

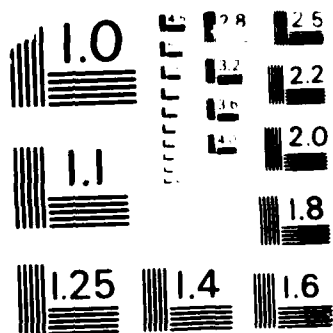
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IITRI

ELF COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING PROGRAM:
ELECTROMAGNETIC FIELD MEASUREMENTS AND
ENGINEERING SUPPORT--1986

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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. 1985 and 1986 activities centered on the operation of full-scale studies. This (Continued on reverse)					
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report documents electromagnetic (EM) field measurements at investigator selected study sites from 1982 through 1986, and presents the status of the sites in light of the EM exposure criteria. Other engineering support activities are also described. *Key: 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100*

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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 1986. The report also describes other engineering activities in support of the 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 and N00039-84-C-0070, to IIT Research Institute (IITRI). IITRI measurement personnel for 1986 were Messrs. D. P. Haradem, R. G. Drexler, J. R. Gauger, and Dr. J. E. Zapotosky.

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1. INTRODUCTION

1.1 ECOLOGICAL MONITORING PROGRAM

In 1981, concurrently with deciding 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/effect relationships between EM exposure and biological/ecological endpoints. As part of the program, IIT Research Institute (IITRI) assists university investigators by providing EM measurements and other EM engineering support. IITRI support activities include analysis of EM aspects of research protocols; design, fabrication, and installation of special EM exposure equipment; and review of EM aspects of investigator 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. This report documents engineering support activities performed during 1986.

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 a second located in the Copper Country and Escanaba River State Forests in Michigan (see Figure 1). Each facility consists mainly of long overhead wires (antennas) with buried ground terminals at each end and a control transmitter building. Both the antenna and grounding elements are located in cleared rights-of-way (ROW). The transmitters broadcast messages using ELF EM fields; these fields are the operational component to be evaluated by the Ecological Monitoring Program.

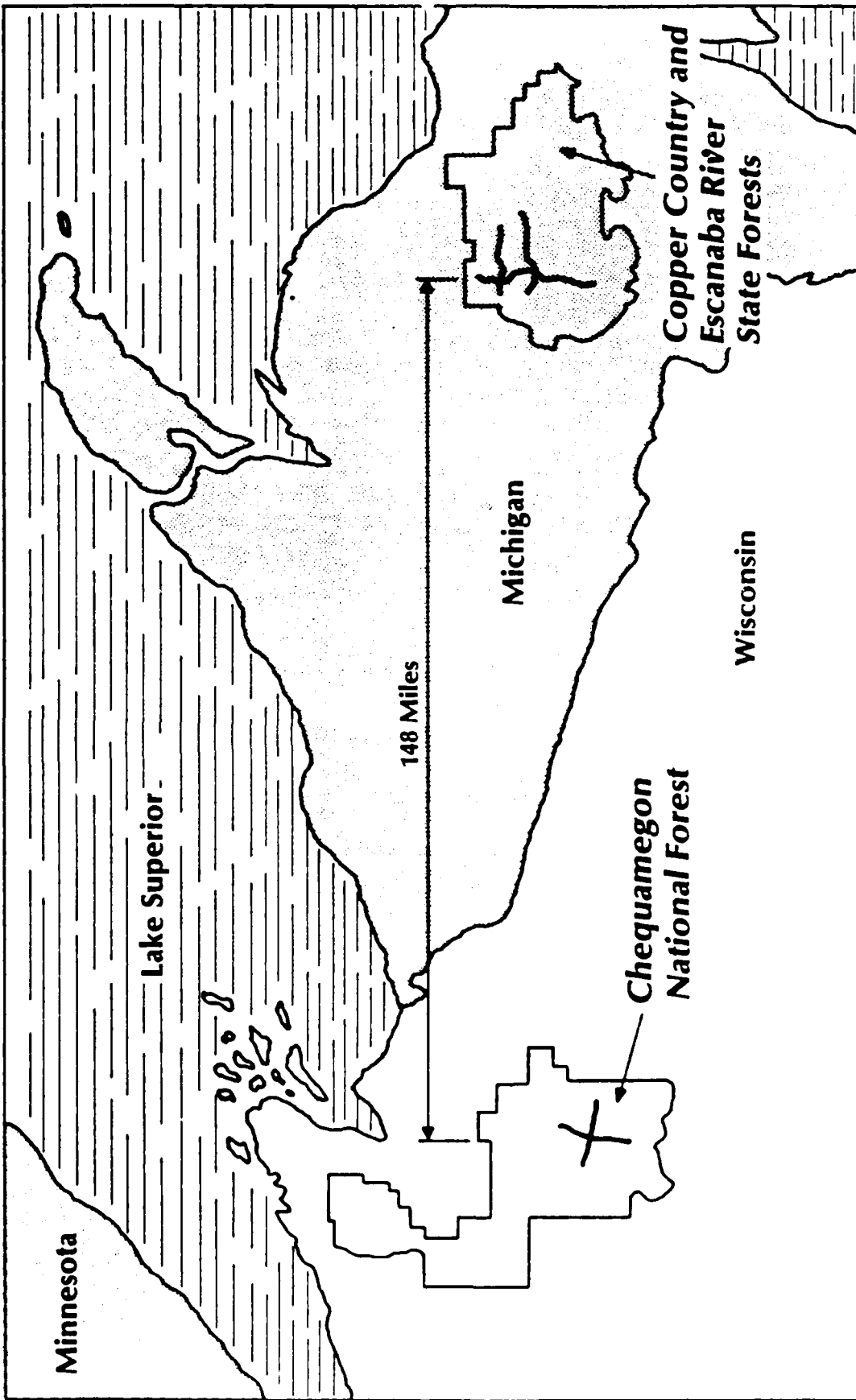


FIGURE 1. ELF COMMUNICATIONS FACILITIES IN WISCONSIN AND MICHIGAN.

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 system. The transitional phase begins with the initiation of system testing; exposures are intermittent and are often at lower intensities than anticipated for an operational system. When the system achieves full operational capability, EM exposure will be nearly continuous and at full intensity. The achievement of a fully operational capability at the Wisconsin Transmitting Facility (WTF) occurred during the last quarter of 1985; achievement of a similar capability at the Michigan Transmitting Facility (MTF) is expected to occur during 1988.

The EM fields produced by the ELF Communications System can be described as follows:

- a magnetic field, the same in air and the earth, which is generated by the electrical current in the antenna element
- an electric field in the earth, which is the sum of the fields induced by the magnetic field and by the current flowing from the buried ground terminals
- an electric field in air, 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 (FSK). An important aspect of MSK modulation is that minimum 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; however, the system can also transmit at other frequencies in the 40 to 80 Hz range.

In their assessments, investigators must consider such EM variables as the frequency of exposure (duty cycle), duration, and intensity, as well as other EM fields (e.g., harmonic frequencies) that may act as synergists. Commercial 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

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power distribution, has been considered in characterizing the EM environment at study sites.

1.3 PAIRED SITE CONCEPT

The Ecological Monitoring Program employs a paired test (or ELF treatment) and control design to examine for possible effects of ELF EM fields on biological and ecological variables. This spatial design pairs potentially impacted (test) sites with nonimpacted (control) sites to assess for effects. The test sites are located within the zone of potential ELF system influence, while control sites are positioned outside the zone. As in classic experimental design, the control site is used to measure the environmental (ambient) conditions, while the treatment site measures the environmental conditions plus the effects of the EM fields produced by the ELF Communications System. Such paired sites have essentially matched biotic and abiotic characteristics, but purposely dissimilar ELF exposures.

In Michigan, temporal comparisons of biotic variables will be made between the preoperational and operational phases of the ELF system, as well as spatial comparisons between test and control sites. Comparisons planned in Wisconsin are spatial only, as the transmitter there has been operating in a transitional mode since 1969 and a preoperational data base does not exist.

Because the EM intensity and operational characteristics required to produce a bioeffect are not known, EM exposure criteria were established as guidelines 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 and the 60 Hz fields at both test and control sites. The exposure criteria also ensure that there is not a substantial difference in the ambient 60 Hz EM fields between the test and control sites.

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

- (1) $T (76 \text{ Hz}) / C (76 \text{ Hz}) > 10$
- (2) $T (76 \text{ Hz}) / T (60 \text{ Hz}) > 10$
- (3) $T (76 \text{ Hz}) / C (60 \text{ Hz}) > 10$
- (4) $0.1 < T (60 \text{ Hz}) / C (60 \text{ Hz}) < 10$

where $T (76 \text{ Hz})$ = Test site exposure due to ELF system
 $T (60 \text{ Hz})$ = Test site exposure due to power lines
 $C (76 \text{ Hz})$ = Control site exposure due to ELF system
 $C (60 \text{ Hz})$ = Control site exposure due to power lines.

Test and control site pairings were assessed for acceptability using the exposure criteria for each of the three EM fields produced by the ELF Communications System. Based on the exposure assessment, each possible test and control site pairing was classified as acceptable, conditionally acceptable, or unacceptable. These categories are defined in Appendix J. The status of site pairings is discussed in Section 2.

1.4 ANNUAL MEASUREMENTS

In addition to making EM measurements for site selection, IITRI performs an annual survey to document the spatial and temporal characteristics of EM fields at each study site. Spatial measurements are important in characterizing the EM exposure at study sites that are extensive in area or at sites where there are large EM field gradients. Temporal comparisons of 60 Hz and 76 Hz fields are also required in order to record changes in EM exposure at study sites from year to year. Ambient 60 Hz fields may change due to construction of new power lines, local changes in the distribution system, and the presence of the ELF antenna. The EM field intensities produced by the ELF Communications System in Wisconsin near the ground terminals have changed as the ground elements have been upgraded for operational status.

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 from operation of the WTF, and EM field values as they relate to the phase angles between antenna legs. The former two aspects were examined

and found to be below detection levels or of such low values as not to be considered a problem. The effects of antenna phase angle on EM exposures at WTF study sites are treated in Appendix K. Protocols and EM measurements are detailed in Sections 3.4 and 3.5, respectively.

1.5 OTHER SUPPORT

In order to accommodate fleet operations, the testing of new hardware, and the testing of utility interference mitigation, the transmitting facilities operate at numerous frequency, modulation, and power conditions during their transitional operating phase. Investigators are provided with a summary of the operating hours and modes of the antennas (see Section 4). This summary, in conjunction with measured values at the study sites, may be used by investigators to construct exposure regimes for correlation with measured biological and ecological endpoints.

Two ecological studies employ buried culture cells that isolate study organisms from the surrounding soil. In 1983, IITRI personnel reviewed the proposed design of the culture cells. At that time, the matching of internal to external EM fields and the measurement of internal EM fields were two areas of concern. Subsequently, IITRI helped to design, fabricate, and install culture cell exposure chambers and control apparatus. Protocols for the setup and measurement of EM fields within the cells were provided to investigators. Culture cells for slime mold studies were established and have been in use since 1984. Exposure control chambers were added in 1985. Electrodes for the soil amoeba studies were also established at the WTF in 1985, in order to perform preliminary studies prior to integrating this technique at Michigan study sites. Technical support for the use of these chambers continued in 1986.

2. ECOLOGICAL MONITORING STUDY SITES

2.1 NEW SITE SELECTION FOR 1986

The site selection process is complete in both Michigan and Wisconsin. New measurement sites established in Michigan in 1986 include the holding facilities and laboratory for the small mammals and nesting birds studies (site 1L1) as well as three bird displacement points (sites 1D1, 1D2, and 1D3) associated with existing study sites. These new measurement sites do not have matched counterparts to be used for site pair ratio calculations. This is because the same holding facilities and laboratory are used for test and control animals, and the displacement points are just one point along a long route in which the animals reside momentarily. A possible future weir net site (site 5T7-1) was also measured for the aquatic ecosystems studies. Detailed descriptions and maps of these as well as all other measurement points have been given to the study investigators. Site overview maps are included in Appendixes A through I.

2.2 SUMMARY OF SITE LOCATIONS AND STATUS

Figure 2 shows the locations of field sites for the Wisconsin studies relative to the Wisconsin Transmitting Facility antenna elements. The three studies for which EM field measurements were made are identified in the upper left-hand corner of the figure. The black dots represent the locations of field sites at which IITRI field crews evaluated the ELF EM fields. No new sites were established in Wisconsin in 1986.

Figure 3 shows the locations of field sites for the Michigan studies relative to the Michigan Transmitting Facility antenna elements. The seven studies for which EM field measurements were made are identified in the upper left-hand corner of the figure. Again, the black dots represent the locations of field sites at which IITRI field crews evaluated the ELF EM fields.

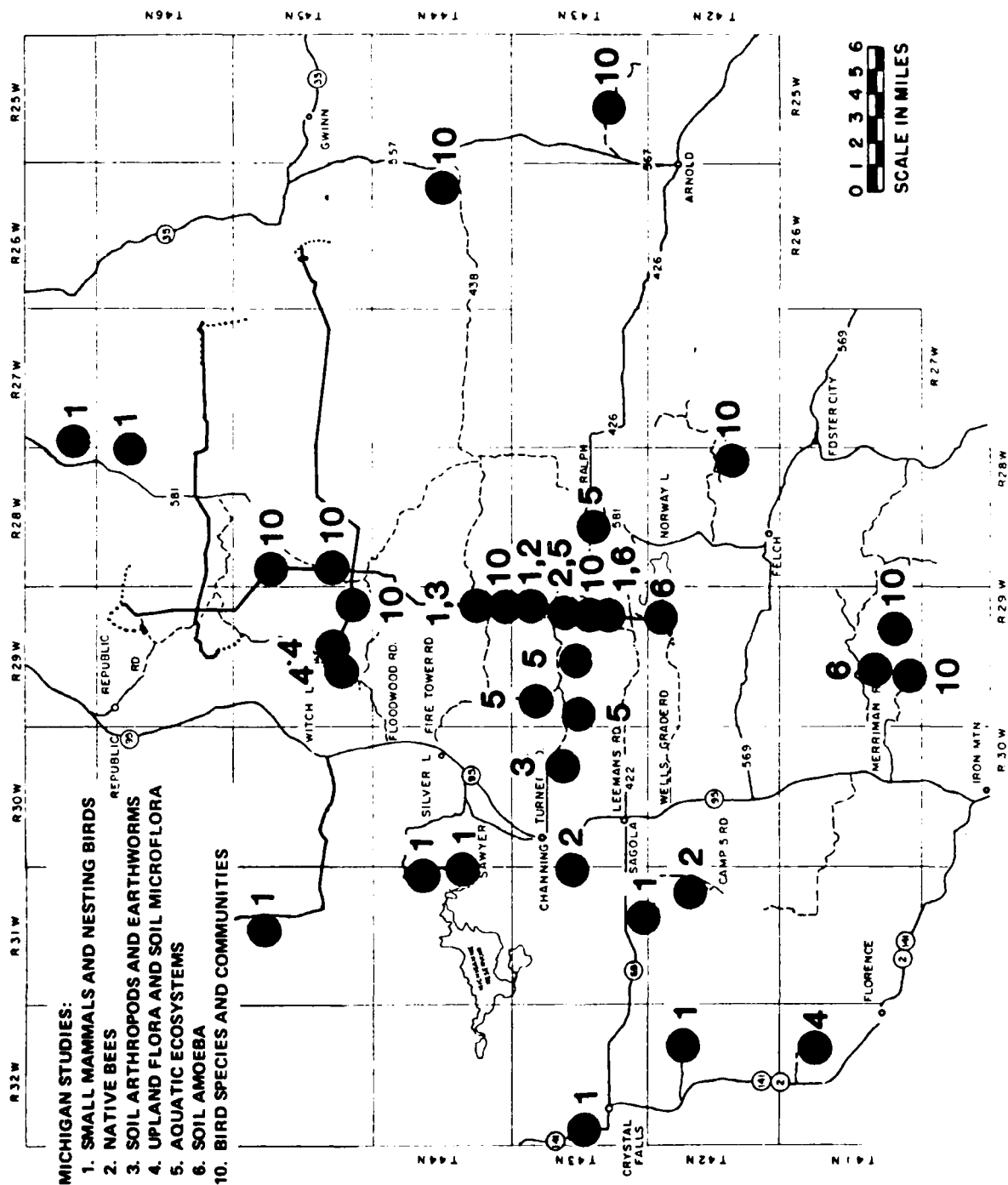


FIGURE 3. FIELD SITES FOR MICHIGAN ECOLOGY STUDIES.

Measurements in Michigan in 1986 showed an increase in 60 Hz magnetic flux densities over previous years' measurements at test sites. This is attributable to coupling of fields from power lines to the newly constructed ELF antenna. As a result, the 60 Hz magnetic flux densities at test sites exceeded those at corresponding control sites by more than a factor of 10 in many instances, but typically differed by less than a factor of 100. Study sites will not be relocated to reduce this ratio between 60 Hz fields at test and control sites for several reasons. First, the ratios come close to satisfying the guideline criteria originally established. Second, the 60 Hz fields are still at least a factor of 10 lower than the 76 Hz fields at the test sites. Third, the ratio between 60 Hz field levels is acceptable provided the researchers show no differences between test and control sites in the pre-operational phase of the study, which has been the case up to the present time. Because the nature of the study requires that the test sites be located near the antenna, one cannot escape these coupled 60 Hz fields. The coupling of 60 Hz fields is discussed in more detail in Section 3.

The significance of 60 Hz coupling to the ELF antennas will diminish when the MTF begins continuous full power operation with a modulated signal. Under these conditions, the currents on the ELF antenna will be composed of a band of frequencies centered about 76 Hz, including 60 Hz components. Thus, the 60 Hz field components at test sites generated by the ELF transmitter as a result of its modulated signal will dwarf the 60 Hz fields generated directly by power lines or by 60 Hz coupling to the antenna wires.

In summary, the site selection process is complete in both Michigan and Wisconsin. All test/control site pairs fall into either acceptable or conditionally acceptable categories. These categories are defined in Appendix J. Table 1 presents a summary of the acceptability of all combinations of test and control site pairs within the studies.

TABLE 1. SUMMARY AND STATUS OF TEST/CONTROL SITE PAIRINGS

Study	Number of Test/Control Site Pairs	Number of Sites That Are:		
		Acceptable	Conditionally Acceptable	Unacceptable
Small Mammals and Nesting Birds	9	2	7	0
Native Bees	4	1	3	0
Soil Arthropods and Earthworms	1	1	0	0
Upland Flora and Soil Microflora	4	1	3	0
Aquatic Ecosystems	11	3	8	0
Soil Amoebae	2	2	0	0
Slime Mold	2	2	0	0
Wetlands	15	14	1	0
Bird Species and Communities:	Michigan	25	17	8
	Wisconsin	25	21	4

3. EM FIELD MEASUREMENTS AND SUPPORT

3.1 EM FIELD DESCRIPTION

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

A magnetic field is generated by current through a conductor. The ELF system and power lines produce consistent and predictable magnetic fields that are generally unaffected by the physical environment such as vegetation, soil, and non-metallic structures. Magnetic fields are unchanged at medium boundaries such as air/earth or air/water. Thus, magnetic field measurement techniques need not consider field shielding, enhancements, or perturbations from the local environment. This local uniformity of the magnetic field allows repeatable measurements over time (even years) provided that the field source 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 system are that induced by the magnetic field and that generated by the ground terminal currents. Longitudinal electric fields produced by power lines are generated by the lines' magnetic fields and by unbalanced currents flowing in the earth. The uniformity of longitudinal electric fields is affected by local soil conductivities and other anomalies such as large rocks, tree roots, and pools of water. Overall, however, soil conductivity is rather uniform. Thus, longitudinal electric field measurements are fairly uniform and repeatable when other anomalies are avoided. Some year-to-year variations may occur as changes in soil moisture content affect soil conductivity.

The ELF 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 byproduct 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 potential difference, 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. Measurements of transverse electric fields are taken in open areas in an effort to obtain a typical "unperturbed" measurement.

3.2 FIELD PROBES AND MEASUREMENT EQUIPMENT

The magnetic flux density, the transverse electric field intensity, and the 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, as appropriate, outputs a voltage proportional to the field intensity. The value of the applied field can be obtained by means of individual sets of laboratory calibration factors for each probe.

The magnetic field probes are composed of multitransformed coils of wire wound on ferrite cores and shunted by appropriately chosen resistors to obtain a flat frequency response. The magnetic field probes output a voltage proportional to the magnetic flux density oriented parallel to the axis of the core. The voltage is converted to magnetic flux density by a calibration factor determined prior to each field outing. Two of the magnetic 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. The transverse electric field probe outputs a voltage proportional to the transverse electric field oriented along the primary axis of the spherical sensor/transmitter. The voltage is converted to electric field intensity by means of a calibration factor determined prior to each field outing. The calibration factor and

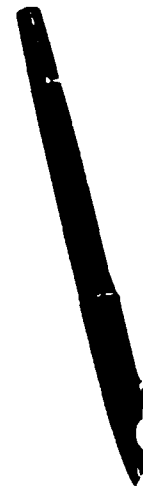
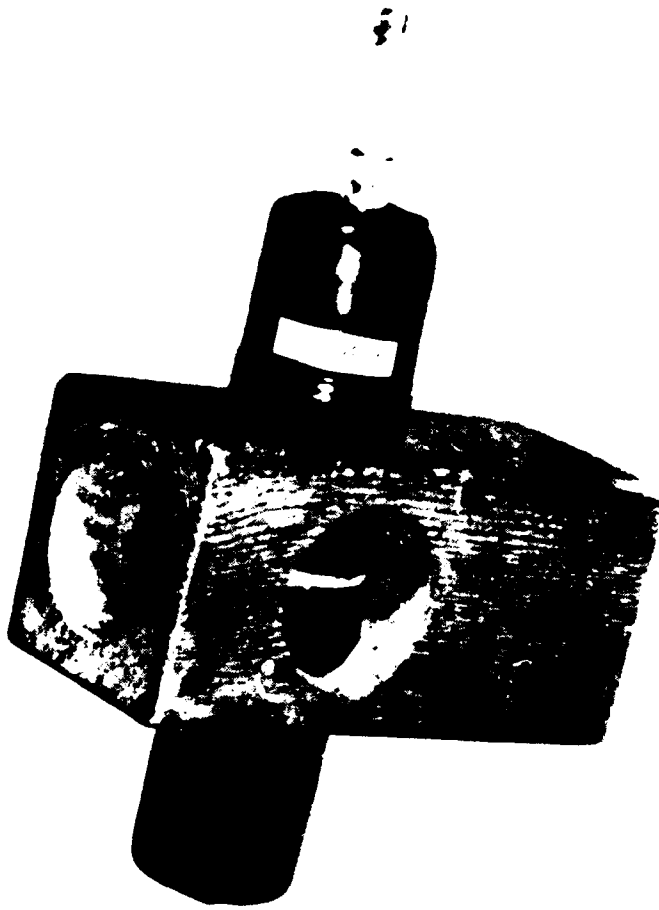


FIGURE 4. MAGNETIC FIELD PROBES.

probe operation are periodically checked using a portable electric field calibrator. The transverse electric field probe is shown in Figure 5.

The longitudinal electric field probe consists of three electrodes mounted on a fiberglass frame so as to form two orthogonal one-meter-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. The longitudinal electric field probe is shown in Figure 6.

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 employed for 60 Hz and unmodulated ELF signal measurements. An IITRI-fabricated active notch filter instrument may be placed in series with the wave analyzer to remove 60 Hz signals and their harmonics when the ELF signal is being modulated, requiring a wider measurement bandwidth, and the 60 Hz and ELF signals are of similar magnitudes.

3.3 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 ease and repeatability, the axes chosen are those parallel to the north and east compass bearings and to the vertical axis. The longitudinal field intensity (electric field measured in the earth) has no vertical component; therefore, only the north-south and east-west directional components are measured. All three orthogonal field components are measured in the case of the transverse electric field and the magnetic flux density. 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.

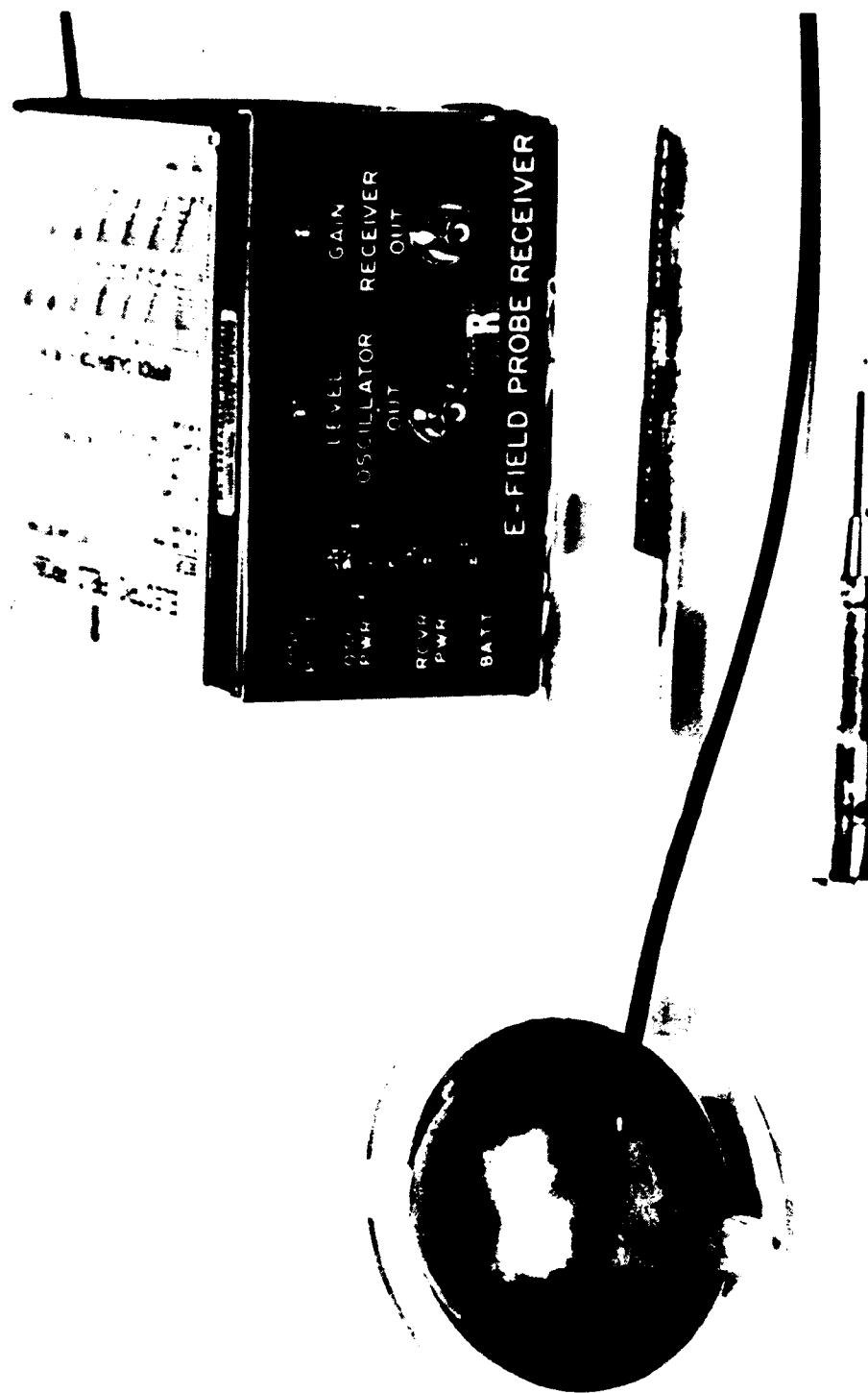


FIGURE 5. TRANSVERSE ELECTRIC FIELD PROBE.

