because each element was estimated to have a 33% duty cycle during cyclic operation periods.

The estimates of MTF operating time and on/off cycles calculated by the above procedures were judged adequate for general use. However, IITRI can obtain exact, minute-by-minute MTF log data for specific periods as required by the researchers.