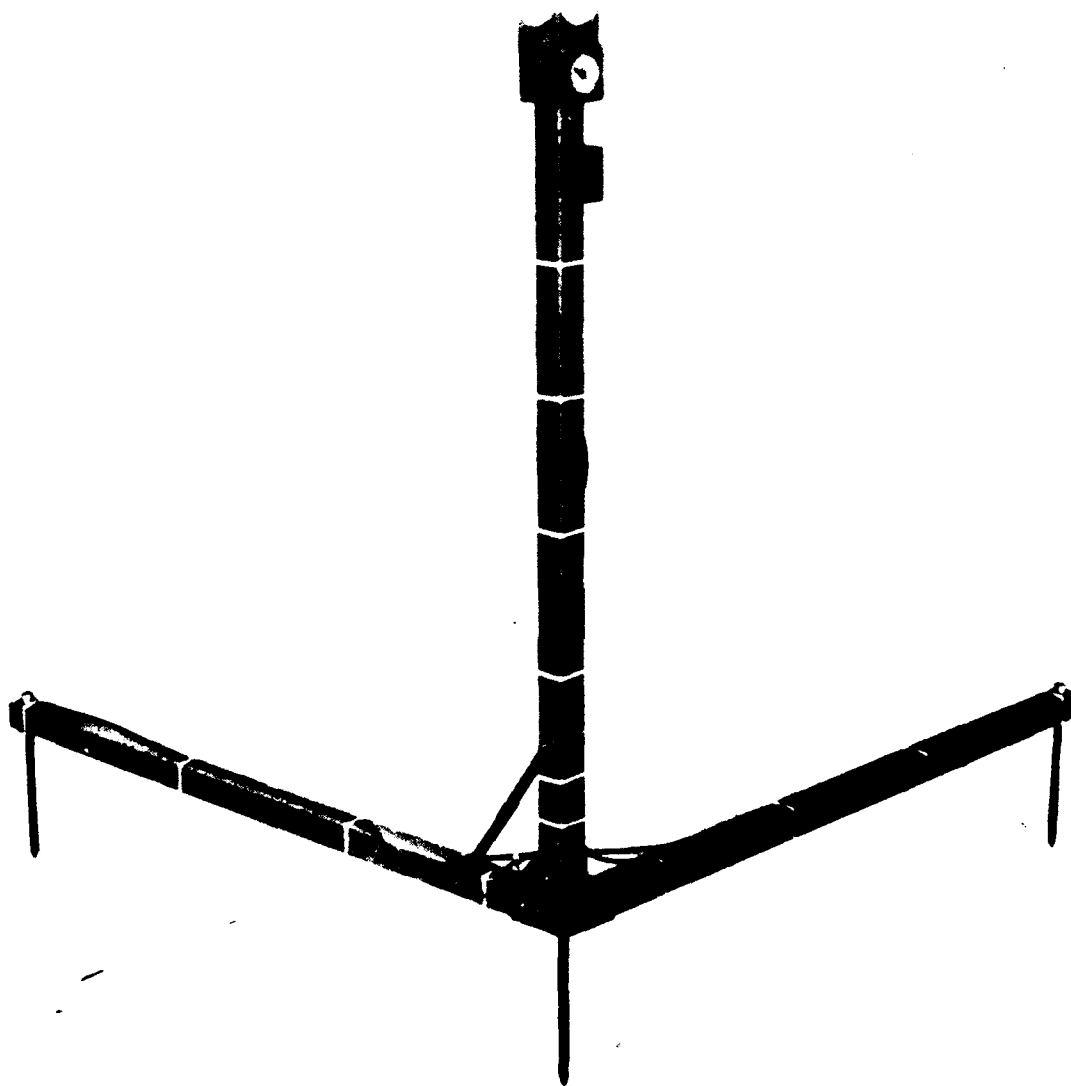


FIGURE 6. LONGITUDINAL ELECTRIC FIELD PROBE.

The technique of orthogonal field measurement is summarized as follows:

- (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 is of essentially zero magnitude in the vertical direction. Therefore, only the two orthogonal components in the plane of the earth's surface are measured. A compass bearing of north (0 degrees) determines the orthogonal reference.

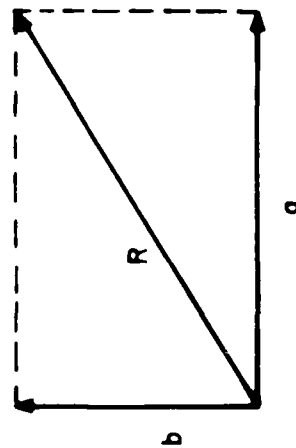
Figure 7 shows the geometric presentation of the measurement of orthogonal components. The figure presents the two-dimensional longitudinal electric field geometry and the three-dimensional magnetic field and transverse electric field probe geometry. The resultant, R , in each case is the vector sum of the individual orthogonal components, and is the value reported in data tables.

3.4 MEASUREMENT PROTOCOLS

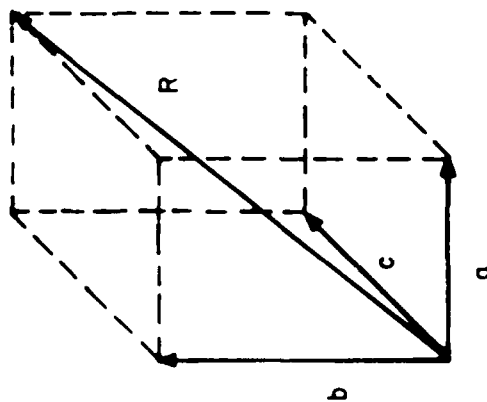
3.4.1 Wisconsin Protocol

The Wisconsin Transmitting Facility (WTF) was built in the late 1960s to be used as a test facility for ELF communications. It has been transmitting intermittently since that time. Before 1985, the WTF operated at numerous frequency, modulation, and intensity conditions with either the north-south, the east-west, or both antenna elements being powered. During this period, the antenna was generally under local control, and specific conditions of antenna current, modulation, frequency, phase angle, and powerings of either antenna element 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 antenna continued full-time transmitting through 1986.



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



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

FIGURE 7. GEOMETRIC PRESENTATION OF THE VECTOR SUM OF ORTHOGONAL MEASUREMENT COMPONENTS.

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

3.4.1.1 Pre-1985 WTF Protocol

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 at each study site for each of the following conditions:

- (1) Measurement of the ambient 60 Hz fields with both antenna elements off.
- (2) Measurement of unmodulated 76 Hz fields from the north-south antenna element with the east-west antenna element off.
- (3) Measurement of unmodulated 76 Hz fields from the east-west antenna element with the north-south antenna element off.

All measurements were taken using a narrow bandwidth meter setting to discriminate the frequency of interest. When necessary, 76 Hz 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 field magnitude. The 76 Hz field magnitudes from the north-south and east-west antenna elements were then added algebraically to compute the worst case or highest field level that could be produced by both antennas operating simultaneously at any phase angle of antenna currents. These worst case values were presented in pre-1985 reports.

3.4.1.2 WTF Protocol--From 1985 Onward

It was necessary to use a new protocol for Wisconsin measurements in 1985 because the antenna operation developed from an intermittent operating test phase to a continuously operating fleet communication phase. The new protocol, used again in 1986, is outlined as follows:

- (1) The EM fields generated by the ELF 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 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 and transverse and longitudinal electric fields are measured, and a vector sum magnitude is computed for each field. The antenna current phase angle is recorded (normally -75° for Wisconsin).
- (4) The longitudinal electric field magnitudes obtained in Step 3 for the six sites where phasing data have been obtained are multiplied by the correction factor from Appendix K to obtain the actual field magnitude.
- (5) The 60 Hz ambient 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 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 K contains tables of conversion factors for these sites that allow comparisons of EM field measurements made in any year at different or similar antenna phasings.

3.4.2 Michigan Protocol

Construction of the Michigan Transmitting Facility (MTF) began in 1984 and continued through 1985. During this period it was not capable of generating ELF EM fields.

The MTF began intermittent operation in 1986 at low power levels and with one antenna element operating at a time. IITRI field crews had control of the MTF antennas and therefore followed a measurement protocol similar to that used at the WTF prior to 1985. The EM measurement protocol in Michigan in 1986 consisted of making orthogonal sets of measurements of the transverse electric field, longitudinal electric field, and magnetic flux at each study site for each of the following conditions:

- (1) Measurement of the ambient 60 Hz fields with all three antenna elements (north-south, northern east-west, and southern east-west) off
- (2) Measurement of the unmodulated 76 Hz fields from the north-south antenna element with both east-west antenna elements off

- (3) Measurement of the unmodulated 76 Hz fields from the northern east-west antenna element with the other antenna elements off.
- (4) Measurement of the unmodulated 76 Hz fields from the southern east-west antenna element with the other antenna elements off.

All measurements were taken using a 3 Hz bandwidth meter setting to discriminate the frequency of interest. Each set of orthogonal components was used to compute a vector sum, or field magnitude. This vector sum was linearly extrapolated to a full power condition (150 amperes) for each antenna element, and the individual elements were algebraically summed to give the worst case, or highest field level that could be produced by all three antenna elements operating simultaneously at any phase angle.

3.5 1986 MEASUREMENTS AND DATA SUMMARY

The annual EM field measurements in Wisconsin were conducted by IITRI field crews during the week of 11 to 16 August 1986. Those in Michigan were conducted during the period from 29 September to 17 October 1986. All active sites were measured during these periods.

Table 2 presents a summary of the number of sites and corresponding measurement locations for 1986. As shown, a total of 244 measurement points were needed to characterize 69 sites. The number of measurement locations per site was based on plot size, the presence of known or anticipated EM field gradients, and the information needed by the study investigators for statistical analysis.

3.5.1 Wisconsin Measurements

The 1986 annual EM survey in Wisconsin involved EM field magnitudes taken during simultaneous operation of both antennas at an antenna current phase angle of -75° . Measurements were taken during periods of modulated signal transmission with a center frequency at 76 Hz and current of 300 amperes.

The data taken during the 1986 annual EM measurements in Wisconsin appear in Appendixes G, H, and I. The 60 Hz data appear as vector sum magnitudes for 1985 and previous measurement years. No 60 Hz data were taken in 1986, since IITRI measurement crews did not have control of antenna conditions during the 1986 annual measurement activities. In these appendixes, 76 Hz data for

TABLE 2. SUMMARY OF 1986 EM FIELD MEASUREMENT LOCATIONS

Study	Number of Test and Control Sites			Number of Measurement Points		
	Pre-Existing, Still in Use	New, 1986	Total	Pre-Existing, Still in Use	New, 1986	Total
Small Mammals and Nesting Birds	9	0	9	12	35	47
Native Bees	4	0	4	7	6	13
Soil Arthropods and Earthworms	2	0	2	2	6	8
Upland Flora and Soil Microflora	3	0	3	28	1	29
Aquatic Ecosystems	9	1	10	14	3	17
Soil Amoeba	3	0	3	4	5	9
Slime Mold	3	0	3	9	0	9
Wetlands	11	0	11	66	0	66
Bird Species and Communities						
Michigan	10	0	10	19	5	24
Wisconsin	<u>10</u>	<u>0</u>	<u>10</u>	<u>22</u>	<u>0</u>	<u>22</u>
Total	62	3	65	176	77	243

years prior to 1985 are presented individually for each antenna element (north-south and east-west). The individual antenna element data are readily compared to data from the new protocol. The 1985 and 1986 76 Hz data are presented in a column labeled "Both, -75°," indicating that both antenna elements were operating at a current phase angle of -75°. At some sites 1985 data are also given in the "NS" and "EW" columns. These data were taken earlier in the year during site selection/relocation activities, during the phasing measurements, or when only one antenna element was operational at the time of the measurement.

The following paragraphs briefly discuss the 1986 annual EM measurements for each study in Wisconsin. Further details appear in Appendixes G, H, and I.

3.5.1.1 Slime Mold Studies

Tabulations of EM data for these studies are found in Appendix G. During the 1986 annual EM survey, longitudinal electric field intensity nearly doubled and a 25% increase in magnetic flux density at 76 Hz was documented at site 7G3, located on the west ground of the antenna. This was due to a

redistribution of the ground currents. Only small variations in the 76 Hz fields were noted at other sites. Tables of culture cell measurements are presented in Section 3.5.3.3.

3.5.1.2 Wetlands Studies

Tabulations of EM data for these studies are found in Appendix H. EM field changes were noted at test sites 8G1 and 8G2 between 1985 and 1986. Earth electric fields at sites 8G1 and 8G2 decreased by an average of 12.2% and 16.8%, and magnetic fields decreased by 50% and 33%, respectively. This change was due to a redistribution of ground currents. The longitudinal electric field at site 8A2 increased between August 1985 and August 1986, although the August 1986 field intensity matched closely with a May 1985 measurement. Only small variations in the 76 Hz fields were noted at other sites.

3.5.1.3 Bird Species and Communities Studies

Tabulations of the EM measurements for these studies are found in Appendix I. No significant changes in 76 Hz EM field levels were noted between 1985 and 1986.

3.5.2 Michigan Measurements

The data taken during the 1986 annual EM measurements in Michigan appear in Appendixes A through F and in Appendix I. Construction of the MTF antenna is now complete, and intermittent operation at low power levels began in March 1986. The 76 Hz field measurements were made, and are presented as vector sum magnitudes in the appendixes. Field intensities are reported for the antenna current at which the measurements were made: 4 amperes for the north-south, 6 amperes for the northern east-west, and 6 amperes for the southern east-west antenna elements, respectively. These were the predominant operational currents for the three antenna elements in 1986. The southern east-west antenna element also operated at 10 amperes for significant periods. The field intensities for the southern east-west antenna element operating at 10 amperes are linearly extrapolated from the 6 ampere measured data and reported in the same tables as the 6 ampere data.

In separate tables, the low power measurement vector sums are linearly extrapolated to a 150 ampere (full power) current for each antenna element.

The algebraic sums of these three individual antenna vector sums are also presented to give the worst case or maximum field intensities that can occur during phased operation of all three antenna elements simultaneously. Extrapolations to 150 ampere current were not made for individual antenna vector sums that were lower than the minimum sensitivities of the measurement probes. In these cases the algebraic sum (or worst case field) column will reflect the sum of only those antenna contributions that could be measured and extrapolated. For test sites, where one antenna element usually dominates the EM field levels by a factor of 10 or more, this will have little effect on the worst case field intensities. At many control sites, however, single antenna dominance of the fields is not established, and the algebraic sum may be low by as much as 3X. Pre-antenna operation field estimates for 150 ampere operation made in 1984 and 1985 are included in these tables for comparison to the extrapolated values.

EM field measurements were made at 60 Hz at all sites in 1986 and are presented as vector sum magnitudes in the appendixes. The 60 Hz fields at test sites showed a change in 1986 due to coupling of 60 Hz ambient fields to the newly installed antenna. As a result, for each study, magnetic flux densities generally increased while the longitudinal electric field decreased from previous years' measured values. The degree of this effect for each study depends on factors such as the distance of the site from the antenna element. Further details on these measurements appear in Appendixes A through F and in Appendix I.

Sections 3.5.2.3 through 3.5.2.9 briefly discuss the 1986 annual EM measurements for each study in Michigan.

3.5.2.1 Measurement Point Selection

With the advent of 76 Hz EM fields at the Michigan study area in 1986, additional measurement points were added at most study sites in order to define the spatial variation of the 76 Hz fields over each site. For the most part, measurement point locations were selected on the basis of study plot size and shape and its location relative to the antenna elements.

Control sites, all of which are several miles away from the nearest antenna element, are expected to have minimal EM field gradients. At small, localized control sites, a single measurement point was deemed sufficient to

characterize the fields. Intermediate-size rectangular sites were measured at the points nearest to and farthest from the antenna grid. Large control sites were measured at several points as necessary to define the extremities of the study area.

EM field gradients at test sites, however, are expected to be large for all but the smallest of sites. It was generally necessary to make several measurements at test sites. The selection of the 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 were typically 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 meter 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 estimations 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 for greater and lesser distances from the antenna. Because the 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 position along the length of the antenna. The EM field can be estimated reasonably accurately by linear interpolation between the two measured points. This accuracy may be improved by plotting the field gradient as shown in Figure 8 for the magnetic flux and longitudinal electric field at a typical study site where measurements were made along a transect perpendicular to the antenna.

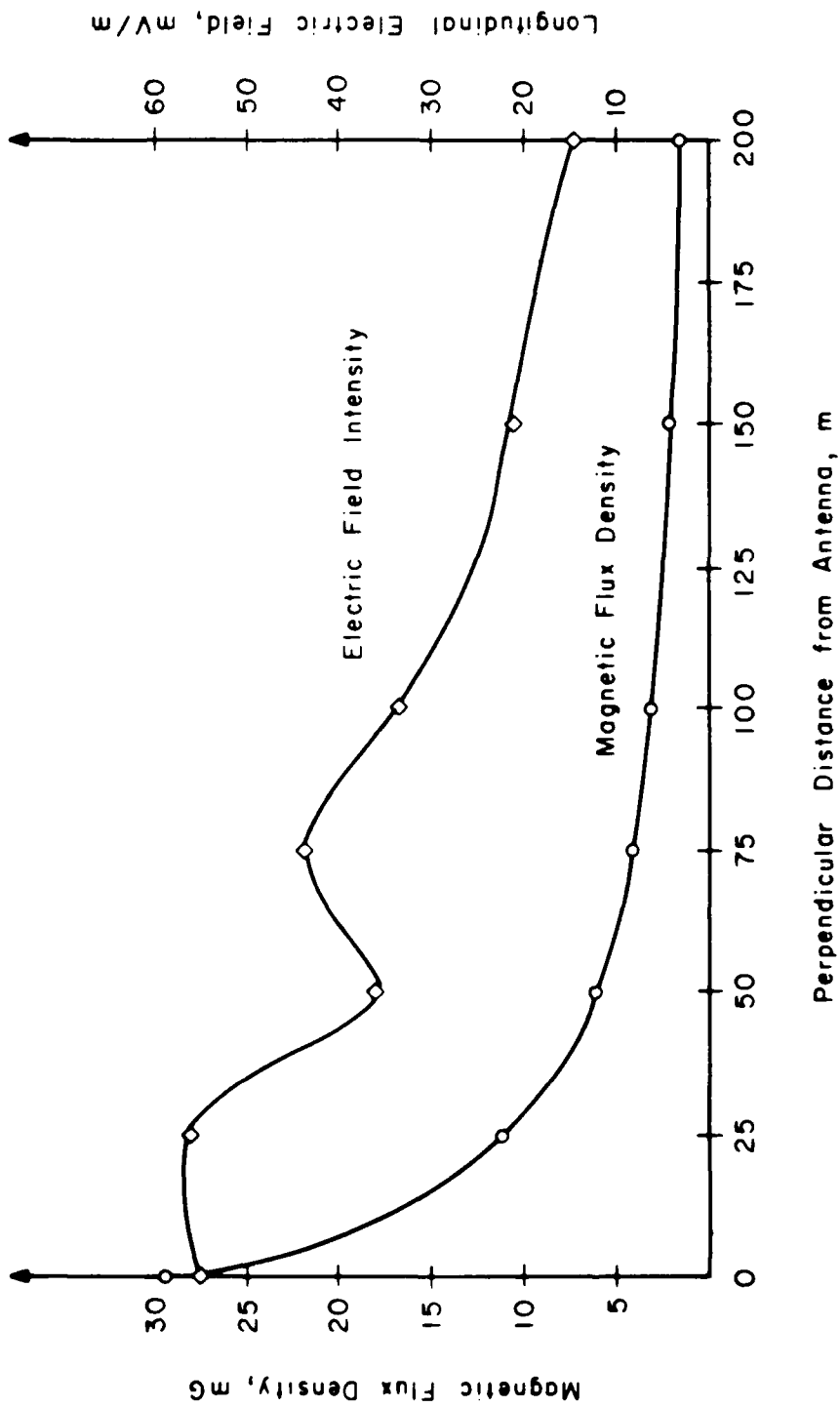


FIGURE 8. 76 Hz EM FIELD GRADIENTS ALONG A PERPENDICULAR MEASUREMENT TRANSECT (EXTRAPOLATED TO 150A).

3.5.2.2 Coupling of 60 Hz Fields

The coupling of 60 Hz ambient fields to the ELF antenna was briefly discussed in relation to its effects on paired site ratios (Section 2.2). The phenomenon will now be considered in more detail.

The 60 Hz EM field measurements were made with the ELF antennas in condition 2; i.e., no power was being delivered to the antennas by the transmitter, and the antennas were grounded at the transmitter. Grounding an antenna element at the transmitter forms two electric conducting loops composed of the antenna element and the earth because the ends of the antenna element are also connected to earth at the ground terminals. A time-varying magnetic field in a direction through these conducting loops will induce electric current flow around the loops. In the case under discussion, the source of the magnetic field is 60 Hz power lines, which generate sinusoidal time-varying 60 Hz magnetic fields by the same principle as that by which the ELF antenna generates 76 Hz magnetic fields. These 60 Hz magnetic fields pass through the electrical loop formed by the antenna element and the earth, thereby generating a 60 Hz current flow around the loops. The 60 Hz current now flowing on the ELF antenna will generate 60 Hz EM fields near the antenna, just as 76 Hz currents supplied by the ELF transmitter generate 76 Hz EM fields. By this analysis, installation of the ELF antenna provided a new source of 60 Hz EM fields at test sites.

The 60 Hz EM fields at test sites now have two sources: currents flowing on power lines and currents flowing on the ELF antenna. The 60 Hz EM fields measured at test sites in the years before the antenna was installed were due solely to currents on the power lines. In 1986, 60 Hz EM fields measured at test sites represented the summed fields of the two sources. In most cases, the longitudinal electric fields due to the two sources appeared to cancel each other, resulting in a summed field in 1986 which was lower than that measured prior to antenna construction. However, the magnetic flux generated by currents on the power lines was low at the test sites relative to the magnetic flux due to currents induced on the antenna. The result was little cancellation of fields from the two sources and a measured 60 Hz magnetic flux at test sites that was typically greater than that measured in years prior to antenna construction.

Figure 9 shows the 60 Hz magnetic flux density and longitudinal electric field measured at the same transect as was used for the 76 Hz EM field data in Figure 8. Comparing Figures 8 and 9, one can see that the 76 Hz and 60 Hz fields have roughly the same gradient shape at this study test site. This is expected, since both are dependent on current flow on the ELF antenna. However, it should be noted that the scales in Figures 8 and 9 are different, reflecting the fact that the 76 Hz fields (and antenna currents) are orders of magnitude greater than the 60 Hz fields (and currents).

3.5.2.3 Small Mammals and Nesting Birds Studies

Tabulations of the EM measurements for these studies are found in Appendix A. Test and control sites were unchanged from 1985, although four new sites--three mammal displacement sites and a site consisting of holding facilities and a laboratory--were established in 1986. Three measurement points were added at control sites and 28 at test sites. The 76 Hz measurements compared well with the pre-antenna operation estimates. Site pair ratios were recalculated using the 76 Hz measurements. Two site pairs fell into the acceptable category, and seven into the conditionally acceptable category, as defined in Appendix J.

3.5.2.4 Native Bees Studies

Tabulations of the EM measurements for these studies are found in Appendix B. Test and control sites were unchanged from 1985. Six measurement points were added to test sites. The 76 Hz measurements compared well with the pre-antenna operation estimates. Site pair ratios were recalculated using the 76 Hz measurements. One site pair fell into the acceptable category, and three into the conditionally acceptable category, as defined in Appendix J.

3.5.2.5 Soil Arthropods and Earthworms Studies

Tabulations of the EM measurements for these studies are found in Appendix C. The test and control sites were unchanged from 1985. One measurement point was added to the control site and five to the test site. The 76 Hz measurements compared well with pre-antenna operation estimates. Site pair ratios were recalculated using the 76 Hz measurements. All site pair ratios were satisfied, and the test/control site pair is therefore categorized as acceptable as defined in Appendix J.

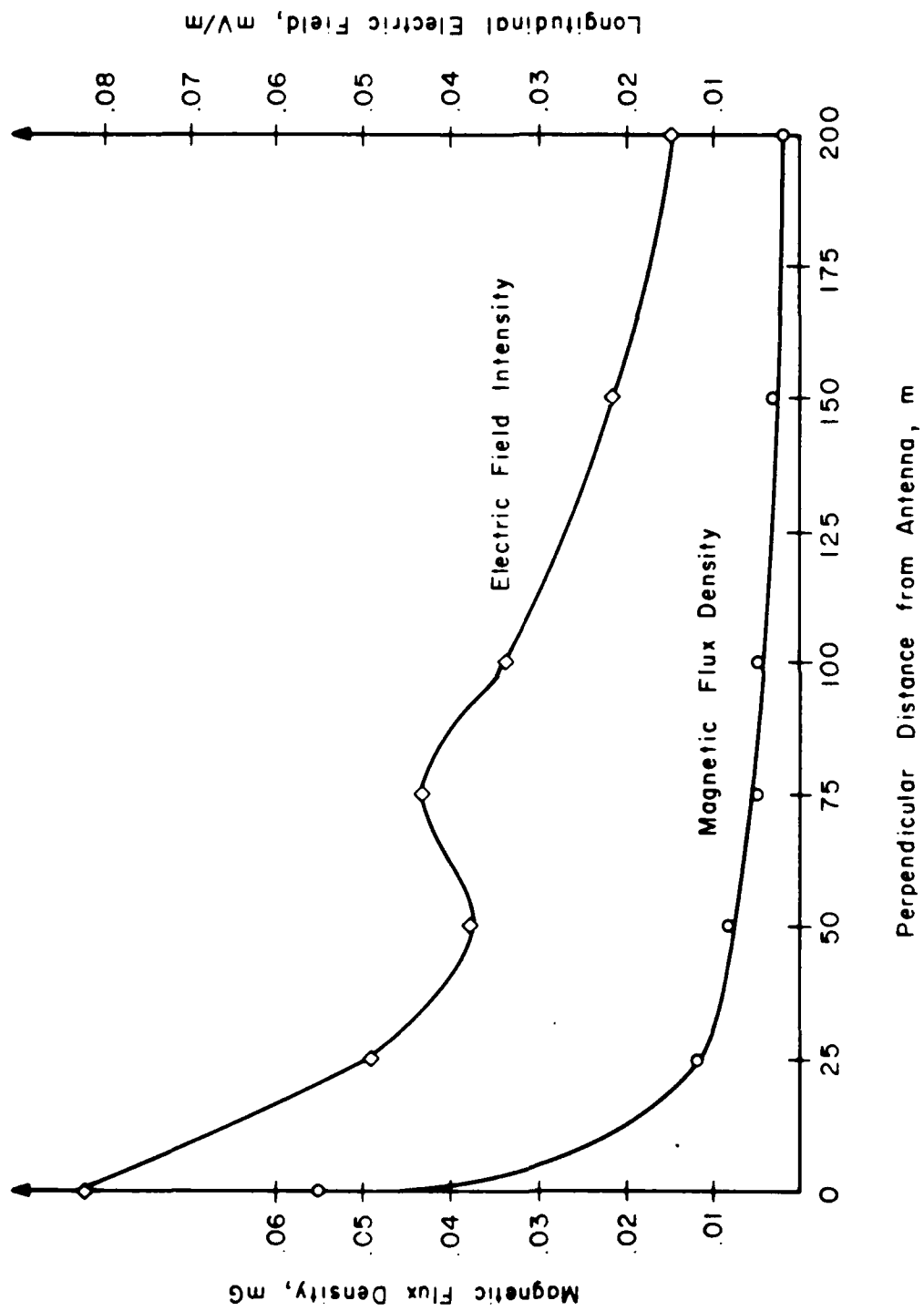


FIGURE 9. 60 Hz EM FIELD GRADIENTS ALONG A PERPENDICULAR MEASUREMENT TRANSECT.

3.5.2.6 Upland Flora and Soil Microflora Studies

Tabulations of the EM measurements for these studies are found in Appendix D. Test and control sites were unchanged from 1985. Measurement points used in 1985 were sufficient to define the spatial variation of the 76 Hz fields, and only one new measurement point was added at the ground test site. The 76 Hz measurements compared well with pre-antenna operation estimates. Site pair ratios were recalculated using the 76 Hz measurements. One site pair fell into the acceptable category, and three into the conditionally acceptable category, as defined in Appendix J.

3.5.2.7 Aquatic Ecosystems Studies

Tabulations of the EM measurements for these studies are found in Appendix E. Test and control sites were unchanged from 1985 with one exception--site 5T7-1, which was added in 1986 for stream monitoring and for use as a possible future weir net site. For the most part, measurement points used in 1985 were sufficient for 76 Hz measurements, since only one measurement was made at each experimental point. Measurement points were added at sites 5T2-3 (insect movement), 5T4-2 (fish feeding), and the new site, 5T7-1. While some unpredicted results were seen in the 76 Hz measurements, probably due to coupling of the ELF fields to a nearby railroad, overall they compared well with pre-antenna operation estimates. Site pair ratios were recalculated using the 76 Hz measurements. Three site pairs fell into the acceptable category, and eight into the conditionally acceptable category, as defined in Appendix J.

3.5.2.8 Soil Amoeba Studies

Tabulations of the EM measurements for these studies are found in Appendix F. No new test or control sites were added in 1986, but the Wells Grade ground site, which was moved slightly in 1985, was moved back to its original 1984 location. Five measurement points were added to this ground site. The 76 Hz measurements compared well with pre-antenna operation estimates. Site pair ratios were recalculated using the 76 Hz measurements. Both test/control site pairs met all ratio criteria, and are therefore categorized as acceptable as defined in Appendix J.

3.5.2.9 Bird Species and Communities Studies

Tabulations of the EM measurements for these studies are found in Appendix I. Test and control sites were unchanged from 1985. Five new measurement points were added at test transects. The 76 Hz measurements compared well with pre-antenna operation estimates. Site pair ratios were recalculated using the 76 Hz measurements. Seventeen site pairs fell into the acceptable category, and eight into the conditionally acceptable category, as defined in Appendix J.

3.5.3 In Vitro Studies EM Exposure

3.5.3.1 Background

The soil amoeba and slime mold studies both employ 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, and is necessary for a controlled study.

Culture cells for both studies are buried in the earth at shallow depths at test and control sites, thus exposing the cultures of soil amoebae and slime mold to the earth's ambient temperature and its variations. It is also desirable to expose the cultures to the same EM environment that they would encounter if living in the soil or litter layer, rather than in or on a culture medium. Ideally, this would be accomplished by simply connecting the culture cell electrodes directly to the earth where they were buried, so that the electric voltages and currents present in the earth could be applied to and flow through the culture medium in the cell. In reality, however, EM exposure in the culture cells is complicated by a mismatch between the conductivities of the soil and those of the culture medium. Therefore, external control circuitry must be used to regulate the drive voltages and currents supplied to the culture cells from a set of collector electrodes in the earth.

Two basic culture cell drive control circuits were developed: one for matching electric field exposure and one for matching current density exposure between the cells and the earth. These drive control circuits and an exposure setup protocol explaining their use are detailed in Appendix L. The magnetic flux is not perturbed by the culture cells, and thus their magnetic flux density is the same as that in the surrounding earth.

3.5.3.2 Slime Mold Exposures

On 24 and 25 April 1985, IITRI field crews set up two matched electric field exposure chambers and one matched current density chamber at each of the three sites of the slime mold studies. Drive electrodes were also installed and wired. At that time, the principal investigator was instructed in the protocol for matching the electric field exposure and the current density exposure between culture cells and the earth using the exposure chambers. The investigator set and monitored the culture cells throughout the 1985 and 1986 seasons.

Exposure chamber voltages V_{CL} and V_R were measured according to the protocol in Appendix L. Culture cell electric fields and current densities were calculated from the exposure chamber measurements as follows:

$$E_{CL} = \frac{V_{CL} (V)}{0.155 \text{ m}} \quad (V/m) \quad (5)$$

Similarly,

$$J_{CL} = \frac{V_R (V)}{R \text{ (ohms)} \ 9 \times 10^{-4} \text{ m}^2} \quad (A/m^2) \quad (6)$$

Here, 0.155 m and $9 \times 10^{-4} \text{ m}^2$ are the measured distance between electrodes and the cross-sectional area, respectively, of the culture cells' agar growth medium. Tables 3 and 4 present the calculated culture cell exposures, along with the measured longitudinal electric field intensities at the chambers, for the years 1984-1986.

The measured culture cell voltages and calculated cell electric fields and current densities at the ground site increased proportionally to the earth electric field increases, as expected. At the antenna site, minor increases in current density were noted only for the matched electric field cells. Culture cell current densities should increase slightly for a given drive voltage (electric field) as the slime mold grows and the area it covers on the agar increases. At the control site, some cell voltage measurements were at or below the sensitivity threshold of the meter. Thus, cell current density calculations for the matched electric field cells are questionable, and the cell electric field for the matched current density cell could not be determined.

TABLE 3. EM EXPOSURES FOR MATCHED E-FIELD CHAMBERS*
(Slime Mold Studies)

Site, Chamber	Meas. Yr.	Measured Longitudinal E-Field (Earth), mV/m			Measured Culture Cell Voltage (V_{CL}), mV			Calculated** E-Field of Culture Cell (E_{CL}), mV/m			Measured 100 Ω Resistor Voltage (V_R), mV			Calculated** Current Density of Culture Cell (J_{CL}), mA/m ²		
		60 Hz	76 Hz	60 Hz	60 Hz	76 Hz	60 Hz	60 Hz	76 Hz	60 Hz	60 Hz	76 Hz	60 Hz	60 Hz	76 Hz	76 Hz
7G3-1*	1984	0.131	1470	--	--	--	--	--	--	--	--	--	--	--	--	--
7G3/Center	1985	0.113	570	0.0145	88	0.094	570	0.0025	14.9	0.028	166	230	0.022	47	53	51
7G3/Center	1986	--	1000	--	140	--	900	--	21	--	167	167	--	56	--	--
7G3/South	1985	0.113	570	0.0160	87	0.103	560	0.0026	15	0.029	167	167	0.0028	51	51	51
7G3/South	1986	--	1170	--	134	--	860	--	15	--	167	167	--	56	--	--
7A2-1*	1984	0.035, 0.052	200, 240	--	--	--	--	--	--	--	--	--	--	--	--	--
7A2/Center	1985	0.039	200	0.0012	28	0.0077	177	0.00020	4.2	0.0022	47	53	0.0028	51	51	51
7A2/Center	1986	--	240	--	33	--	210	--	4.8	--	56	56	--	--	--	--
7A2/North	1985	0.039	200	0.0016	31	0.0100	200	0.00025	4.6	0.0028	51	51	0.0028	51	51	51
7A2/North	1986	--	220	--	33	--	210	--	5.0	--	56	56	--	--	--	--
7C-1*	1984	0.099	2.24	--	--	--	--	--	--	--	--	--	--	--	--	--
7C1/Center	1985	0.060	1.17	0.042	0.62	0.27	4.0	0.0054	0.090	0.060	1.00	0.111	0.060	1.00	0.111	0.111
7C1/Center	1986	--	1.20	--	0.38	--	2.5	--	0.010	--	0.111	0.111	--	--	--	--
7C1/South	1985	0.060	1.17	0.050	0.84	0.32	5.4	0.0086	0.115	0.096	1.28	1.28	0.096	1.28	1.28	1.28
7C1/South	1986	--	1.35	--	0.27	--	1.74	--	0.010	--	0.111	0.111	--	--	--	--

* i. Test chambers were not in place in 1984.

ii. 76 Hz E-fields in 1984 are the sum of single antenna measurements.

iii. 76 Hz measurements in 1985 and 1986 were made with both antennas operating at a phase angle of -75° .

**i. $E_{CL} = V_{CL}/L$ (mV/m) where $L = 0.155$ m.

ii. $J_{CL} = V_R/(R)(A)$ (mA/m²) where $R = 100 \Omega$, $A = 9.0E-04$ m².

--- = Data not taken.

TABLE 4. EM EXPOSURES FOR MATCHED CURRENT DENSITY CHAMBERS*
(Slime Mold Studies)

Site, Chamber	Meas. Yr.	Measured Longitudinal E-Field (Earth), mV/m			Measured Culture Cell Voltage (V_{CL}), mV			Calculated** E-Field of Culture Cell (E_{CL}), mV/m			Measured 500 k Ω Resistor Voltage (V_R), mV			Calculated** Current Density of Culture Cell (J_{CL}), mA/m ²		
		60 Hz	76 Hz		60 Hz	76 Hz		60 Hz	76 Hz		60 Hz	76 Hz		60 Hz	76 Hz	
7G3-1*	1984	0.131	1470		--	--	--	--	--	--	--	--	--	--	--	--
7G3/North	1985	0.113	570		0.3E-4	0.94		0.00116	6.1		0.110	770		0.0024	1.71	
7G3/North	1986	--	960		--	1.42		--	9.2		--	960		--	2.1	
7A2-1*	1984	0.035,	200,		--	--		--	--		--	--		--	--	
		0.052	240													
7A2/South	1985	0.039	200		5.0E-5	0.22		0.00032	1.42		0.015	181		0.000033	0.40	
7A2/South	1986	--	156		--	0.28		--	1.81		--	185		--	0.41	
7C-1*	1984	0.099	2.2		--	--		--	--		--	--		--	--	
7C1/North	1985	0.060	1.17		3E-5 -	0.00175		1.94E-4	-0.0113		0.067	1.30		0.000149	0.0029	
					7E-5			4.5E-4								
7C1/North	1986	--	1.38		--	#		--	#		--	1.25		--	0.0028	

* i. All measurements were made with both antennas on, except where noted below.

ii. Test chambers were not in place in 1984, so only one measurement was made at each site.

iii. Measurements were made under a single antenna operation mode in 1984. The E-field was calculated as the sum of contributions from each antenna.

**i. $E_{CL} = V_{CL}/L$ (mV/m) where $L = 0.155$ m.

ii. $J_{CL} = V_R/(R)(A)$ (mA/m²) where $R = 500$ k Ω , $A = 9.0E-04$ m².

-- = Data not taken.

= Below instrument sensitivity.

3.5.3.3 Soil Amoeba Exposures

On 26 April 1985, IITRI field crews set up two matched electric field chambers and two matched current density chambers in Wisconsin for the Michigan-based soil amoeba studies. Because the antenna system in Michigan was not yet operational, the site was established in Wisconsin along the west ground ROW of the Wisconsin Transmitting Facility. This test site in Wisconsin is being used by the investigator to become acquainted with the EM exposure protocol and equipment before incorporating the exposure setup into his studies in Michigan.

Exposure chamber voltages V_{CL} and V_R and open circuit voltage V_{OC} were measured according to the protocol in Appendix L in Wisconsin in 1986. Culture cell electric fields and current densities were calculated from the exposure chamber measurements as follows:

$$E_{CL} = \frac{V_{CL} (V)}{0.113 \text{ m}} \quad (V/m) \quad (7)$$

Similarly,

$$J_{CL} = \frac{V_R (V)}{R \text{ (ohms)} 1.42 \times 10^{-4} \text{ m}^2} \quad (A/m^2) \quad (8)$$

Here, 0.113 m and $1.42 \times 10^{-4} \text{ m}^2$ are the measured distance between electrodes and the cross-sectional area, respectively, of the culture cells' growth medium. Table 5 presents the calculated culture cell exposures, along with the measured longitudinal electric field intensities at the chambers, for the years 1985 and 1986.

TABLE 5. EM MEASUREMENTS
FOR MATCHED E-FIELD AND CURRENT DENSITY EXPOSURE SETUPS
(Soil Amoeba Study--Wisconsin Test Site)^a

Site/ Electrode Pair	Meas. Year	Frequency, Hz	Earth Electric Field (E), mV/m	Electrode Open-Circuit Voltage (V _{OC}), mV	Culture Cell Voltage ^b (V _{CL}), mV	Current- Sensing Resistor Voltage (V _R), mV	Calculated Culture Cell Current Density ^c (J _{CL}), mA/m ²	E-Field ^d (E _{CL}), mV/m
6W1/J1	1985	60	0.16	0.15	0.00008	0.15	0.00041	0.00071
	1985	76 (MSK)	1220-1270	1210-1230	0.69	1190-1210	3.4	6.1
	1986	76 (MSK)	--	1090	--	--	--	--
6W1/J2	1985	60	0.15	0.17	0.00009	0.17	0.00047	0.0008
	1985	76 (MSK)	1700-1750	1310-1330	0.73	1290-1310	3.6-3.7	6.5
	1986	76 (MSK)	--	1300	0.92	1300	3.7	8.1
6W1/E3	1985	60	0.15	0.22	0.024	0.0017	0.12	0.21
	1985	76 (MSK)	1400	2020-2070	157-159	10.9-11.1	770-780	1390-1410
	1986	76 (MSK)	1100	1450	124	--	--	1100
6W1/E4	1985	60	0.13	0.24	0.024	0.0017	0.12	0.21
	1985	76 (MSK)	1240-1290	2000-2040	138-142	9.9-10.0	700	1220-1260
	1986	76 (MSK)	1120	1640	132	10.8	760	1170

^a1985 measurements for EW antenna only.

^b1985 culture cell simulated with 1.43 k Ω resistor.

$C_{J_{CL}} = V_R/(R)(A)$ (mA/m²) where $A = 1.42E-04$ m²
 $R = 100 \Omega$ for E3,E4
 $R = 2.5$ M Ω for J1,J2.

$E_{CL} = V_{CL}/L$ (mV/m) where $L = 0.113$ m.

-- = Data not taken.

4. ANALYSIS OF TRANSMITTER OPERATIONS

4.1 OPERATING LOG DATA BASE

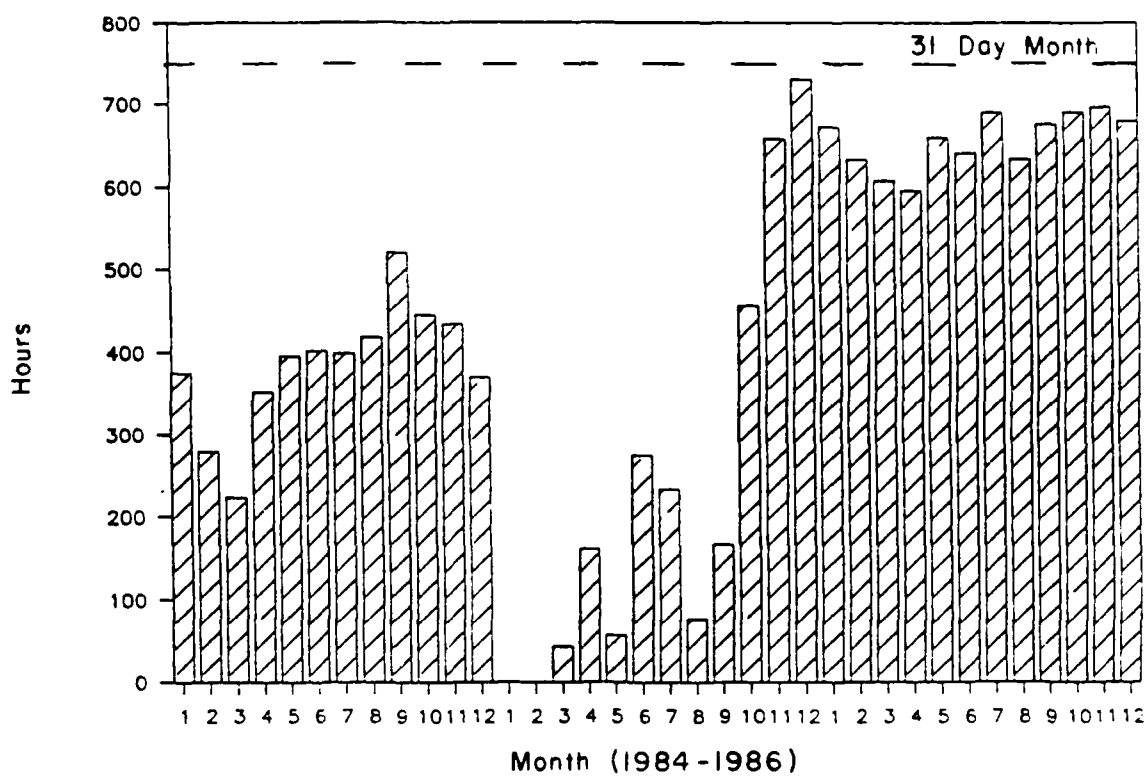
In order to calculate the field exposure at study sites, investigators must have both field intensity measurements and data on the operating times of the antennas. Field intensity measurements were discussed in Section 2, and data tables are presented in Appendixes A through I. Data on antenna operating conditions have been provided to IITRI on a minute-by-minute basis, including all changes in the operation frequency, modulation, power, and phasing for each antenna element. This log information is entered into a computer-based spreadsheet. The data base allows generation of operating condition summaries in both graphical and tabular form. Graphical summaries for both the WTF and MTF are presented in this section. More detailed tabular summaries appear in Appendix M.

4.2 SUMMARY OF WTF OPERATIONS, 1984-1986

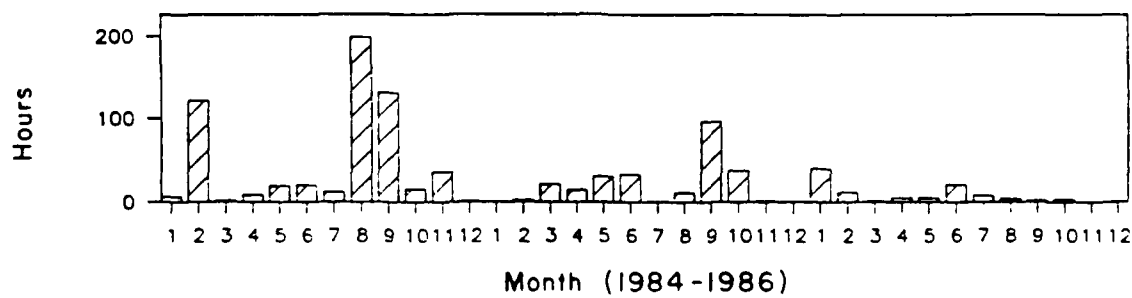
The WTF has gone through three stages of development from an operational standpoint. The first stage began in the late 1960s, when the WTF was constructed as a test system for a Navy ELF communications system. The test procedures required various modulations, frequencies, currents, and separate as well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

The second phase began in early 1985 with the installation of the new transmitter equipment. This changeover period was marked by short powerings interspersed with long periods when the antenna was not powered. After this initial test period was completed, the third phase began: the WTF began operational testing, operating nearly 24 hours per 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 10. The figure shows the hours of operation on a month-by-month basis for the years 1984-1986. Operation of both antenna elements simultaneously was predominant in 1984, with only

Both Antennas



North-South Antenna Only



East-West Antenna Only

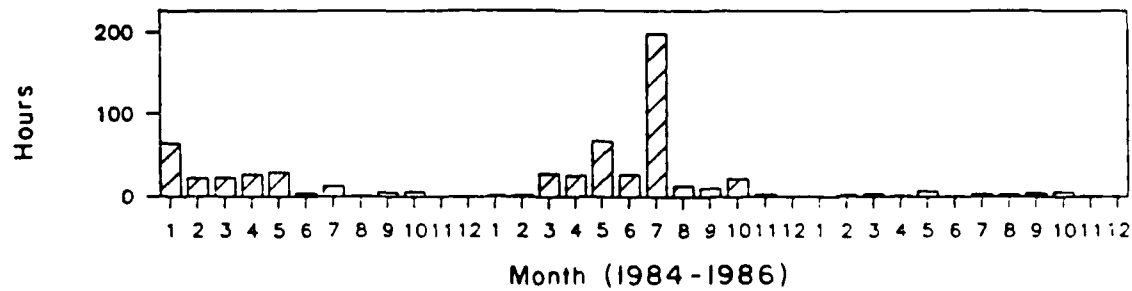


FIGURE 10. WTF MONTHLY OPERATING SUMMARY, 1984-1986.

sporadic operation of the antenna elements individually. There was little operation of the WTF in the first quarter of 1985, followed by intermittent use in the second and third quarters, and nearly full-time operation by the fourth quarter. This nearly full-time operation continued through 1986. Figure 11 shows the data from Figure 10 for 1986 only.

Figure 12 provides a bar graph of the WTF annual operating summary by mode of operation for 1984-1986. As indicated, the predominant operating condition for all three years was modulated signal transmission at a center frequency of 76 Hz. The pie charts of Figures 13, 14, and 15 illustrate WTF annual operation 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. The total "on" time decreased somewhat in 1985 as a result of the transmitter equipment changeover, and then increased dramatically in 1986.

WTF operation from 1984 through 1986 can be summarized as follows:

1984

- The WTF was transmitting about 60% of the time (about 5000 hours) (see Figures 10 and 13)
- About 81% of "on" time was with a modulated 76 Hz signal (see Figure 12)
- 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 accounts 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 10 and 14)
- About 81% of "on" time was with a modulated 76 Hz signal (see Figure 12)
- 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 accounts for most of the transmitter changes in operational mode

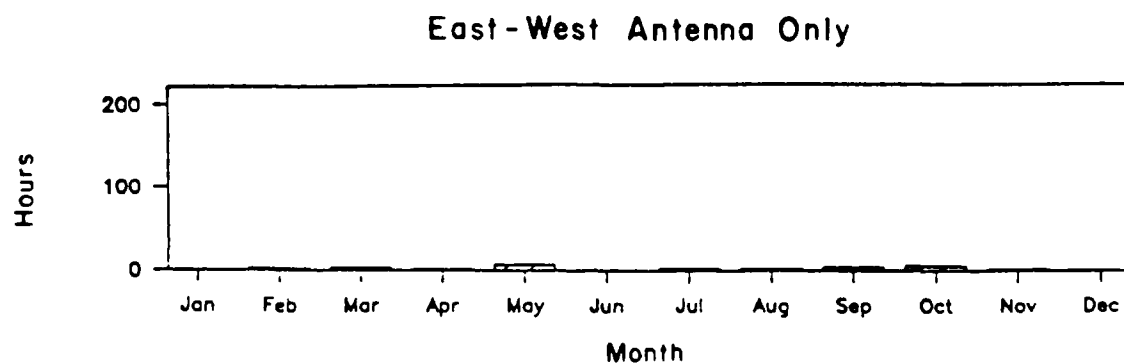
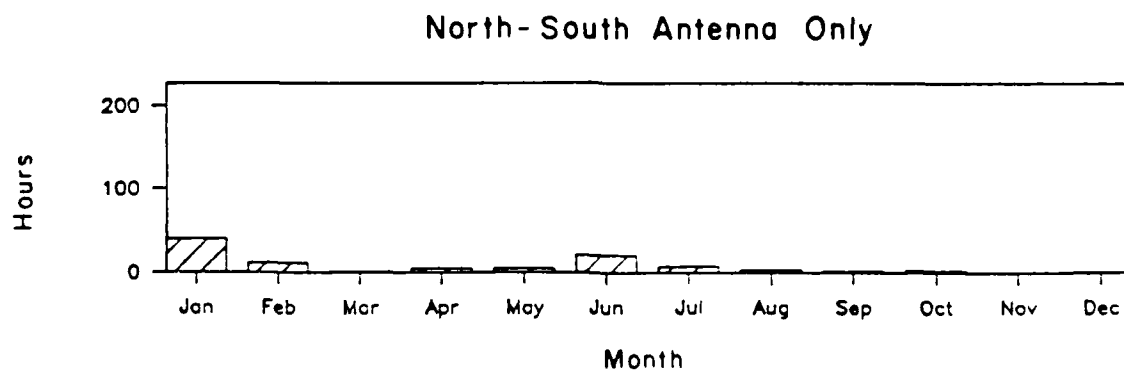
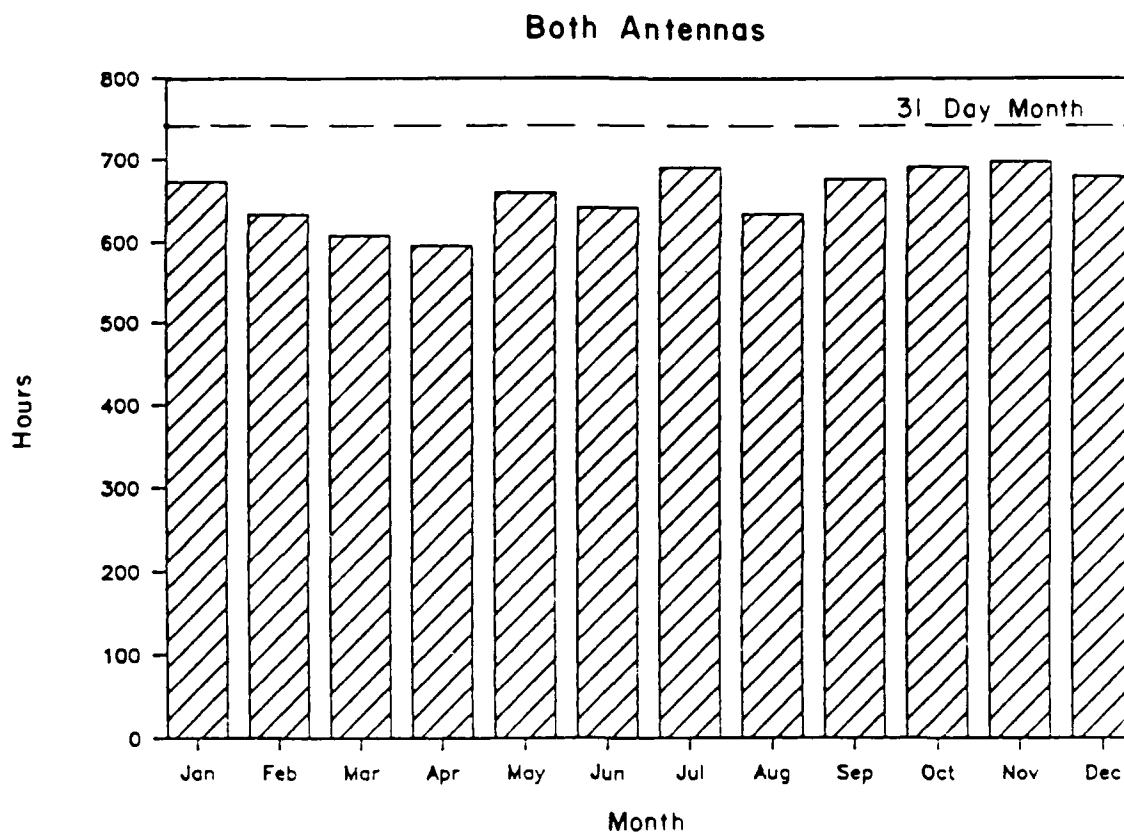


FIGURE 11. WTF MONTHLY OPERATING SUMMARY, 1986.

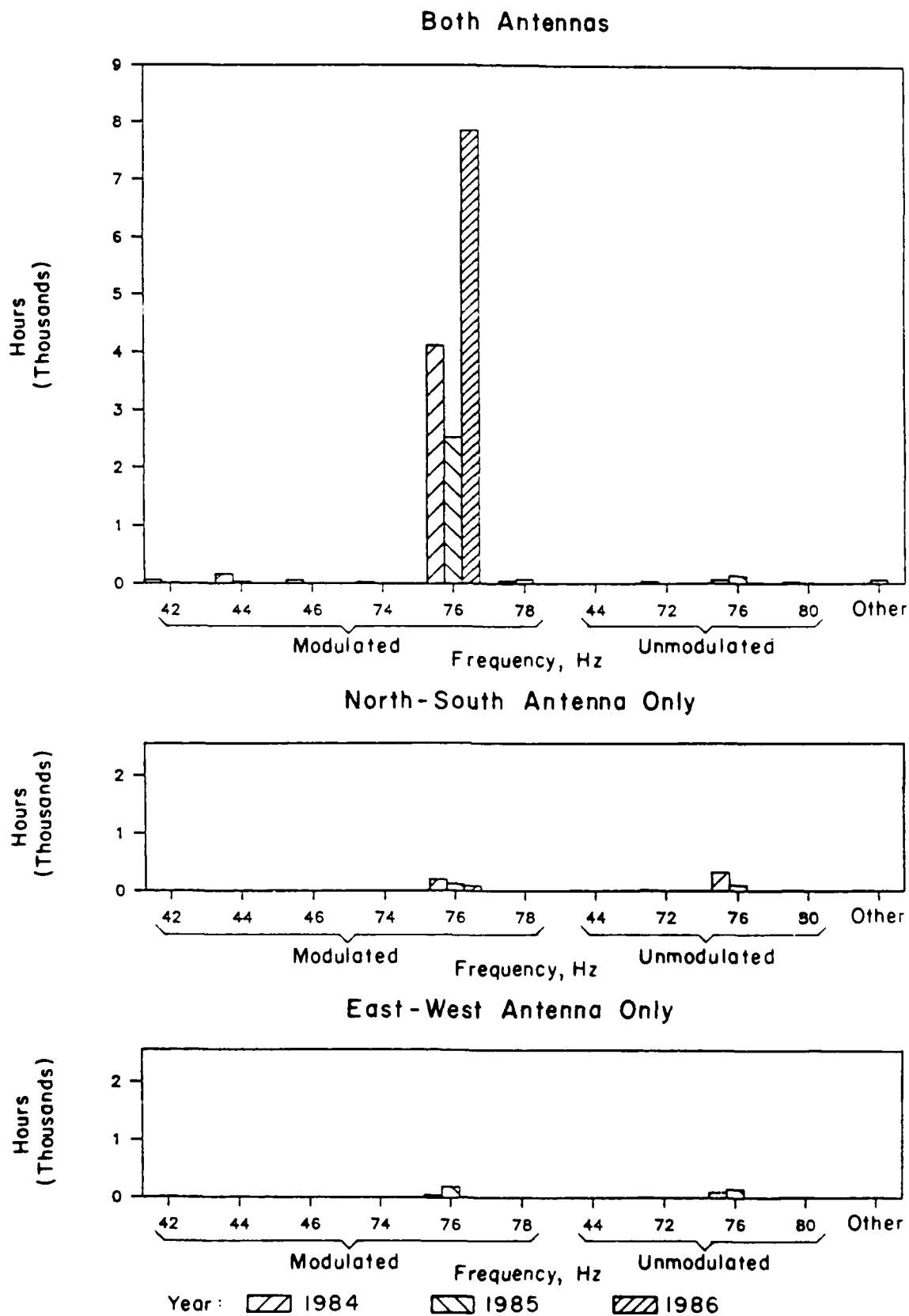


FIGURE 12. WTF OPERATING MODE SUMMARY, 1984-1986.

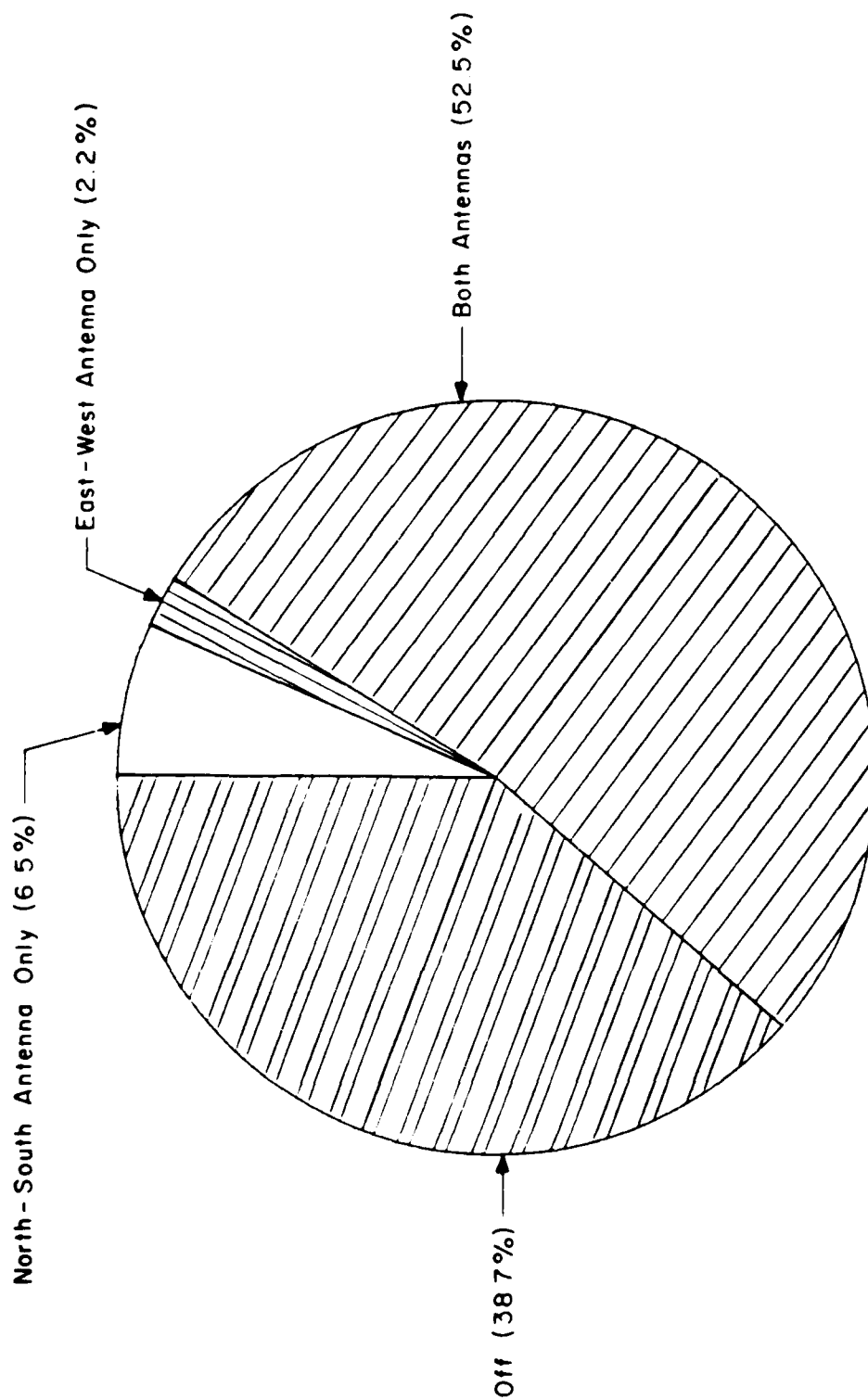


FIGURE 13. WTF OPERATING SUMMARY: PERCENTAGE OF TIME PER ANTENNA ELEMENT, 1984.

[illegible]

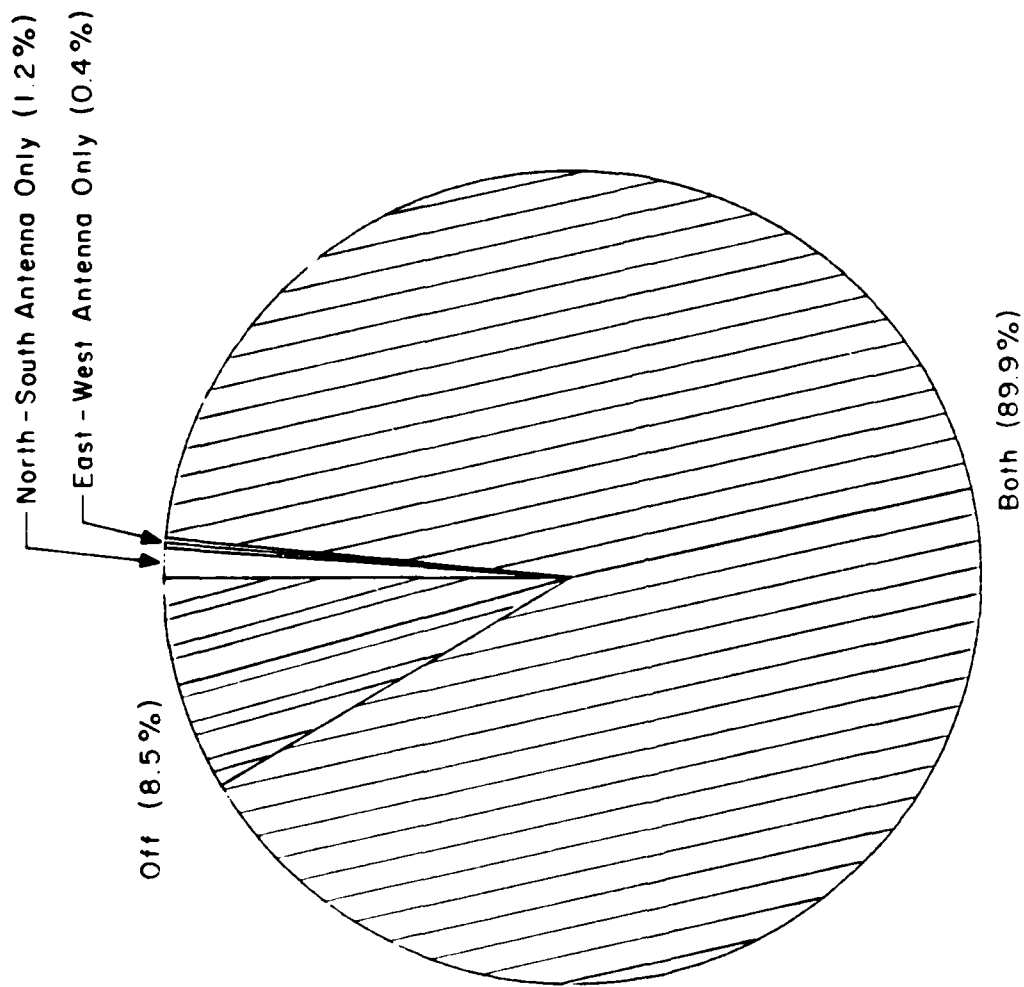


FIGURE 15. WTF OPERATING SUMMARY: PERCENTAGE OF TIME PER ANTENNA ELEMENT, 1986.

- 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 10 and 15)
- About 99.8% of "on" time was with a modulated 76 Hz signal (see Figure 12)
- The transmitter was off weekly for a 4-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.

Detailed breakdowns of WTF operation during specific periods are available to investigators as needed.

4.3 SUMMARY OF MTF OPERATIONS, 1986

The MTF will go through stages of development similar to those of 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 at the MTF were operated individually and intermittently with this signal throughout 1986. The primary operational currents in 1986 were 4, 6, and 10 amperes. It is expected that these currents will increase to 15 amperes and then 75 amperes in 1987.

Figure 16 shows the number of hours of operation in 1986 for each antenna element on a month-by-month basis. It can be seen from this figure that operation began in March 1986 and continued through October. Not shown in this figure are the operating currents. The north-south antenna element carried a current of 4 amperes for more than 99% of its operating time in 1986. The northern east-west antenna element carried a current of 6 amperes for more than 99% of its operating time in 1986. The southern east-west antenna element carried both 6 and 10 ampere currents for approximately equal time periods during its 1986 operating time.

The pie charts in Figure 17 show that the total "on" time for any antenna element at the MTF was 1.8% of the 1986 year. This percentage of time is

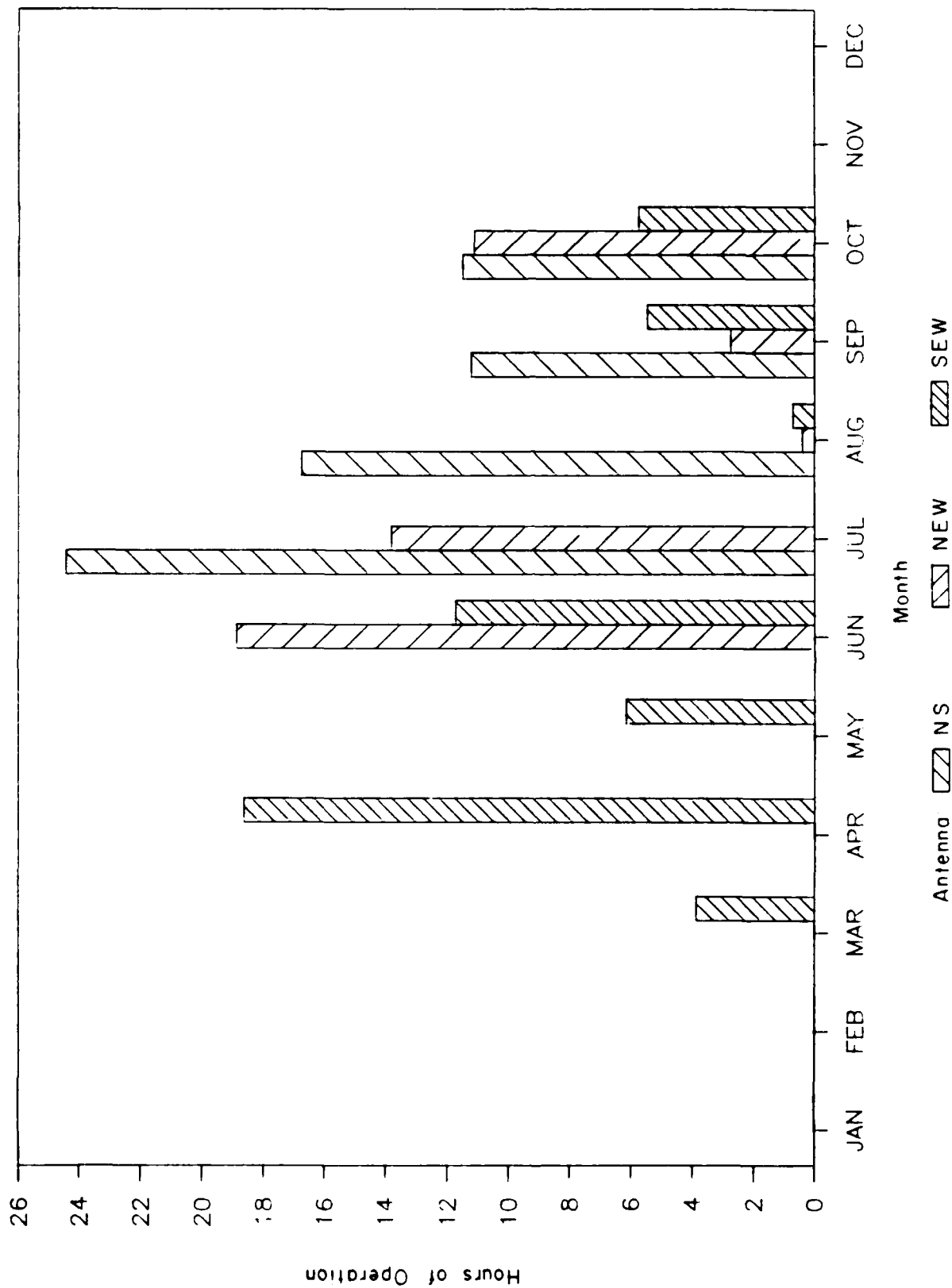


FIGURE 16. MTF MONTHLY OPERATING SUMMARY, 1986.

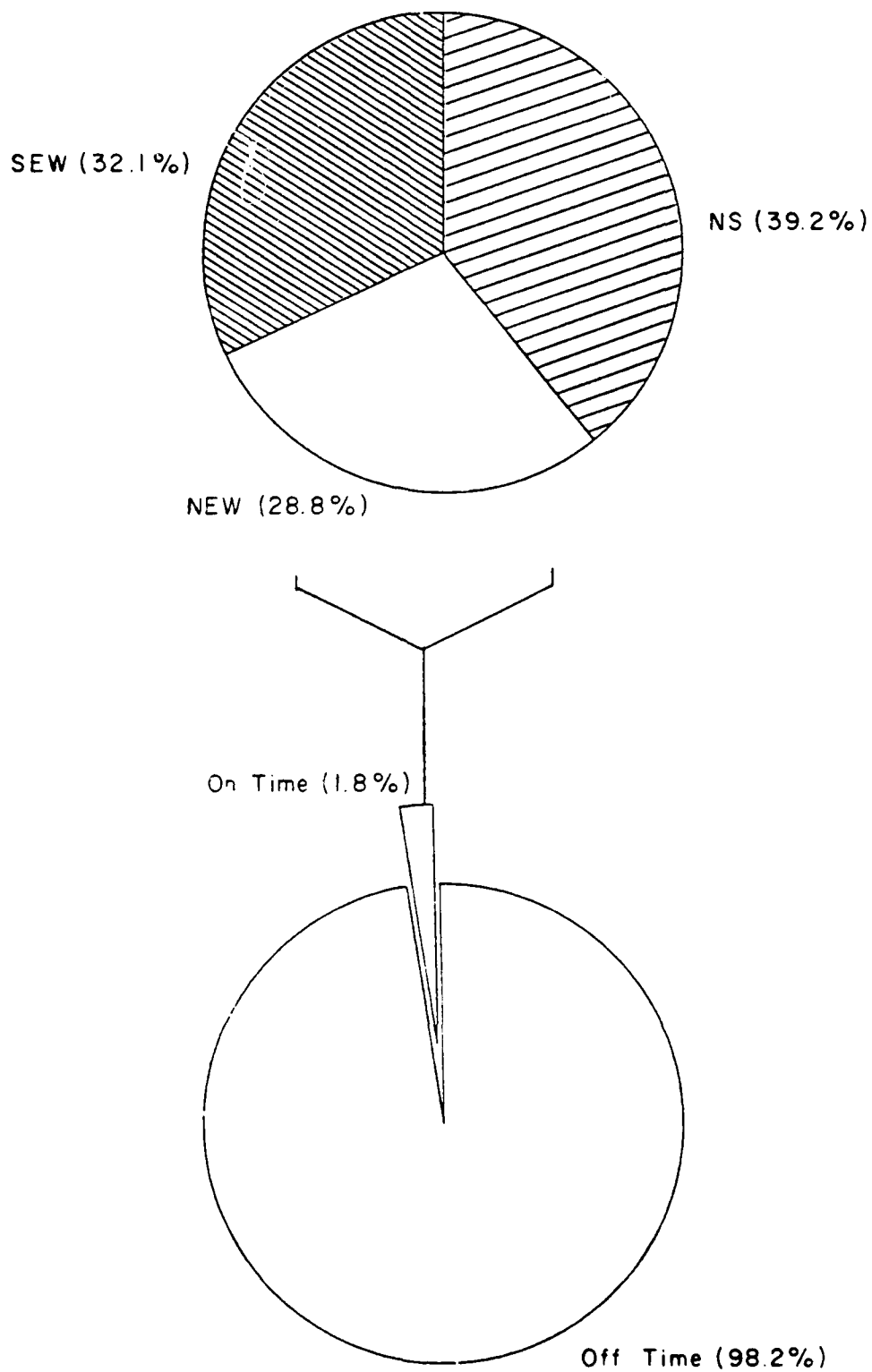


FIGURE 17. MTF ANNUAL OPERATING SUMMARY
PER ANTENNA ELEMENT, 1986.

expanded in the figure to show the contribution of each antenna element to the total. As can be seen from the figure, each antenna element was operated for roughly equal periods of time. MTF operation in 1986 can be summarized as follows:

1986

- The MTF was transmitting about 1.8% of the time (about 160 hours) (see Figures 16 and 17)
- 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 north-south and northern east-west antenna elements, respectively, and both 6 and 10 amperes for the southern east-west antenna element.

5. CONCLUSIONS AND DISCUSSION

EM field measurements were performed at both Wisconsin and Michigan study sites during August, September, and October of 1986. Measurements were made at a total of 244 points at 69 study sites; this compares with 162 measurement points at 63 sites in 1985. Measurement points were added at most Michigan study sites to define the spatial variation of 76 Hz EM fields, which were present for the first time in 1986.

The measurement protocol used in Wisconsin was the same in 1986 as in 1985. Measurement points were the same in 1986 as in 1985, but measurements were made at all three slime mold chambers instead of just the center chamber. Yearly measurement variations were within expected limits at all sites. Significant changes occurred in field intensities at sites 7G3, 8G1, and 8G2 due to a redistribution of ground currents.

Although several measurement points were added to the Michigan regime in 1986, there was only one new test site established (site 5T7). This is a stream monitoring point and possible future weir net site. Also established in Michigan were three bird displacement sites (sites 1D1, 1D2, and 1D3) and a site consisting of holding facilities and a laboratory for the small mammals and nesting birds studies (site 1L1). The 60 Hz fields measured at the holding facility at site 1L1 were nominally 200 times larger than those measured at the study sites. It is therefore recommended that this holding facility be repositioned.

The MTF was operational for the first time at low currents in 1986. The measurement protocol at Michigan study sites included 60 Hz measurements and 76 Hz measurements for each of the three individual antenna elements at operating currents of 4 or 6 amperes. The 76 Hz low current measurements were extrapolated to a full power current of 150 amperes and compared with pre-antenna operation field estimates calculated for the 150 ampere current. The measured values compared very well with the estimates.

The 60 Hz fields at Michigan test sites varied considerably between 1985 and 1986. Typically the magnetic flux density increased and the longi-

tudinal electric field decreased at test sites in 1986 due to coupling of 60 Hz ambient fields to the newly constructed antenna.

Site pair ratios were recalculated in 1986 for Michigan study sites using 76 Hz measurements rather than estimates. The R1, R2, and R3 ratios, which set up criteria to ensure that the 76 Hz field at test sites dominates all other fields, were satisfied for all study site pairs with the exception of the R1 longitudinal electric field ratio at eight aquatic ecosystems site pairs and two bird species and communities site pairs. Physical limitations in site location for the aquatic ecosystems studies make it impossible to meet all criteria established for site selection. As to the bird species and communities studies, there is an excess of acceptable site pairs, and the two R1 ratio criteria not met are of little consequence. The ratio criterion most often unsatisfied was the R4 ratio (which compares the 60 Hz fields at test and control sites), because of the change in 60 Hz fields at test sites seen after antenna installation. Site selection is complete in both Wisconsin and Michigan. All studies have an adequate number of electromagnetically acceptable or conditionally acceptable site pairings.

IITRI is provided with a detailed log of WTF and MTF activities. This data is entered into an operating log data base so that summary reports of exposure periods under various transmitter conditions can be provided to the investigators. Data on field intensities and antenna operation periods provide the researchers with a complete picture of the EM field exposure at their study sites. The operating log data base begins in 1984 for the WTF and in 1986 for the MTF.

A question has arisen as to the effect of changes in the soil conductivity with climate and its effect on the longitudinal electric field. Until now, all EM measurements have been made during the warmer months. In 1987, electrodes will be positioned near the WTF terminal grounds to monitor seasonal variations in the longitudinal electric field.

The slime mold and wetlands studies will undergo their final field season in Wisconsin in 1987. The bird species and communities studies, which began later, will continue in Wisconsin beyond 1987. No significant changes in the mode of operation of the WTF are expected in 1987. The WTF 1987 annual field measurements therefore will likely be made under the same protocol as used in 1986.

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The MTF is expected to begin operating at one-tenth to one-half power (15 to 75 amperes) in 1987 with the two east-west antenna elements connected in parallel. The measurement protocol for annual measurements in Michigan in 1987 will be similar to that in 1986, with the exception that EM fields from the two east-west antenna elements will not be measured individually but together.

APPENDIX A
SMALL MAMMALS AND NESTING BIRDS STUDIES

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SMALL MAMMALS AND NESTING BIRDS STUDIES

On 2, 3, 6, 8 and 14-17 October 1986, IITRI field crews made ELF electro-magnetic (EM) field measurements at 47 measurement points at a total of five test sites, four control sites, three (bird) displacement sites, and one laboratory site for the small mammals and nesting birds studies. The nine test and control sites were all measured in each of the two previous years (1984, 1985); the laboratory site and displacement sites were added to the measurement regime in 1986.

The Michigan Transmitting Facility (MTF) was operational for the first time in 1986. Therefore, 76 Hz EM field measurement points were added within sites to better define the spatial variation of the 76 Hz EM fields at the sites. The positions of the 13 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. Details of measurement locations within sites are shown in Figures A-2 through A-13. Table A-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites.

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. Table A-2 shows the test/control site pairings of interest to the investigator, the corresponding study parameters, and site pair status.

The field ratios for the site pairs given in Table A-2 were recalculated using the measured values of the 76 Hz fields extrapolated to the planned operational antenna current of 150 amperes; Table A-3 shows the results. All of the ratio criteria were met except for the R4 ratio ($T(60)/C(60)$) for the longitudinal electric field and magnetic flux densities at some site pairs. The R4 magnetic flux density ratio did not meet criteria at five site pairs (1T2/1C4, 1T2/1C6, 1T4/1C4, 1T5/1C4, and 1T6/1C4). This was the result, in each case, of additional 60 Hz magnetic fields coupled by the antenna wire.

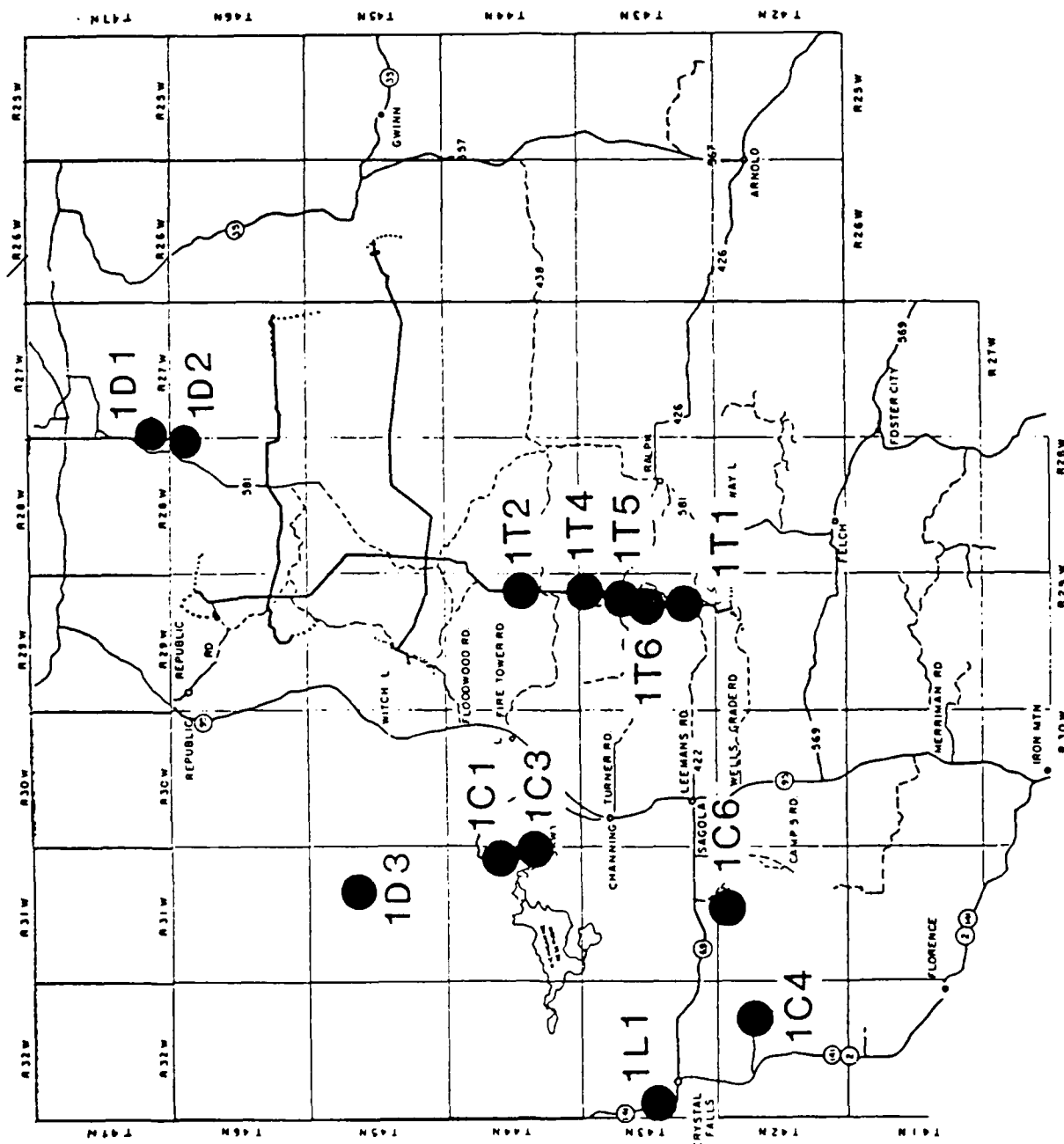


FIGURE A-1. POSITIONS OF SMALL MAMMALS AND NESTING BIRDS STUDY SITES RELATIVE TO MICHIGAN TRANSMITTING FACILITY ANTENNA ELEMENTS.

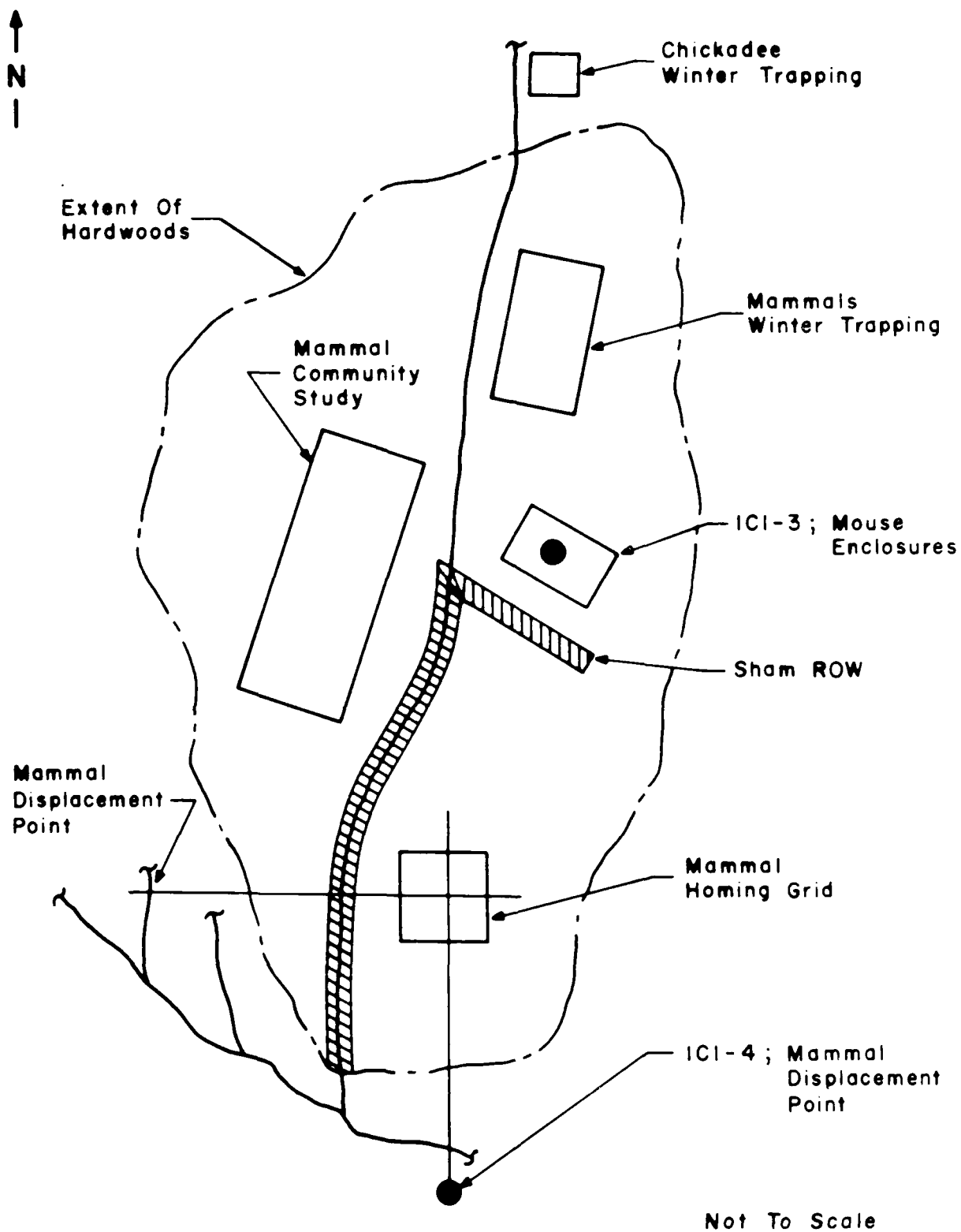


FIGURE A-2. MEASUREMENT POINTS AT MICHIGAMME NORTH;
ICI-3, 4.

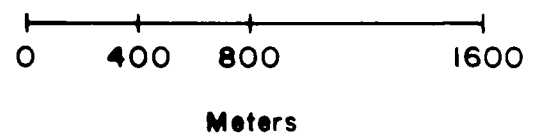
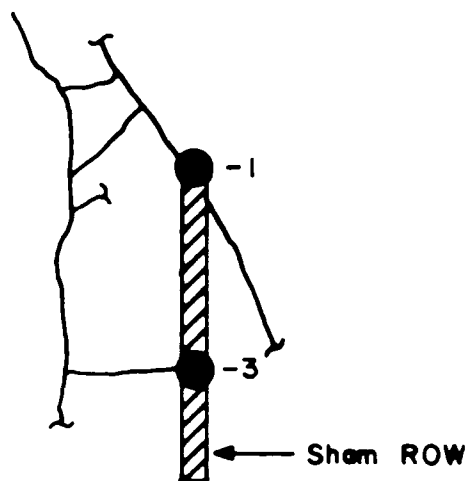


FIGURE A-3. MEASUREMENT POINTS AT MICHIGAMME SOUTH ;
IC3-1,3.

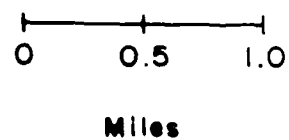
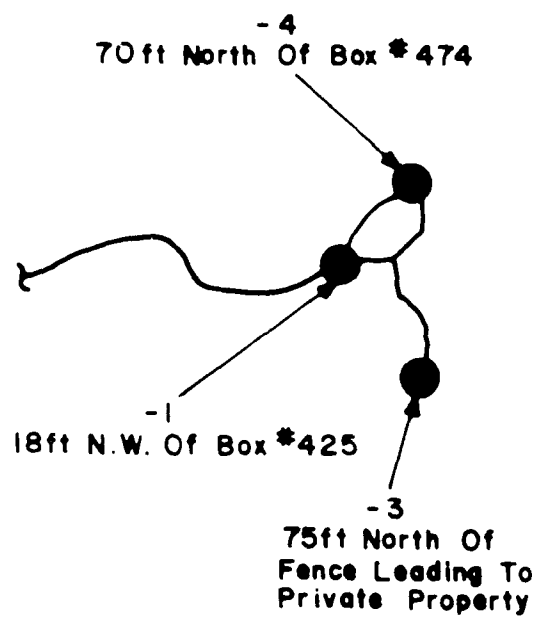


FIGURE A - 4. MEASUREMENT POINTS AT PANOLA PLAINS;
IC4-1, 3, 4.

↑
N

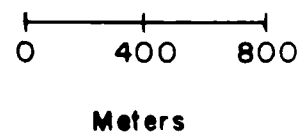
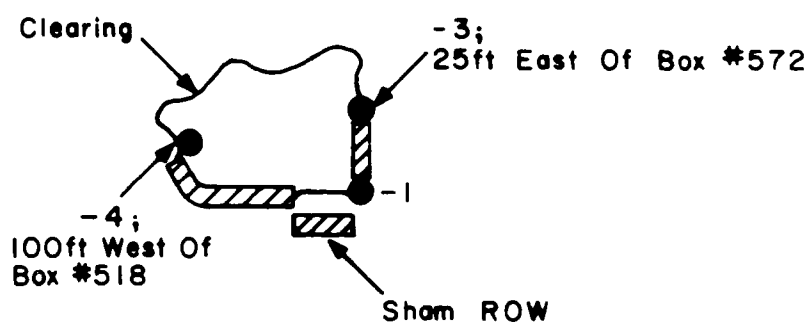


FIGURE A-5. MEASUREMENT POINTS AT TACHYGINETA MEADOW;
IC6-1, 3, 4.

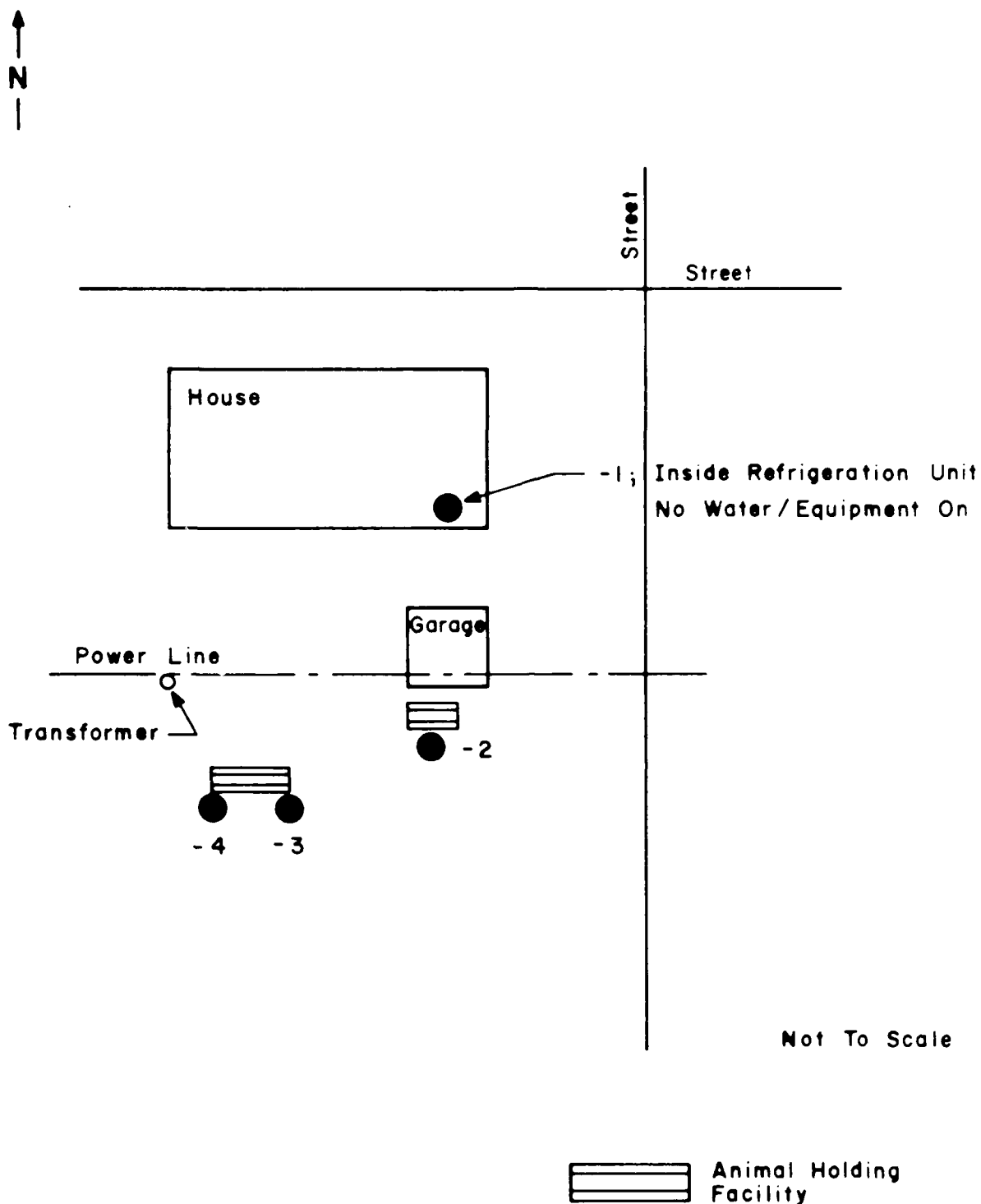
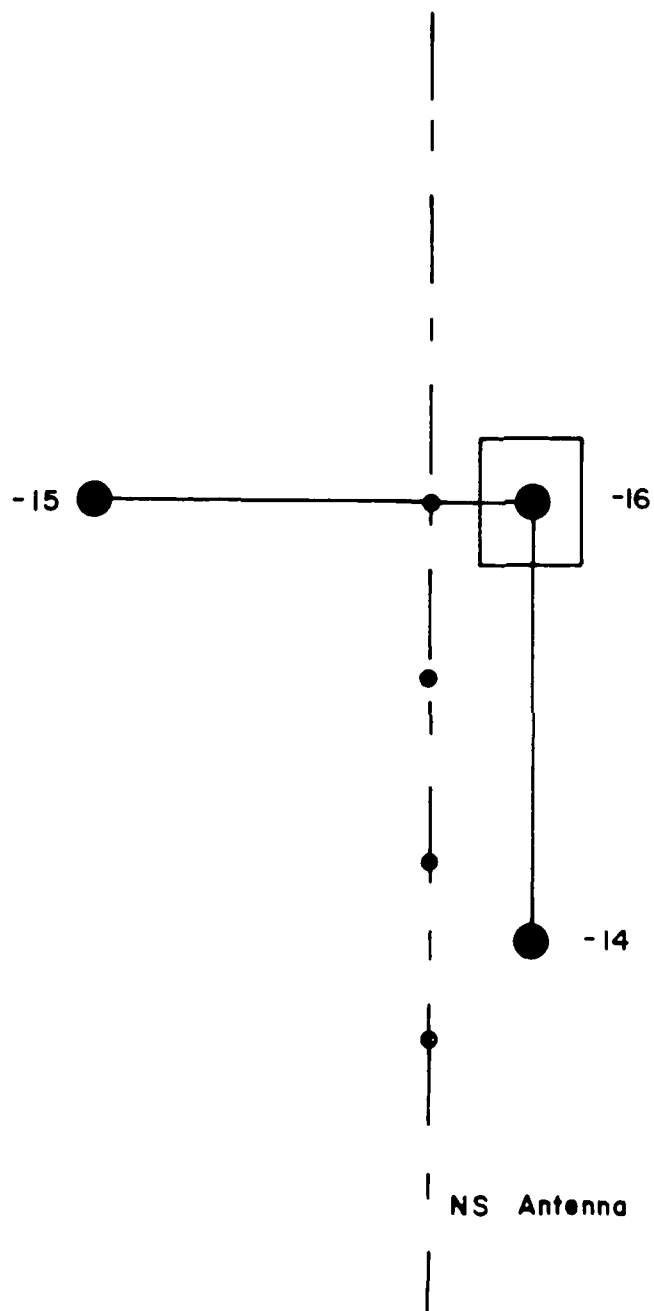


FIGURE A-6. MEASUREMENT POINTS AT MAMMAL LABORATORY; ILI-1 THROUGH 4.

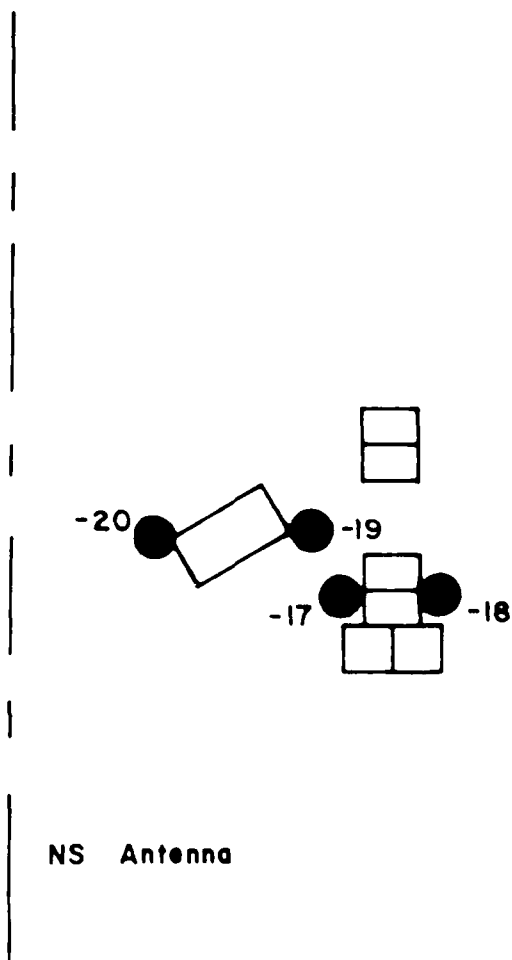
↑
N



Not To Scale

FIGURE A-7. MEASUREMENT POINTS AT PIRLOT ROAD MAMMAL
DISPLACEMENT ; ITI -14,15,16.

↑
N



Not To Scale

FIGURE A-8. MEASUREMENT POINTS AT PILOT ROAD
MOUSE ENCLOSURES; ITI - 17 THROUGH 20.

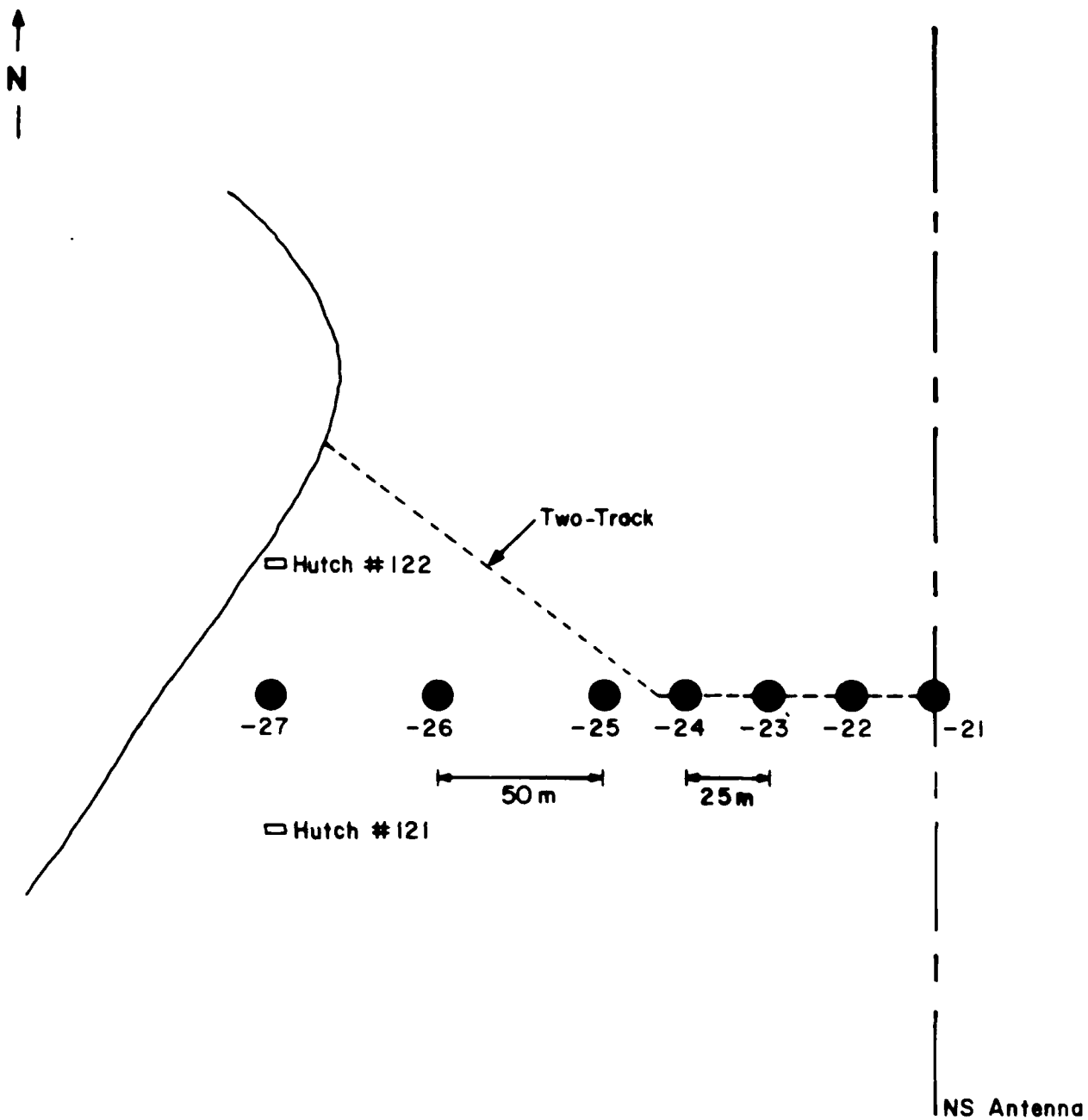


FIGURE A-9. MEASUREMENT POINTS AT PIRLOT ROAD
NEST BOXES ; ITI-21 THROUGH 27.

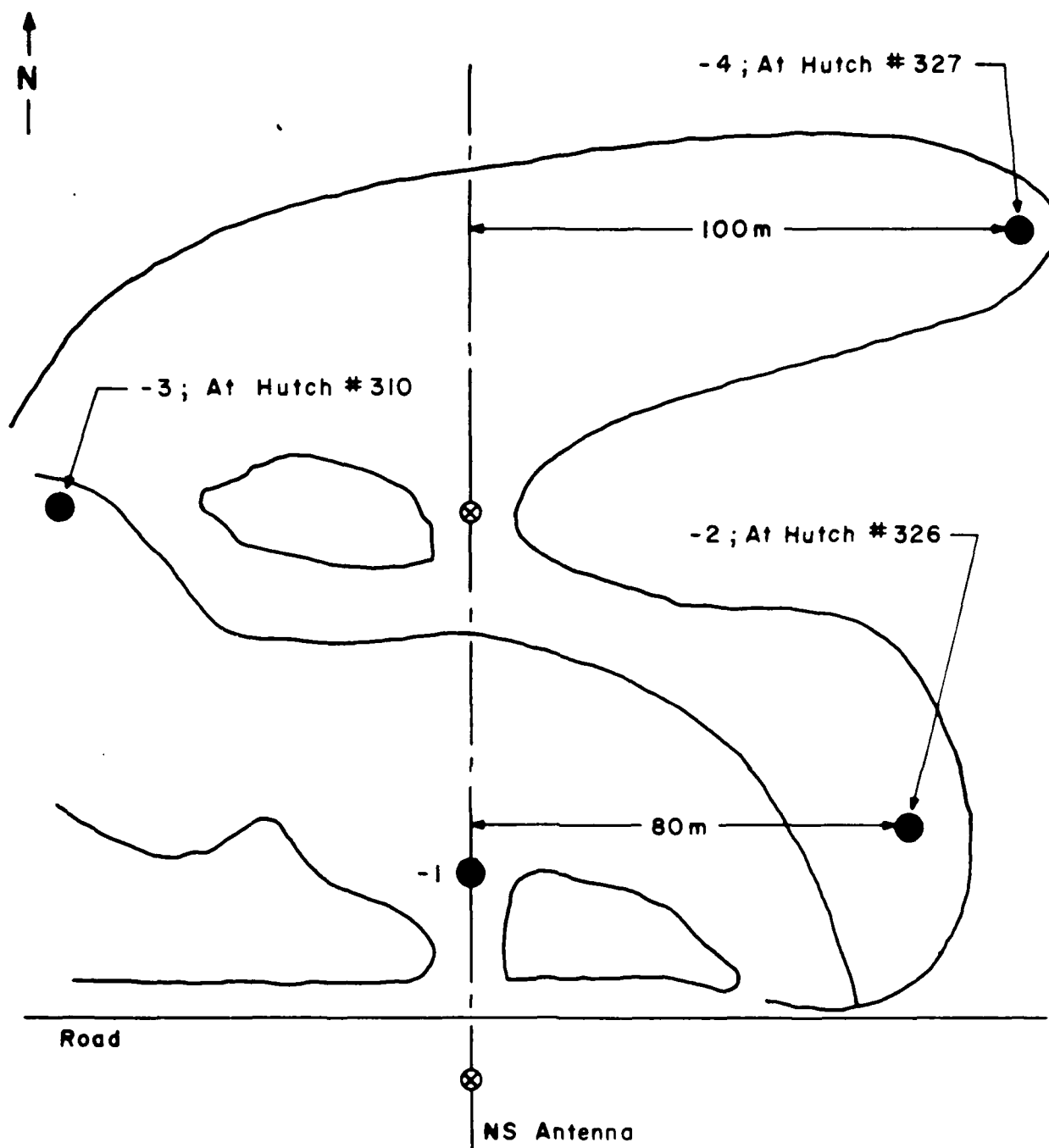


FIGURE A-10. MEASUREMENTS AT CLEVELAND HOMESTEAD;
IT2-1 THROUGH 4.

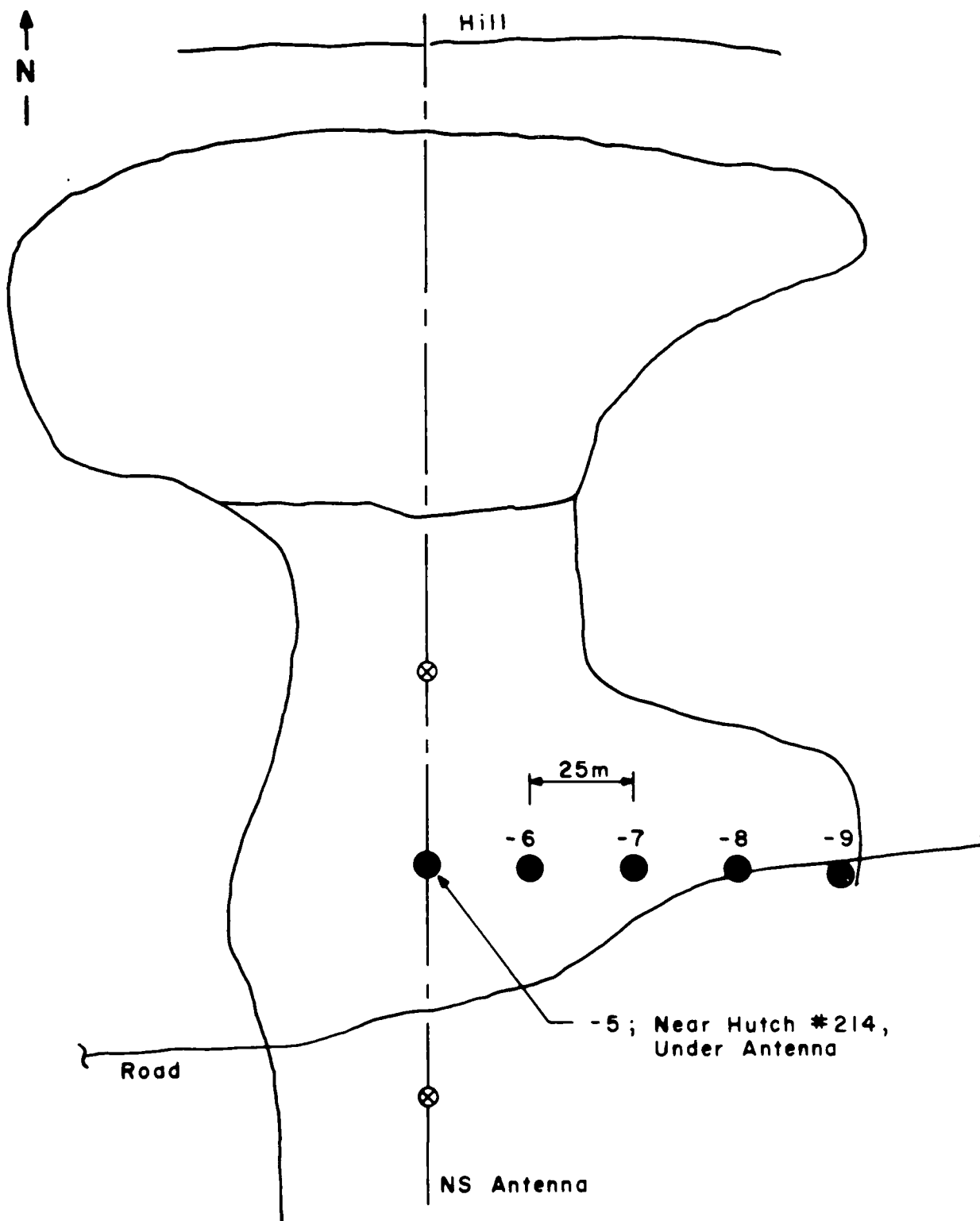


FIGURE A-II. MEASUREMENT POINTS AT NORTH TURNER ROAD;
IT4-5 THROUGH 9.

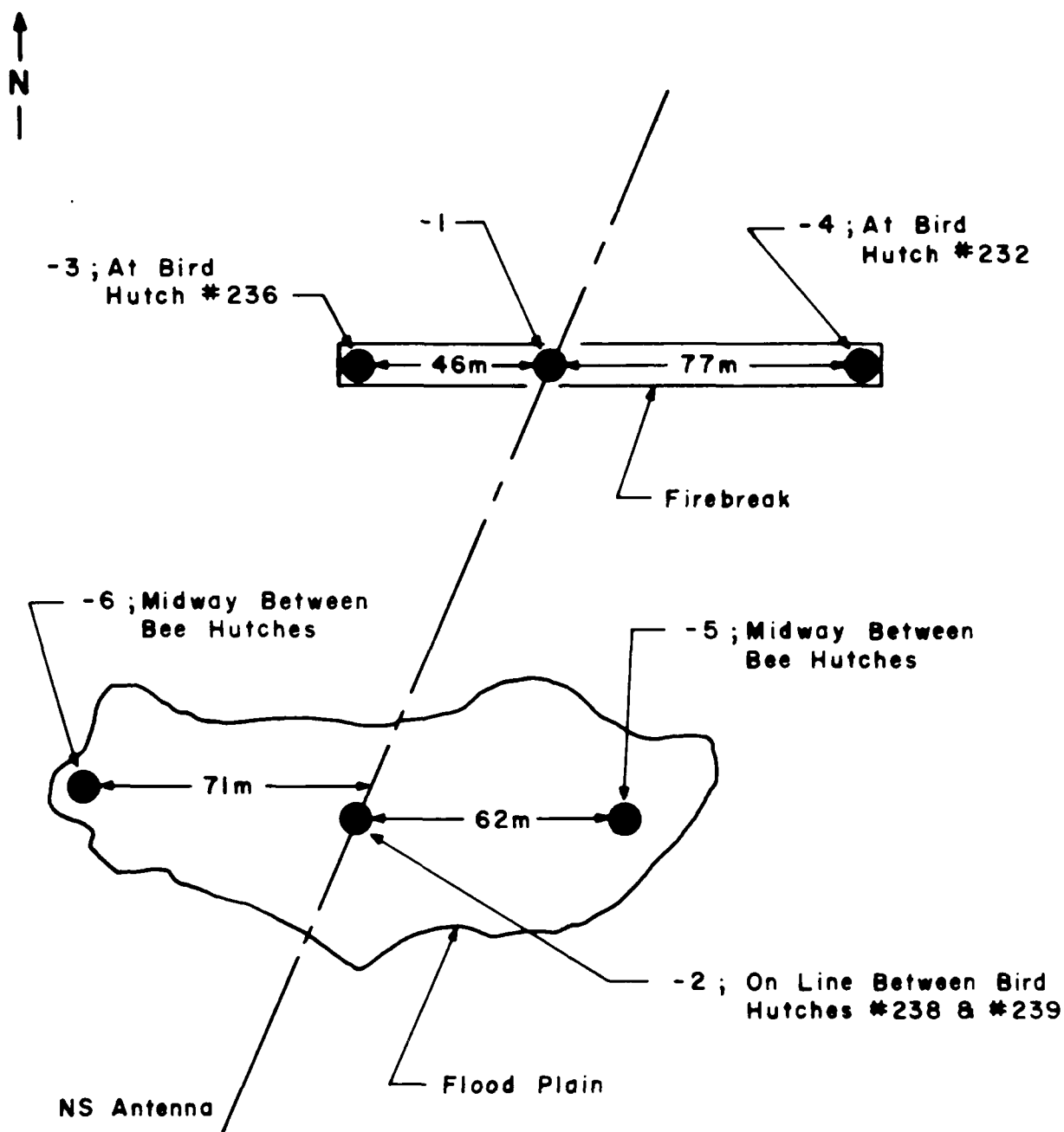


FIGURE A-12. MEASUREMENT POINTS AT FORD RIVER NORTH;
IT5-1 THROUGH 6.

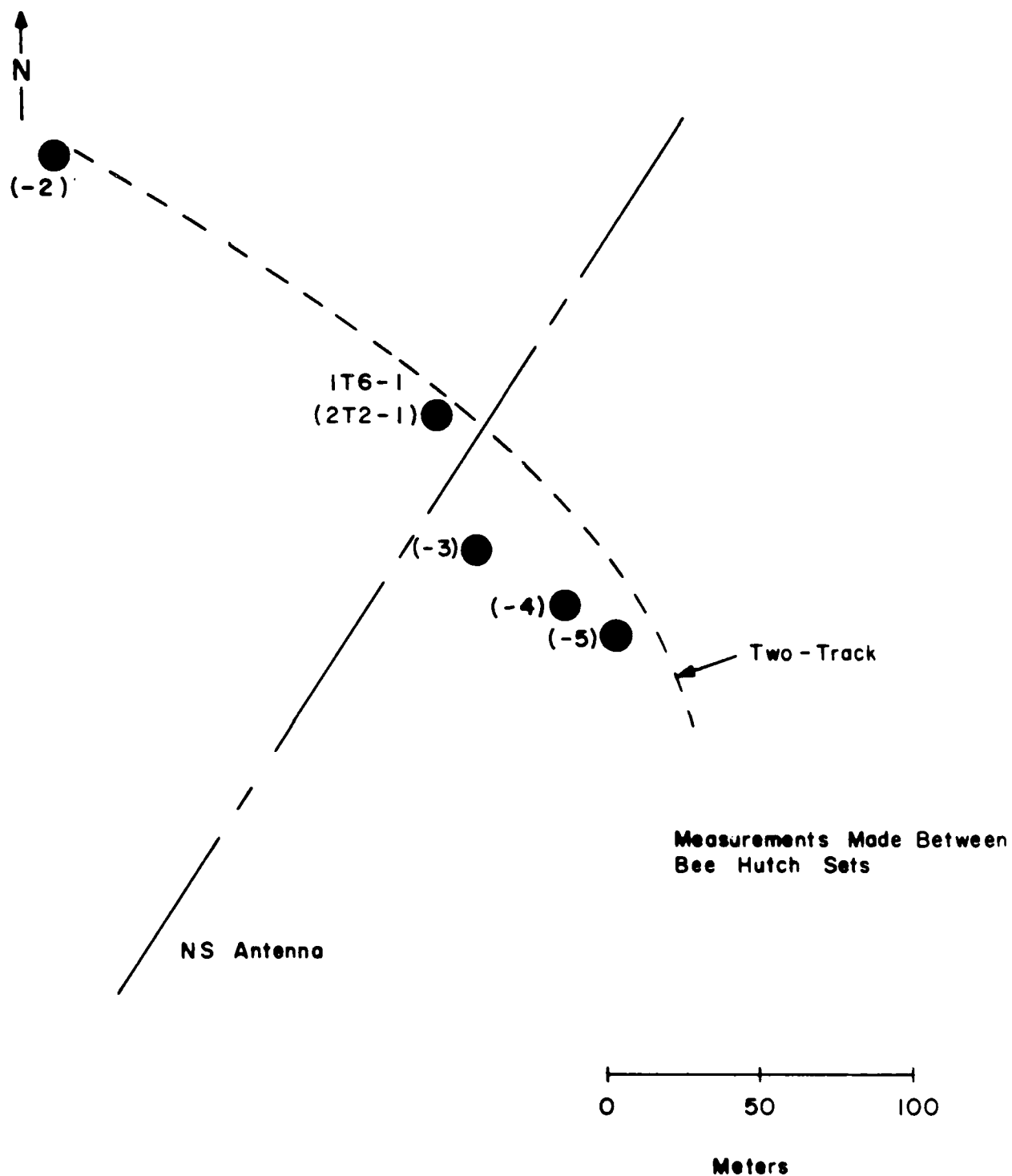


FIGURE A-13. MEASUREMENT POINTS AT FORD RIVER SOUTH ;
IT6-1 AND 2T2-1 THROUGH 5.

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 Lab	T43N	:	R32W : 29

TABLE A-2. SITE PAIRINGS, STUDY PARAMETERS, AND STATUS
Small Mammals and Nesting Birds Studies

Test Site	Control Site	Study Parameters	EM Status
1T1	1C1	Mammal Enclosure, Homing, and Community Studies	A
1T1	1C3	Small Mammal Physiology Trapping	A
1T1	1C4	Parental Care and Growth Studies (Birds)	CA
1T1	1C6	Fecundity, Postnatal Growth (Birds)	CA
1T2	1C4	Embryology, Homing, Parental Care (Birds)	CA
1T2	1C6	Growth Studies (Birds)	CA
1T4	1C4	Homing Studies (Birds)	CA
1T5	1C4	Embryology (Birds)	CA
1T6	1C4	Embryology (Birds)	CA

A = Acceptable
CA = Conditionally Acceptable
U = Unacceptable

**TABLE A-3. FIELD INTENSITY RATIOS
Small Mammals and Nesting Birds Studies**

Compared Sites	Transverse E-Field (Air)				Longitudinal E-Field (Earth)				Magnetic Flux Density			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
1T1/1C1	38	38	38	1.00	15.0	320	144	0.34 - 1.44	71	270	1060	1.00 - 9.0
1T1/1C3	38	38	38	1.00	13.7	320	200	0.47 - 1.59	71	270	1060	1.00 - 9.0
1T1/1C4	38	38	38	1.00	16.8	320	142	0.34 - 10.7	71	270	530	0.50 - 9.0
1T1/1C6	38	38	38	1.00	270	320	154	0.37 - 16.9	106	270	350	0.33 - 4.5
1T2/1C4	38	38	38	1.00	44	840	370	0.37 - 11.1	33	430	250	3.0 - 77
1T2/1C6	38	38	38	1.00	700	840	400	0.40 - 17.4	49	430	163	2.0 - 39
1T4/1C4	75	75	75	1.00	77	850	650	0.44 - 9.5	220	600	1650	2.0 - 21
1T5/1C4	75	75	75	1.00	44	690	370	0.36 - 11.4	320	670	2400	2.0 - 51
1T6/1C4	6800	6800	6800	1.00	210	910	1780	1.95 - 21	1030	770	7700	0.0 - 20

The R4 longitudinal electric field ratio did not meet criteria at six site pairs (1T1/1C4, 1T1/1C6, 1T2/1C4, 1T2/1C6, 1T5/1C4, and 1T6/1C4). These ratios were not met in 1985 at four site pairs (1T1/1C4, 1T2/1C4, 1T5/1C4, and 1T6/1C4). They were not met at the other two (1T1/1C6 and 1T2/1C6) because of a decrease in the field measured at site number 1C6-4, which was measured to be considerably lower than in 1985.

All other criteria were met, and all of the test/control site pairs for the small mammals and nesting birds studies fell into either the acceptable or conditionally acceptable categories, as shown in Table A-2.

EM field measurements for 1986 and previous years are found in Tables A-5 through A-13. Tables A-5, A-6, and A-7 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables A-8, A-9, and A-10 present 76 Hz data for these three fields at 1986 MTF operating currents. Tables A-11, A-12, and A-13 present 76 Hz data extrapolated to a full power condition of 150 amperes as well as pre-operation estimates for comparison. (See Section 3.5.2.)

Several measurement points within study sites were added in 1986 in order to define the spatial variation of 76 Hz EM fields, while many previously established measurement points were dropped. The Pirlot Road and North Turner Road nest box sites provide examples in which measurements were made along a transect perpendicular to the antenna. The 60 Hz and 76 Hz magnetic and

longitudinal field gradients for these sites are plotted in Figures A-14 through A-17. It is important to note that the 76 Hz fields in these figures have been extrapolated to an antenna current of 150 amperes. The MTF antenna never operated at 150 amperes in 1986, and 76 Hz field intensities on these graphs are therefore not to be interpreted as actual exposure levels in 1986. The purpose of the graphs is to show the field gradients. Actual exposure levels can be determined by linear extrapolation of the 150 ampere data to the actual antenna current. Only one measurement location is listed for the Ford River South nest box site: 1T6-1. However, this site is shared with the native bees study, which has five measurement locations, 2T2-1 through 5. EM field data for these locations can be found in Tables B-4 through B-12 of Appendix B. Transect measurement sets are planned for the Ford River North, Ford River South, and Cleveland Homestead nest box sites in 1987.

The 60 Hz data tables include data for the new measurement points as well as those that were dropped in 1986. The reason for dropping points was simply that they did not fit well with the group of points selected to define the EM field gradient at the site. In several cases, however, old measurement points are close enough to new points that the fields can be compared at the two points to determine temporal variations. Table A-4 lists such measurement points that can be compared. In making such comparisons at test sites, one should expect the magnetic flux densities to be greater and the longitudinal electric fields to be less in 1986 than they were in previous years. This is due to coupling of 60 Hz fields to the antenna.

TABLE A-4. COMPARABLE MEASUREMENT POINTS

Pre-1986	1986
1C1-2	1C1-4
1C4-2	1C4-4
1T1-3	1T1-17, 18, 19, 20
1T1-10	1T1-14
1T1-12	1T1-21, 22, 23, 24, 25, 26, 27
1T1-13	1T1-21, 22, 23, 24, 25, 26, 27
1T4-1	1T4-5

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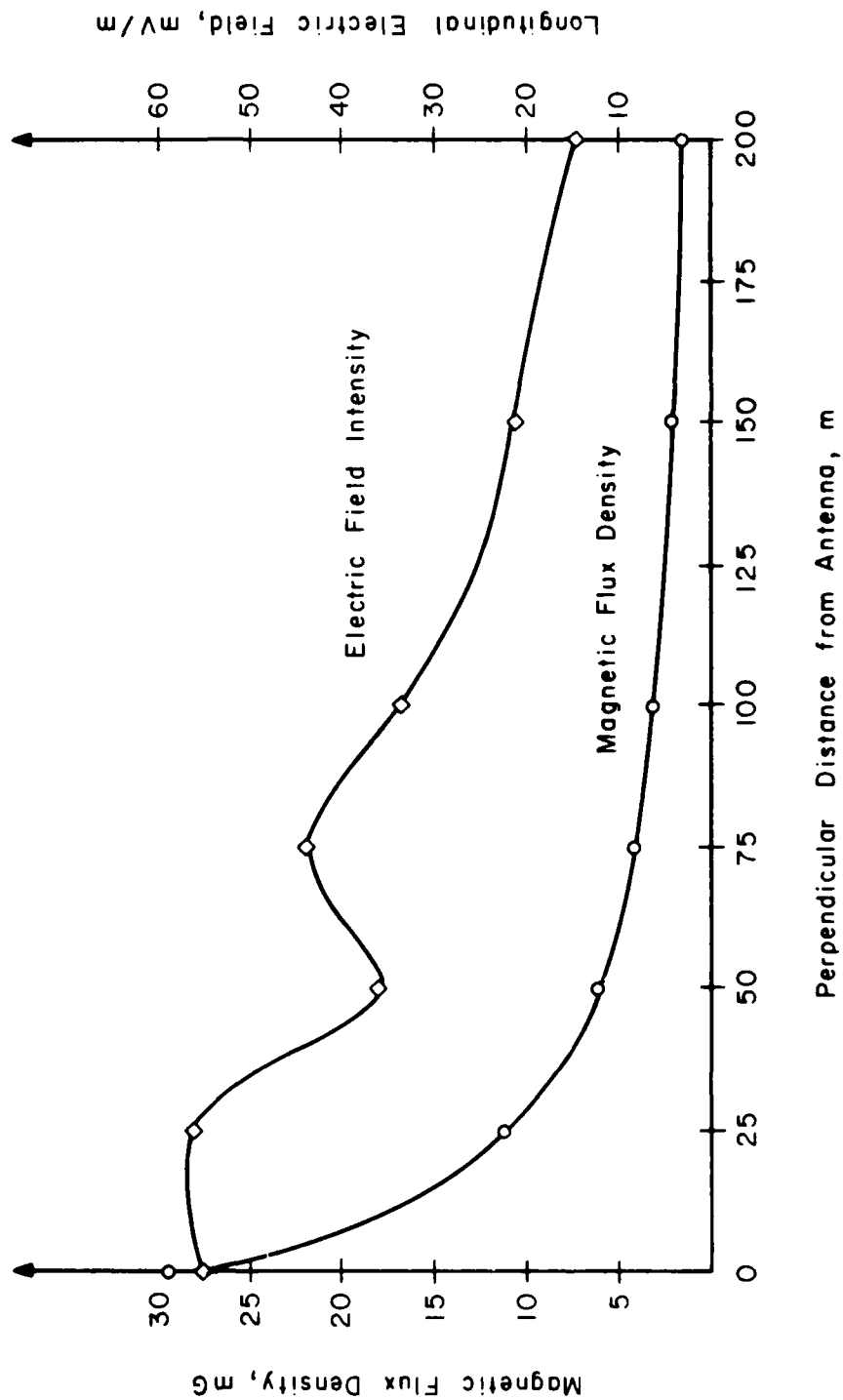


FIGURE A-14. 76 Hz EM FIELD GRADIENT PLOTS FOR PILOT ROAD NEST BOXES; ITI-21 THROUGH 27 (EXTRAPOLATED TO 150A).

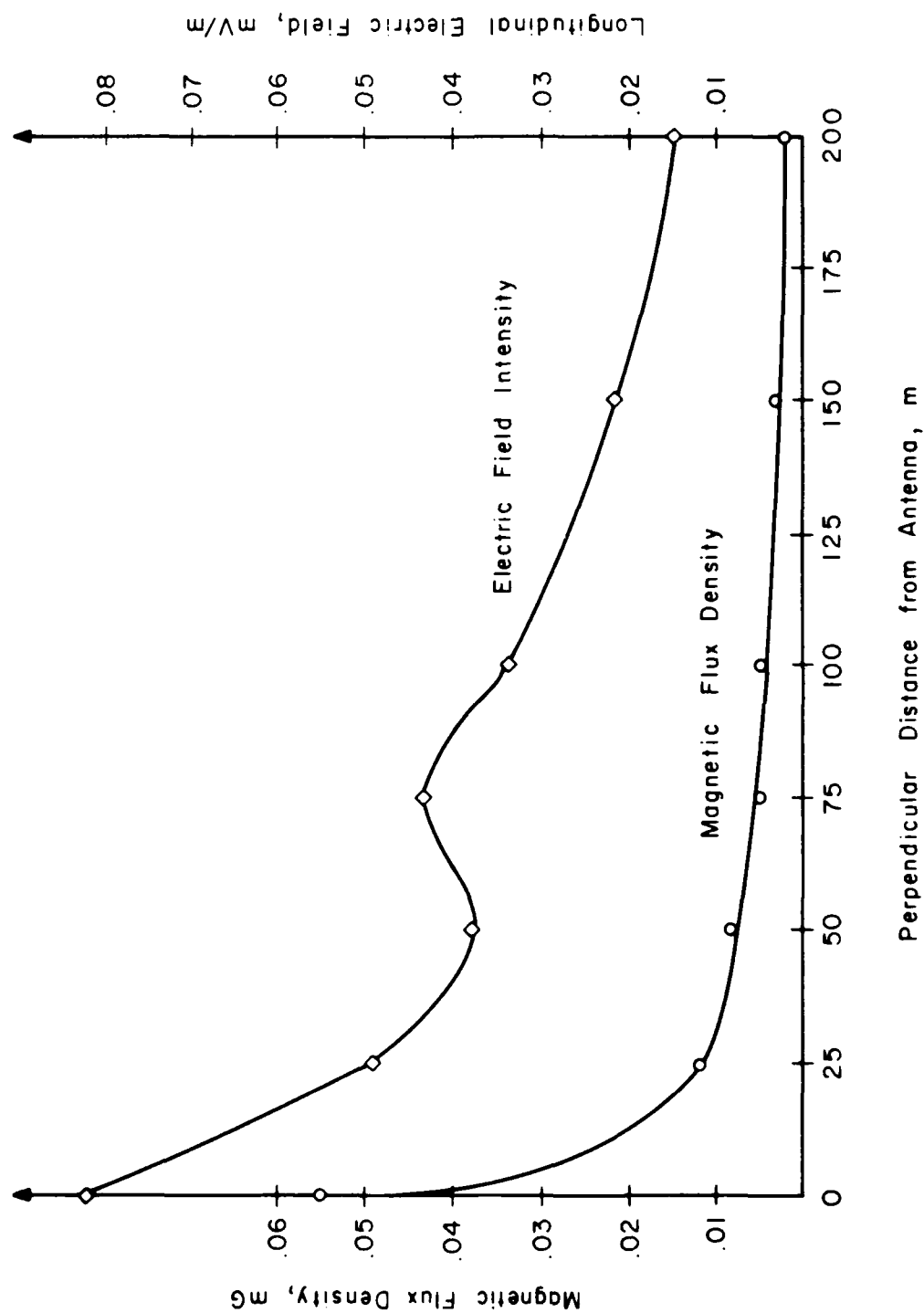


FIGURE A-15. 60 Hz EM FIELD GRADIENT PLOTS FOR PILOT ROAD NEST BOXES; ITI-21 THROUGH 27.

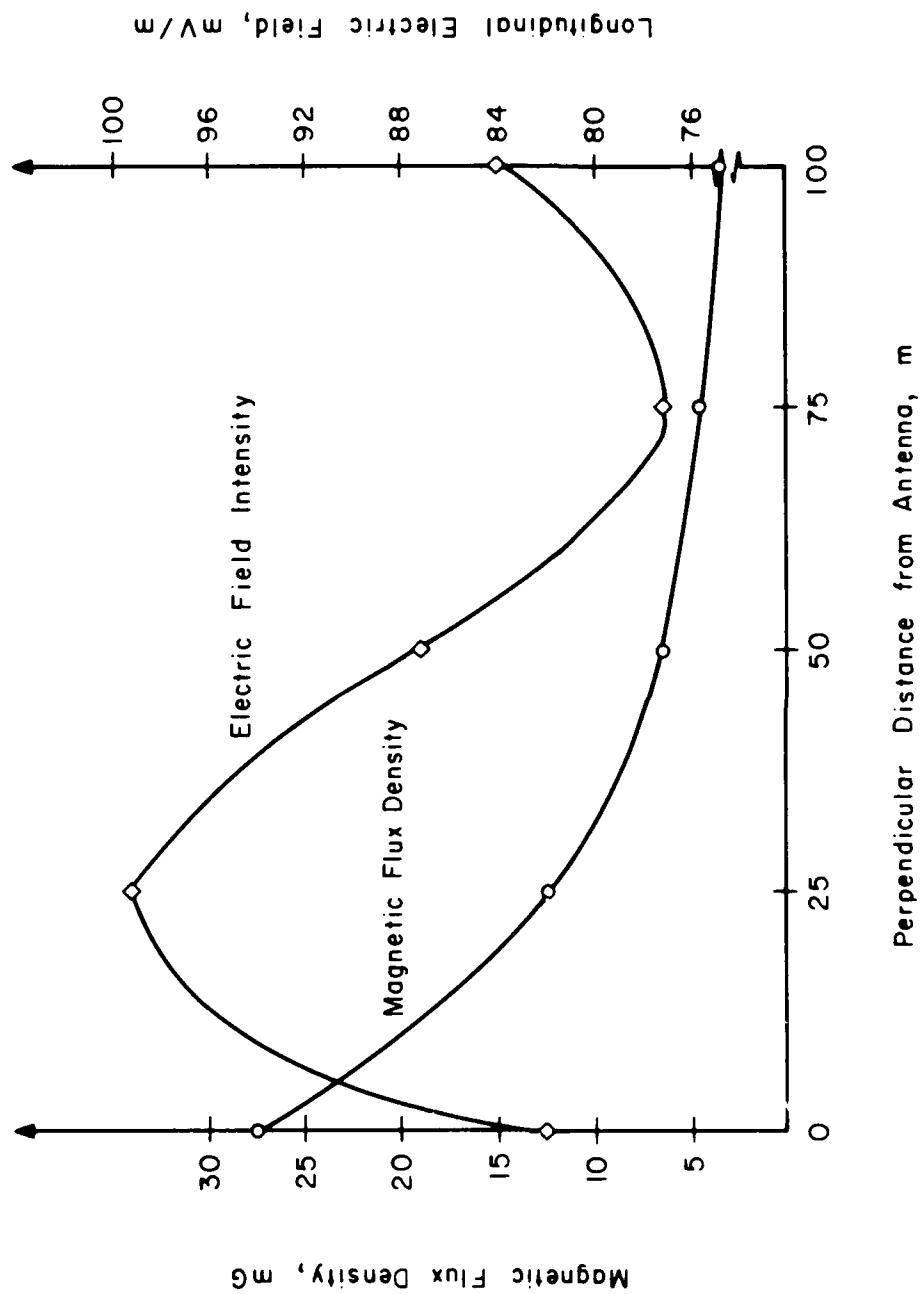


FIGURE A-16. 76 Hz EM FIELD GRADIENTS FOR NORTH TURNER ROAD NEST BOXES;
IT4-5 THROUGH 9 (EXTRAPOLATED TO 150A).

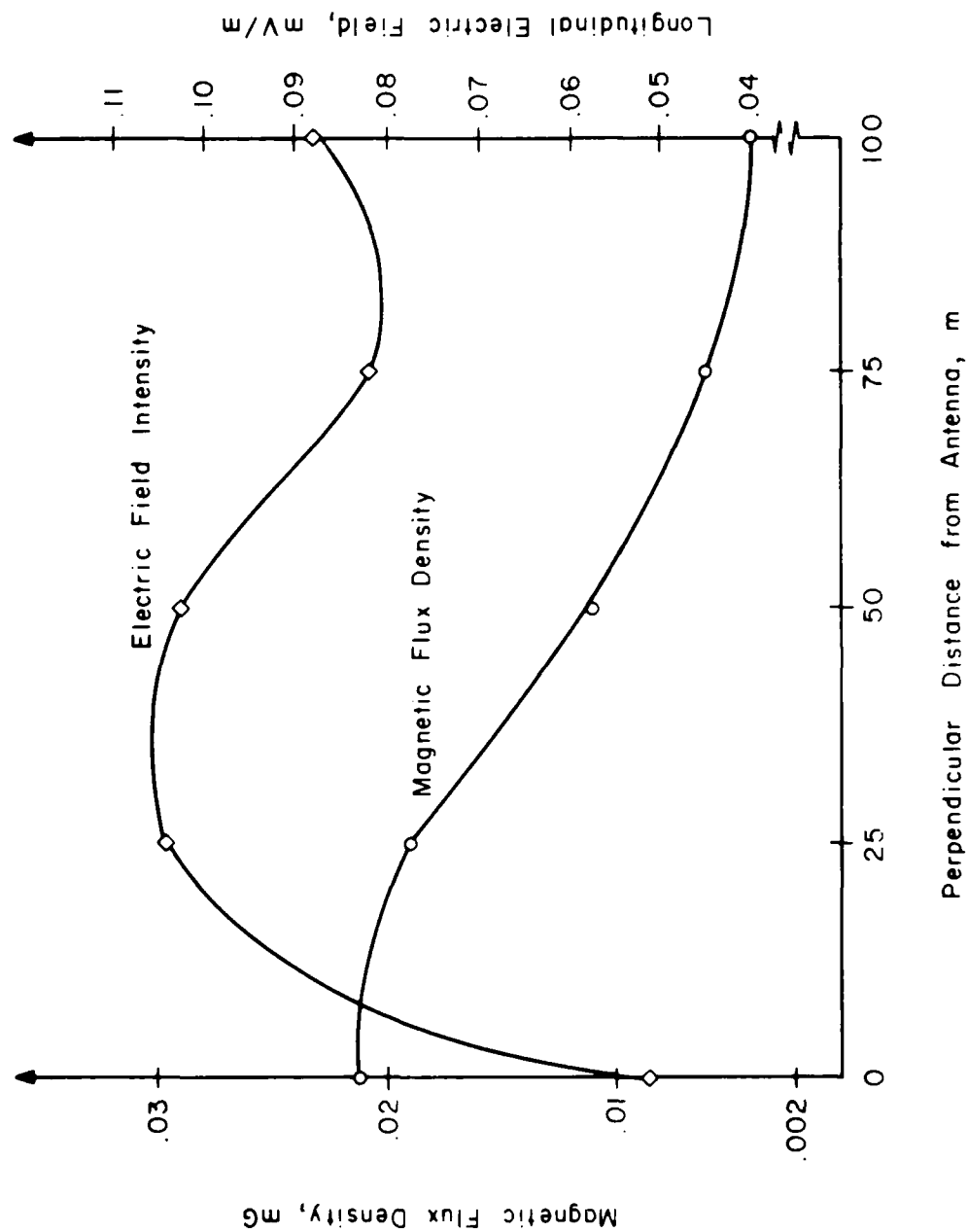


FIGURE A-17. 60 Hz EM FIELD GRADIENTS FOR NORTH TURNER ROAD NEST BOXES; IT4-5 THROUGH 9.

TABLE A-5. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies (page 1 of 2)

Site No., Meas. Pt.	Measurement Year			
	1983	1984	1985	1986
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	-	-	-	-
1D3-1	-	-	-	-
1C6-1	-	0.001	-	-
1C6-3	-	-	-	-
1C6-4	-	-	-	-
1L1-1	-	-	-	/
1L1-2	-	-	-	0.94
1L1-3	-	-	-	0.79
1L1-4	-	-	-	0.042
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	-	-	-	-
1T1-21	-	-	-	-
1T1-22	-	-	-	-
1T1-23	-	-	-	-
1T1-24	-	-	-	-
1T1-25	-	-	-	-
1T1-26	-	-	-	-
1T1-27	-	-	-	-

TABLE A-5. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies (page 2 of 2)

Site No., Meas. Pt.	Measurement Year			
	1983	1984	1985	1986
1T2-1	<0.001	0.001	-	-
1T2-2	-	-	-	-
1T2-3	-	-	-	-
1T2-4	-	-	-	-
1D1-1	-	-	-	2.5
1T4-1	-	<0.001	-	--
1T4-3	-	-	-	--
1T4-4	-	-	-	--
1T4-5	-	-	-	-
1T4-6	-	-	-	-
1T4-7	-	-	-	-
1T4-8	-	-	-	-
1T4-9	-	-	-	-
1D2-1	-	-	-	-
1T5-1	-	<0.001	-	-
1T5-2	<0.001	<0.001	-	-
1T5-3	-	-	-	-
1T5-4	-	-	-	-
1T5-5	-	-	-	-
1T5-6	-	-	-	-
1T6-1	<0.001	<0.001, 0.001		-

- = site measurement point has not been established.

- = measurement is expected to be <0.001 V/m based on the longitudinal electric field measurement.

-- = site measurement point has been dropped.

/ = data not taken.

TABLE A-6. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Bird Species and Communities Studies (page 1 of 2)

Site No., Meas. Pt.	Measurement Year			
	1983	1984	1985	1986
1C1-2	0.041	0.146	0.056	--
1C1-3	-	-	0.128	0.082
1C1-4	-	-	-	0.117
1C3-1	0.106	0.26	0.133	0.086
1C3-2	0.125	0.191	/	--
1C3-3	-	-	-	0.074
1C4-1	-	0.028, 0.030	0.045	0.065
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
1D3-1	-	-	-	0.052
1C6-1	-	0.072	0.095	0.088
1C6-3	-	-	0.123	0.109
1C6-4	-	-	0.038	0.007
1L1-1	-	-	-	/
1L1-2	-	-	-	25
1L1-3	-	-	-	10.7
1L1-4	-	-	-	3.9
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
1T1-15	-	-	-	0.040
1T1-16	-	-	-	0.115
1T1-17	-	-	-	0.118
1T1-18	-	-	-	0.100
1T1-19	-	-	-	0.112
1T1-20	-	-	-	0.118
1T1-21	-	-	-	0.082
1T1-22	-	-	-	0.050
1T1-23	-	-	-	0.037
1T1-24	-	-	-	0.042
1T1-25	-	-	-	0.033
1T1-26	-	-	-	0.022
1T1-27	-	-	-	0.014

TABLE A-6. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Bird Species and Communities Studies (page 2 of 2)

Site No., Meas. Pt.	Measurement Year			
	1983	1984	1985	1986
1T2-1	0.170	0.22	0.197	0.122
1T2-2	-	-	-	0.047
1T2-3	-	-	-	0.083
1T2-4	-	-	-	0.044
1D1-1	-	-	-	9.6
1T4-1	-	0.178, 0.184	0.150	--
1T4-3	-	-	0.22	--
1T4-4	-	-	0.131	--
1T4-5	-	-	-	0.052
1T4-6	-	-	-	0.104
1T4-7	-	-	-	0.102
1T4-8	-	-	-	0.082
1T4-9	-	-	-	0.088
1D2-1	-	-	-	0.47
1T5-1	-	0.24, 0.42	0.25	0.115
1T5-2	0.23	0.26	0.22	0.042
1T5-3	-	-	-	0.125
1T5-4	-	-	-	0.061
1T5-5	-	-	-	0.077
1T5-6	-	-	-	0.051
1T6-1	0.071	0.65-0.88	0.86, 0.88	0.23

- = site measurement point has not been established.

-- = site measurement point has been dropped.

/ = data not taken.

TABLE A-7. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies (page 1 of 2)

Site No., Meas. Pt.	Measurement Year			
	1983	1984	1985	1986
1C1-2	<0.001	0.001	0.001	--
1C1-3	-	-	0.001	0.001
1C1-4	-	-	-	0.001
1C3-1	<0.001	0.002	0.002	0.001
1C3-2	0.001	0.003	/	--
1C3-3	-	-	-	0.001
1C4-1	-	<0.001, 0.001	0.001	0.001
1C4-2	-	0.002	0.002	--
1C4-3	-	<0.001, 0.002	<0.001	0.001
1C4-4	-	-	0.003	0.002
1D3-1	-	-	-	0.003
1C6-1	-	0.003	0.003	0.002
1C6-3	-	-	0.003	0.003
1C6-4	-	-	0.003	0.003
1L1-1	-	-	-	9.13
1L1-2	-	-	-	0.179
1L1-3	-	-	-	0.080
1L1-4	-	-	-	0.114
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
1T1-15	-	-	-	0.004
1T1-16	-	-	-	0.009
1T1-17	-	-	-	0.007
1T1-18	-	-	-	0.006
1T1-19	-	-	-	0.001
1T1-20	-	-	-	0.008
1T1-21	-	-	-	0.055
1T1-22	-	-	-	0.012
1T1-23	-	-	-	0.008
1T1-24	-	-	-	0.005
1T1-25	-	-	-	0.005
1T1-26	-	-	-	0.003
1T1-27	-	-	-	0.002

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TABLE A-7. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies (page 2 of 2)

Site No., Meas. Pt.	Measurement Year			
	1983	1984	1985	1986
1T2-1	<0.001	0.001	0.001	0.077
1T2-2	-	-	-	0.009
1T2-3	-	-	-	0.006
1T2-4	-	-	-	0.006
1D1-1	-	-	-	0.109
1T4-1	-	0.001	0.001	--
1T4-3	-	-	0.001	--
1T4-4	-	-	0.001	--
1T4-5	-	-	-	0.021
1T4-6	-	-	-	0.019
1T4-7	-	-	-	0.011
1T4-8	-	-	-	0.006
1T4-9	-	-	-	0.004
1D2-1	-	-	-	0.004
1T5-1	-	0.001, 0.002	0.001	0.051
1T5-2	0.001	0.002	0.001	0.038
1T5-3	-	-	-	0.007
1T5-4	-	-	-	0.006
1T5-5	-	-	-	0.005
1T5-6	-	-	-	0.004
1T6-1	0.002	0.001	0.001	0.020

- = site measurement point not established.

-- = site measurement point has been dropped.

/ = data not taken.

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

Site No., Meas. Pt.	Antenna Current and Element			
	(4 Amps) NS (M)	(6 Amps) NEW (M)	(6 Amps) SEW (M)	(10 Amps) SEW (Ex)
1C1-3	-	-	-	--
1C1-4	-	-	-	--
1C3-1	-	-	-	--
1C3-3	-	-	-	--
1C4-1	-	-	-	--
1C4-3	-	-	-	--
1C4-4	-	-	-	--
1D3-1	-	-	-	--
1C6-1	-	-	-	--
1C6-3	-	-	-	--
1C6-4	-	-	-	--
1L1-1	/	/	/	/
1L1-2	/	/	/	/
1L1-3	/	/	/	/
1L1-4	/	/	/	/
1T1-14	-	-	-	--
1T1-15	-	-	-	--
1T1-16	-	-	-	--
1T1-17	0.002	-	-	--
1T1-18	0.001	-	-	--
1T1-19	0.002	-	-	--
1T1-20	0.002	-	-	--
1T1-21	1.08	-	-	--
1T1-22	0.002	-	-	--
1T1-23	-	-	-	--
1T1-24	-	-	-	--
1T1-25	-	-	-	--
1T1-26	-	-	-	--
1T1-27	-	-	-	--
1T2-1	0.33	-	-	--
1T2-2	0.003	-	-	--
1T2-3	0.002	-	-	--
1T2-4	-	-	-	--
1D1-1	-	-	-	--

TABLE A-8. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
 Small Mammals and Nesting Birds Studies
 Measured (M) and Extrapolated (Ex) Data (page 2 of 2)

Site No., Meas. Pt.	Antenna Current and Element			
	(4 Amps) NS (M)	(6 Amps) NEW (M)	SEW (M)	(10 Amps) SEW (Ex)
1T4-5	0.58	-	-	--
1T4-6	0.091	-	-	--
1T4-7	0.022	-	-	--
1T4-8	0.005	-	-	--
1T4-9	0.002	-	-	--
1D2-1	-	-	-	--
1T5-1	0.182	-	-	--
1T5-2	0.59	-	-	--
1T5-3	0.004	-	-	--
1T5-4	0.002	-	-	--
1T5-5	0.005	-	-	--
1T5-6	0.009	-	-	--
1T6-1	0.182	-	-	--

- = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

/ = data not taken.

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

Site No., Meas. Pt.	Antenna Current and Element			
	(4 Amps)	(6 Amps)		(10 Amps)
	NS (M)	NEW (M)	SEW (M)	SEW (Ex)
1C1-3	0.021	0.003	0.010	0.017
1C1-4	/	/	/	/
1C3-1	/	/	/	/
1C3-3	0.022	0.004	0.012	0.020
1C4-1	/	/	/	/
1C4-3	/	/	/	/
1C4-4	<0.001	<0.001	<0.001	--
1D3-1	0.008	0.004	0.005	0.008
1C6-1	/	/	/	/
1C6-3	0.001	<0.001	0.001	0.002
1C6-4	/	/	/	/
1L1-1	/	/	/	/
1L1-2	/	/	/	/
1L1-3	/	/	/	/
1L1-4	/	/	/	/
1T1-14	0.86	0.026	0.021	0.035
1T1-15	0.43	0.013	0.015	0.025
1T1-16	1.11	0.035	0.035	0.058
1T1-17	1.55	0.049	0.053	0.088
1T1-18	1.44	0.042	0.050	0.083
1T1-19	1.54	0.050	0.053	0.088
1T1-20	1.45	0.046	0.043	0.072
1T1-21	1.45	0.044	0.009	0.015
1T1-22	1.50	0.042	0.009	0.015
1T1-23	0.96	0.030	0.003	0.005
1T1-24	1.15	0.036	0.010	0.017
1T1-25	0.87	0.027	0.062	0.103
1T1-26	0.56	0.017	0.004	0.007
1T1-27	0.38	0.012	0.004	0.007
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
1D1-1	0.042	0.28	0.066	0.110

TABLE A-9. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
 Small Mammals and Nesting Birds Studies
 Measured (M) and Extrapolated (Ex) Data (page 2 of 2)

Site No., Meas. Pt.	Antenna Current and Element			
	(4 Amps) NS (M)	(6 Amps) NEW (M)	SEW (M)	(10 Amps) SEW (Ex)
1T4-5	2.1	0.062	0.054	0.090
1T4-6	2.5	0.076	0.103	0.172
1T4-7	2.2	0.067	0.092	0.153
1T4-8	1.91	0.061	0.123	0.21
1T4-9	2.1	0.062	0.126	0.21
1D2-1	0.094	0.44	0.113	0.188
1T5-1	2.6	0.079	0.074	0.123
1T5-2	1.97	0.064	0.108	0.180
1T5-3	3.4	0.099	0.077	0.128
1T5-4	1.39	0.042	0.061	0.102
1T5-5	1.31	0.051	0.101	0.168
1T5-6	1.08	0.037	0.070	0.117
1T6-1	5.4	0.159	0.086	0.143

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

/ = data not taken.

TABLE A-10. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
Measured (M) and Extrapolated (Ex) Data (page 1 of 2)

Site No., Meas. Pt.	Antenna Current and Element			
	(4 Amps) NS (M)	(6 Amps) NEW (M)	SEW (M)	(10 Amps) SEW (Ex)
1C1-3	<0.001	<0.001	<0.001	--
1C1-4	/	/	/	/
1C3-1	/	/	/	/
1C3-3	<0.001	<0.001	<0.001	--
1C4-1	/	/	/	/
1C4-3	/	/	/	/
1C4-4	<0.001	<0.001	<0.001	--
1D3-1	<0.001	<0.001	<0.001	--
1C6-1	/	/	/	/
1C6-3	<0.001	<0.001	<0.001	--
1C6-4	/	/	/	/
1L1-1	/	/	/	/
1L1-2	/	/	/	/
1L1-3	/	/	/	/
1L1-4	/	/	/	/
1T1-14	0.032	0.001	0.001	0.002
1T1-15	0.027	0.001	0.001	0.002
1T1-16	0.069	0.002	0.001	0.002
1T1-17	0.076	0.003	0.001	0.002
1T1-18	0.071	0.002	0.001	0.002
1T1-19	0.081	0.003	0.001	0.002
1T1-20	0.089	0.003	0.001	0.002
1T1-21	0.78	0.024	0.004	0.007
1T1-22	0.31	0.010	0.002	0.003
1T1-23	0.169	0.005	0.001	0.002
1T1-24	0.113	0.004	0.001	0.002
1T1-25	0.084	0.003	0.007	0.012
1T1-26	0.055	0.002	0.001	0.002
1T1-27	0.040	0.012	0.001	0.002
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
1D1-1	<0.001	0.003	0.001	0.002

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TABLE A-10. 76 Hz MAGNETIC FLUX DENSITIES (mG)
 Small Mammals and Nesting Birds Studies
 Measured (M) and Extrapolated (Ex) Data (page 2 of 2)

Site No., Meas. Pt.	Antenna Current and Element			
	(4 Amps) NS (M)	(6 Amps) NEW (M)	SEW (M)	(10 Amps) SEW (Ex)
1T4-5	0.70	0.022	0.004	0.007
1T4-6	0.32	0.010	0.002	0.003
1T4-7	0.171	0.005	0.001	0.002
1T4-8	0.116	0.003	0.001	0.002
1T4-9	0.085	0.003	0.001	0.002
1D2-1	<0.001	0.003	0.001	0.002
1T5-1	0.89	0.029	0.005	0.008
1T5-2	0.77	0.024	0.004	0.007
1T5-3	0.20	0.006	0.001	0.002
1T5-4	0.124	0.004	0.001	0.002
1T5-5	0.131	0.004	0.001	0.002
1T5-6	0.125	0.004	<0.001	--
1T6-1	0.40	0.013	0.002	0.003

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

/ = data not taken.

-- = site measurement point has been dropped.

TABLE A-11. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Bird Species and Communities Studies (page 1 of 2)

Site No., Meas. Pt.	Data Extrapolated to 150 Amperes				Pre-Antenna Estimates
	NS	NEW	SEW	NS+NEW+SEW	
1C1-3	--	--	--	--	<0.001
1C1-4	--	--	--	--	<0.001
1C3-1	--	--	--	--	<0.001
1C3-3	--	--	--	--	<0.001
1C4-1	--	--	--	--	<0.001
1C4-3	--	--	--	--	<0.001
1C4-4	--	--	--	--	<0.001
1D3-1	--	--	--	--	*
1C6-1	--	--	--	--	<0.001
1C6-3	--	--	--	--	<0.001
1C6-4	--	--	--	--	<0.001
1L1-1	/	/	/	/	*
1L1-2	/	/	/	/	*
1L1-3	/	/	/	/	*
1L1-4	/	/	/	/	*
1T1-14	--	--	--	--	0.100 - 150
1T1-15	--	--	--	--	0.100 - 150
1T1-16	--	--	--	--	0.100 - 150
1T1-17	0.075	--	--	0.075	0.50 - 1.00
1T1-18	0.038	--	--	0.038	0.50 - 1.00
1T1-19	0.075	--	--	0.075	0.50 - 1.00
1T1-20	0.075	--	--	0.075	0.50 - 1.00
1T1-21	41	--	--	41	0.100 - 150
1T1-22	0.075	--	--	0.075	0.100 - 150
1T1-23	--	--	--	--	0.100 - 150
1T1-24	--	--	--	--	0.100 - 150
1T1-25	--	--	--	--	0.100 - 150
1T1-26	--	--	--	--	0.100 - 150
1T1-27	--	--	--	--	0.100 - 150
1T2-1	12.4	--	--	12.4	0.100 - 150
1T2-2	0.113	--	--	0.113	0.100 - 150
1T2-3	0.075	--	--	0.075	0.100 - 150
1T2-4	--	--	--	--	0.100 - 150
1D1-1	--	--	--	--	*

TABLE A-11. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Bird Species and Communities Studies (page 2 of 2)

Site No., Meas. Pt.	Data Extrapolated to 150 Amperes				Pre-Antenna Estimates
	NS	NEW	SEW	NS+NEW+SEW	
1T4-5	22	--	--	22	0.100 - 150
1T4-6	3.4	--	--	3.4	0.100 - 150
1T4-7	0.83	--	--	0.83	0.100 - 150
1T4-8	0.188	--	--	0.188	0.100 - 150
1T4-9	0.075	--	--	0.075	0.100 - 150
1D2-1	--	--	--	--	*
1T5-1	6.8	--	--	6.8	0.100 - 150
1T5-2	22	--	--	22	0.100 - 150
1T5-3	0.150	--	--	0.150	0.100 - 150
1T5-4	0.075	--	--	0.075	0.100 - 150
1T5-5	0.188	--	--	0.188	0.100 - 150
1T5-6	0.34	--	--	0.34	0.100 - 150
1T6-1	6.8	--	--	6.8	0.100 - 150

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

/ = data not taken.

* = measurement point established after antenna construction.

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ELF (EXTREMELY LOW FREQUENCY) COMMUNICATIONS SYSTEM
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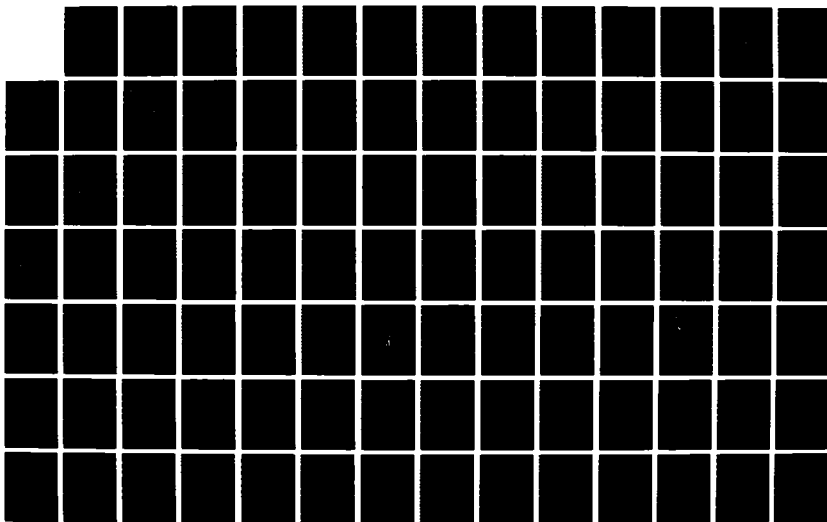
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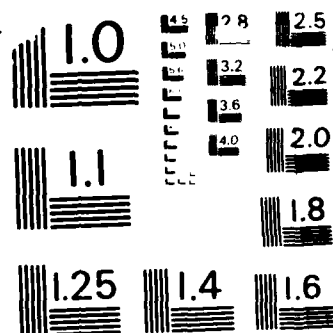
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NATIONAL BUREAU OF STANDARDS - 1963-A

TABLE A-12. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (V/m)
Bird Species and Communities Studies (page 1 of 2)

Site No., Meas. Pt.	Data Extrapolated to 150 Amperes				Pre-Antenna Estimates
	NS	NEW	SEW	NS+NEW+SEW	
1C1-3	0.79	0.075	0.25	1.12	1.50
1C1-4	/	/	/	/	1.50
1C3-1	/	/	/	/	<1.00
1C3-3	0.83	0.100	0.30	1.23	
1C4-1	/	/	/	/	<1.00
1C4-3	/	/	/	/	<1.00
1C4-4	--	--	--	--	<1.00
1D3-1	0.30	0.100	0.125	0.53	*
1C6-1	/	/	/	/	<1.00
1C6-3	0.038	--	0.025	0.063	<1.00
1C6-4	/	/	/	/	<1.00
1L1-1	/	/	/	/	*
1L1-2	/	/	/	/	*
1L1-3	/	/	/	/	*
1L1-4	/	/	/	/	*
1T1-14	32	0.65	0.53	33	55 - 80
1T1-15	16.1	0.33	0.38	16.8	55 - 80
1T1-16	42	0.88	0.88	44	55 - 80
1T1-17	58	1.23	1.33	61	55 - 80
1T1-18	54	1.05	1.25	56	55 - 80
1T1-19	58	1.25	1.33	61	55 - 80
1T1-20	54	1.15	1.08	56	55 - 80
1T1-21	54	1.10	0.23	55	55 - 80
1T1-22	56	1.05	0.23	57	55 - 80
1T1-23	36	0.75	0.075	37	55 - 80
1T1-24	43	0.90	0.25	44	55 - 80
1T1-25	33	0.68	1.55	35	55 - 80
1T1-26	21	0.43	0.100	22	55 - 80
1T1-27	14.3	0.30	0.100	14.7	55 - 80
1T2-1	96	2.1	5.0	103	55 - 80
1T2-2	48	1.13	3.6	53	55 - 80
1T2-3	72	1.83	6.8	81	55 - 80
1T2-4	39	1.08	3.9	44	55 - 80
1D1-1	1.58	7.0	1.65	10.2	55 - 80

TABLE A-12. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (V/m)
Bird Species and Communities Studies (page 2 of 2)

Site No., Meas. Pt.	Data Extrapolated to 150 Amperes				Pre-Antenna Estimates
	NS	NEW	SEW	NS+NEW+SEW	
1T4-5	79	1.55	1.35	82	55 - 80
1T4-6	94	1.90	2.6	99	55 - 80
1T4-7	83	1.68	2.3	87	55 - 80
1T4-8	72	1.53	3.1	77	55 - 80
1T4-9	79	1.55	3.2	84	55 - 80
1D2-1	3.5	11.0	2.8	17.3	55 - 80
1T5-1	98	1.98	1.85	102	55 - 80
1T5-2	74	1.60	2.7	78	55 - 80
1T5-3	128	2.5	1.93	132	55 - 80
1T5-4	52	1.05	1.53	55	55 - 80
1T5-5	49	1.28	2.5	53	55 - 80
1T5-6	41	0.93	1.75	44	55 - 80
1T6-1	200	4.0	2.2	210	55 - 80

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

/ = data not taken.

* = measurement point established after antenna construction.

TABLE A-13. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies (page 1 of 2)

Site No., Meas. Pt.	Data Extrapolated to 150 Amperes				Pre-Antenna Estimates
	NS	NEW	SEW	NS+NEW+SEW	
1C1-3	--	--	--	--	0.015
1C1-4	/	/	/	/	0.015
1C3-1	/	/	/	/	0.015
1C3-3	--	--	--	--	0.015
1C4-1	/	/	/	/	0.015
1C4-3	/	/	/	/	0.015
1C4-4	--	--	--	--	0.015
1D3-1	--	--	--	--	*
1C6-1	/	/	/	/	0.010
1C6-3	--	--	--	--	0.010
1C6-4	/	/	/	/	0.010
1L1-1	/	/	/	/	*
1L1-2	/	/	/	/	*
1L1-3	/	/	/	/	*
1L1-4	/	/	/	/	*
1T1-14	1.20	0.025	0.025	1.25	1.50 - 30
1T1-15	1.01	0.025	0.025	1.06	1.50 - 30
1T1-16	2.6	0.050	0.025	2.7	1.50 - 30
1T1-17	2.9	0.075	0.025	3.0	1.50 - 30
1T1-18	2.7	0.050	0.025	2.8	1.50 - 30
1T1-19	3.0	0.075	0.025	3.1	1.50 - 30
1T1-20	3.3	0.075	0.025	3.4	1.50 - 30
1T1-21	29	0.60	0.100	30	1.50 - 30
1T1-22	11.6	0.25	0.050	11.9	1.50 - 30
1T1-23	6.3	0.125	0.025	6.5	1.50 - 30
1T1-24	4.2	0.100	0.025	4.3	1.50 - 30
1T1-25	3.2	0.075	0.175	3.5	1.50 - 30
1T1-26	2.1	0.050	0.025	2.2	1.50 - 30
1T1-27	1.50	0.30	0.025	1.83	1.50 - 30
1T2-1	36	0.73	0.150	37	1.50 - 30
1T2-2	3.9	--	--	3.9	1.50 - 30
1T2-3	2.8	0.050	0.025	2.9	1.50 - 30
1T2-4	2.7	0.050	0.025	2.8	1.50 - 30
1D1-1	--	0.075	0.025	0.100	*

TABLE A-13. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies (page 2 of 2)

Site No., Meas. Pt.	Data Extrapolated to 150 Amperes				Pre-Antenna Estimates
	NS	NEW	SEW	NS+NEW+SEW	
1T4-5	26	0.55	0.100	27	1.50 - 30
1T4-6	12.0	0.25	0.050	12.3	1.50 - 30
1T4-7	6.4	0.125	0.025	6.6	1.50 - 30
1T4-8	4.4	0.075	0.025	4.5	1.50 - 30
1T4-9	3.2	0.075	0.025	3.3	1.50 - 30
1D2-1	--	0.075	0.025	0.100	*
1T5-1	33	0.73	0.125	34	1.50 - 30
1T5-2	29	0.60	0.100	30	1.50 - 30
1T5-3	7.5	0.150	0.025	7.7	1.50 - 30
1T5-4	4.7	0.100	0.025	4.8	1.50 - 30
1T5-5	4.9	0.100	0.025	5.0	1.50 - 30
1T5-6	4.7	0.100	--	4.8	1.50 - 30
1T6-1	15.0	0.33	0.050	15.4	1.50 - 30

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

/ = data not taken.

* = measurement point established after antenna construction.

Site 1L1 is new in 1986. This is the site consisting of a laboratory and holding facilities for all mammals (test and control) under investigation in this study. It was found that the 60 Hz EM fields were dramatically higher (> 200x in several cases) at this site than at the test and control sites. The reason for these high 60 Hz fields is the grid of power lines that feed the neighborhood homes and encompass the laboratory and holding facilities. It is recommended that a new holding facility with lower ambient fields be located for this study.

Other new measurement sites (1D1, 1D2, and 1D3) are the release points for studies of displaced birds. Although EM measurements have been taken at these sites, the values have not been used in ratio calculations comparing test and control sites. The birds are at the release points for only short periods of time, and it is unclear how the release point relates to other points along the flight path. It is more useful to have the EM field gradients along the flight path to compare the test and control experiments.

Measurements of the EM field gradient at ground level along the flight path would be overly cumbersome and would not directly indicate the EM exposure at the height of flight. As an alternative, the EM field environment can be estimated using Figures A-18 and A-19. 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-18) and 60 Hz power distribution lines (Figure A-19). The 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 fields produced by the transmission lines can be considerably higher, depending on operating conditions. The 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.

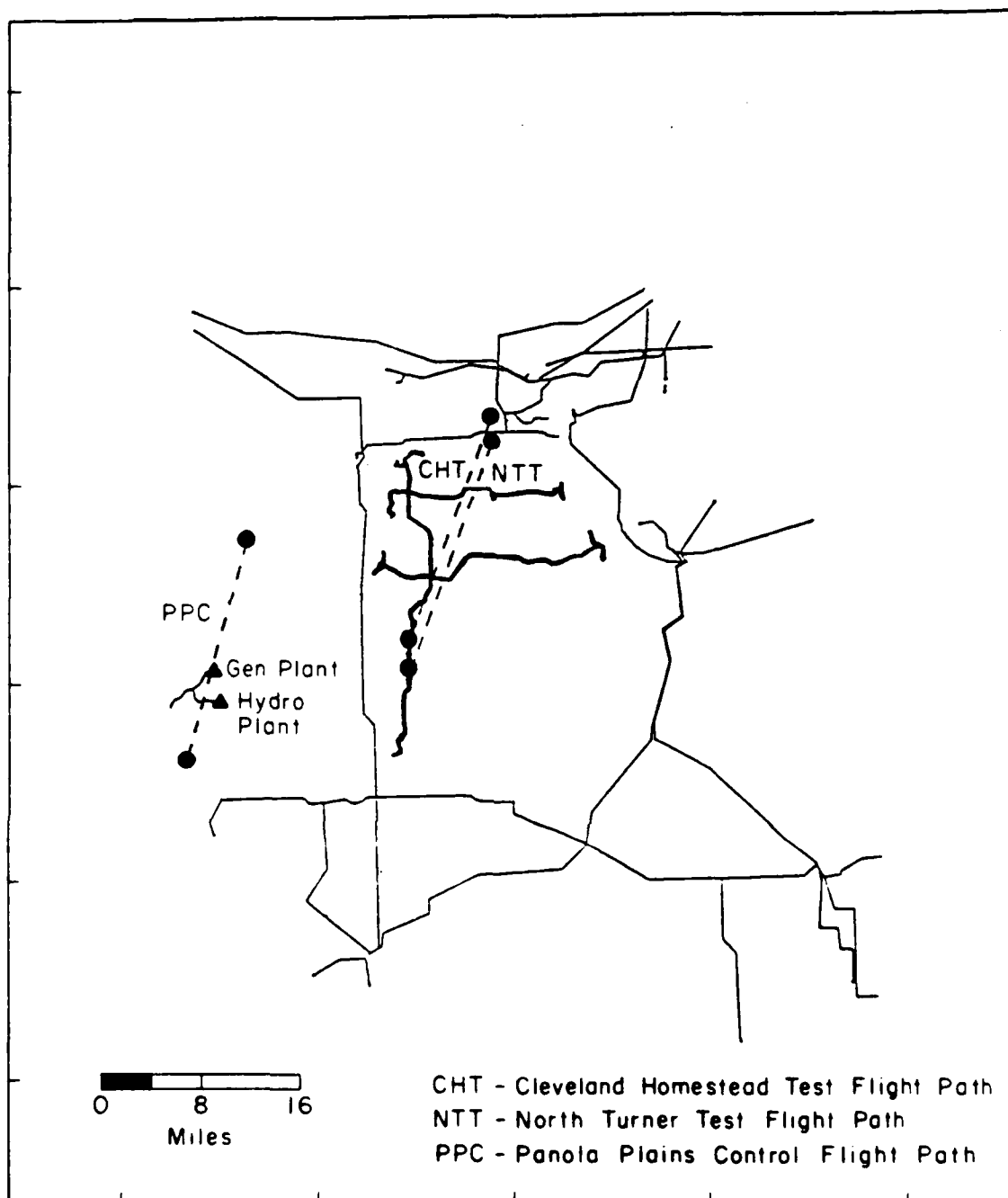


FIGURE A-18. BIRD DISPLACEMENT FLIGHT PATH LOCATIONS RELATIVE TO HIGH VOLTAGE 60 Hz TRANSMISSION LINES.

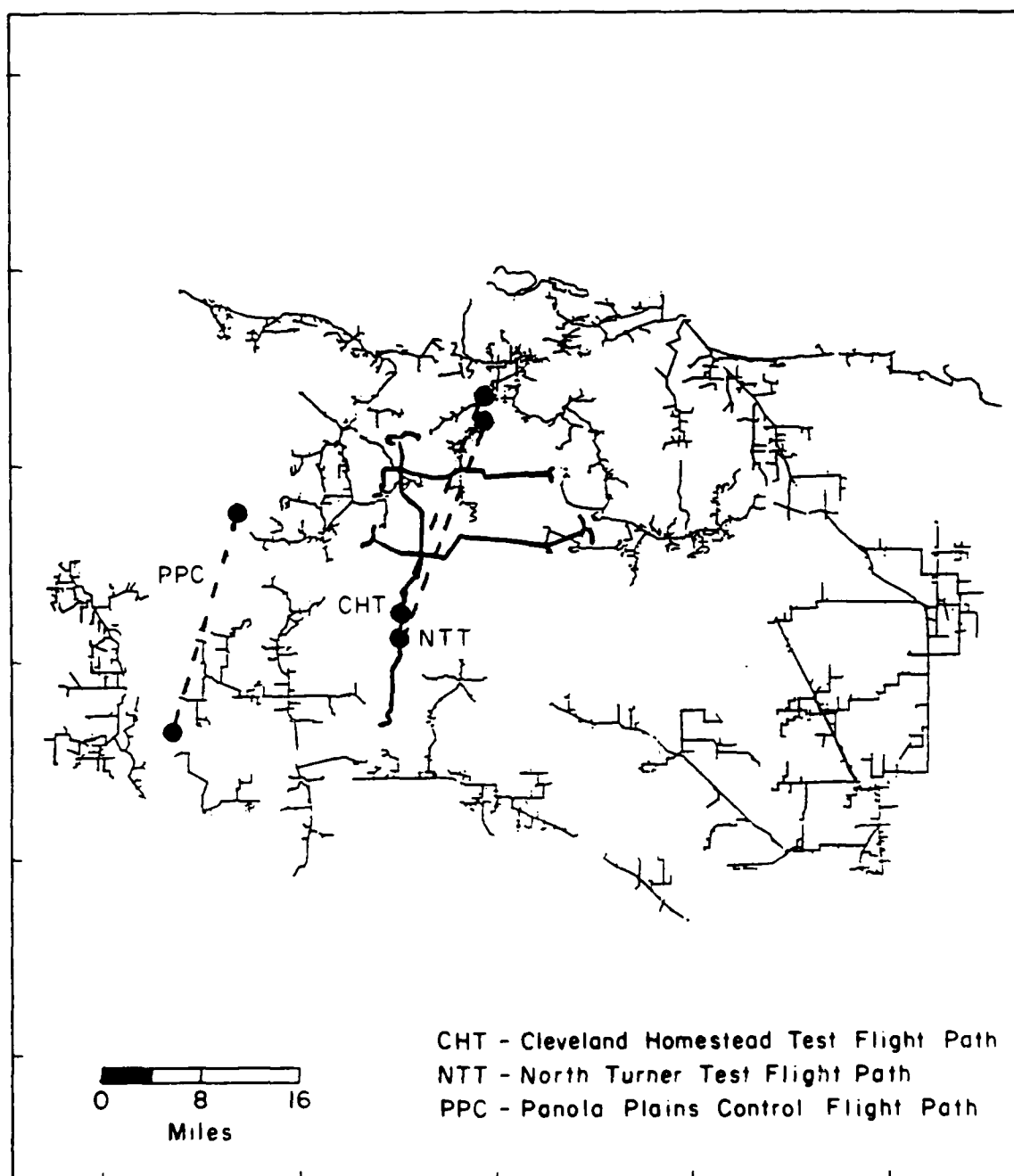


FIGURE A-19. BIRD DISPLACEMENT FLIGHT PATH LOCATIONS
 RELATIVE TO 60 Hz POWER DISTRIBUTION LINES.

APPENDIX B
NATIVE BEES STUDIES

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NATIVE BEES STUDIES

On 6, 8, 13, and 16 October 1986, IITRI field crews made ELF electro-magnetic (EM) field measurements at 13 measurement points at a total of two test and two control sites for the native bees studies. The test and control sites measured in 1986 were the same as those measured in 1985. The Michigan Transmitting Facility (MTF) was operational for the first time in 1986. Therefore, 76 Hz EM field measurements were possible for the first time, and measurement points were added within sites to better define the spatial variations of the 76 Hz EM fields at the sites.

The positions of the four 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. Details of measurement locations within sites are given in Figures B-2 through B-5. Table B-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites.

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. Table B-2 shows the test/control site pairings of interest to the investigator and the site pair status.

The field ratios for the site pairs given in Table B-2 were recalculated using the measured values of the 76 Hz fields extrapolated to a 150 ampere antenna current; Table B-3 shows the results. All of the ratio criteria were met except for the R4 ratio (T(60)/C(60) for the longitudinal electric field and magnetic flux densities at some site pairs. The R4 magnetic flux density ratio did not meet criteria at three site pairs (2T1/2C4, 2T1/2C5, and 2T2/2C5). This was the result, in each case, of nearby 60 Hz signals coupled by the antenna wire. The R4 longitudinal electric field ratio did not meet criteria at one site pair (2T1/2C5). This was the result of a reduced 60 Hz longitudinal electric field at the test site (2T1). A reduction in the 60 Hz longitudinal electric field was generally observed at all test sites after the

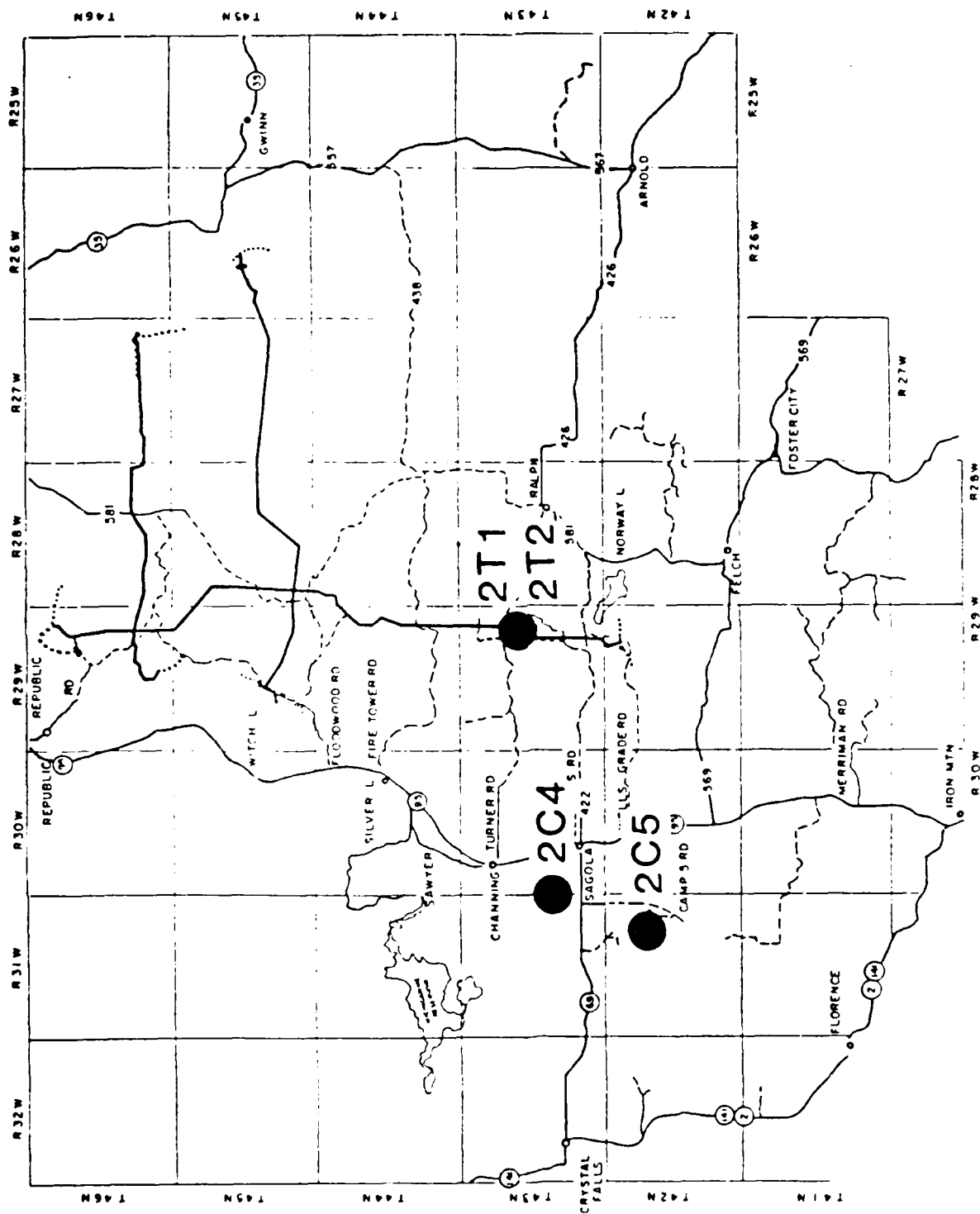
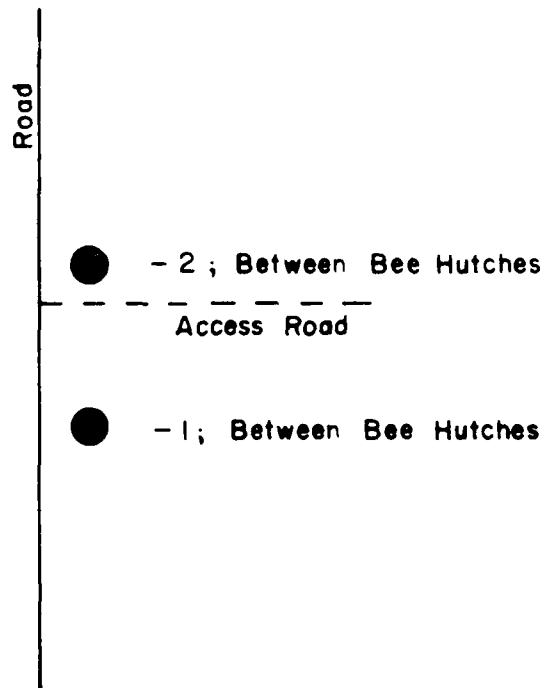


FIGURE B-1. POSITIONS OF NATIVE BEES STUDY SITES RELATIVE TO MICHIGAN TRANSMITTING FACILITY ANTENNA ELEMENTS.



Not To Scale

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

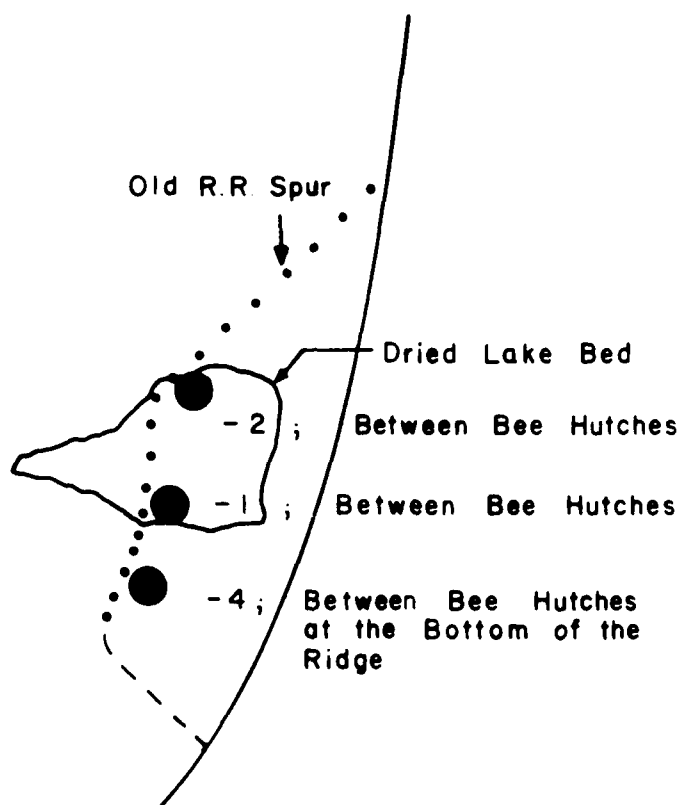


FIGURE B-3. MEASUREMENT POINTS AT CAMP 5 (C5);
2C5-1, 2, 4.

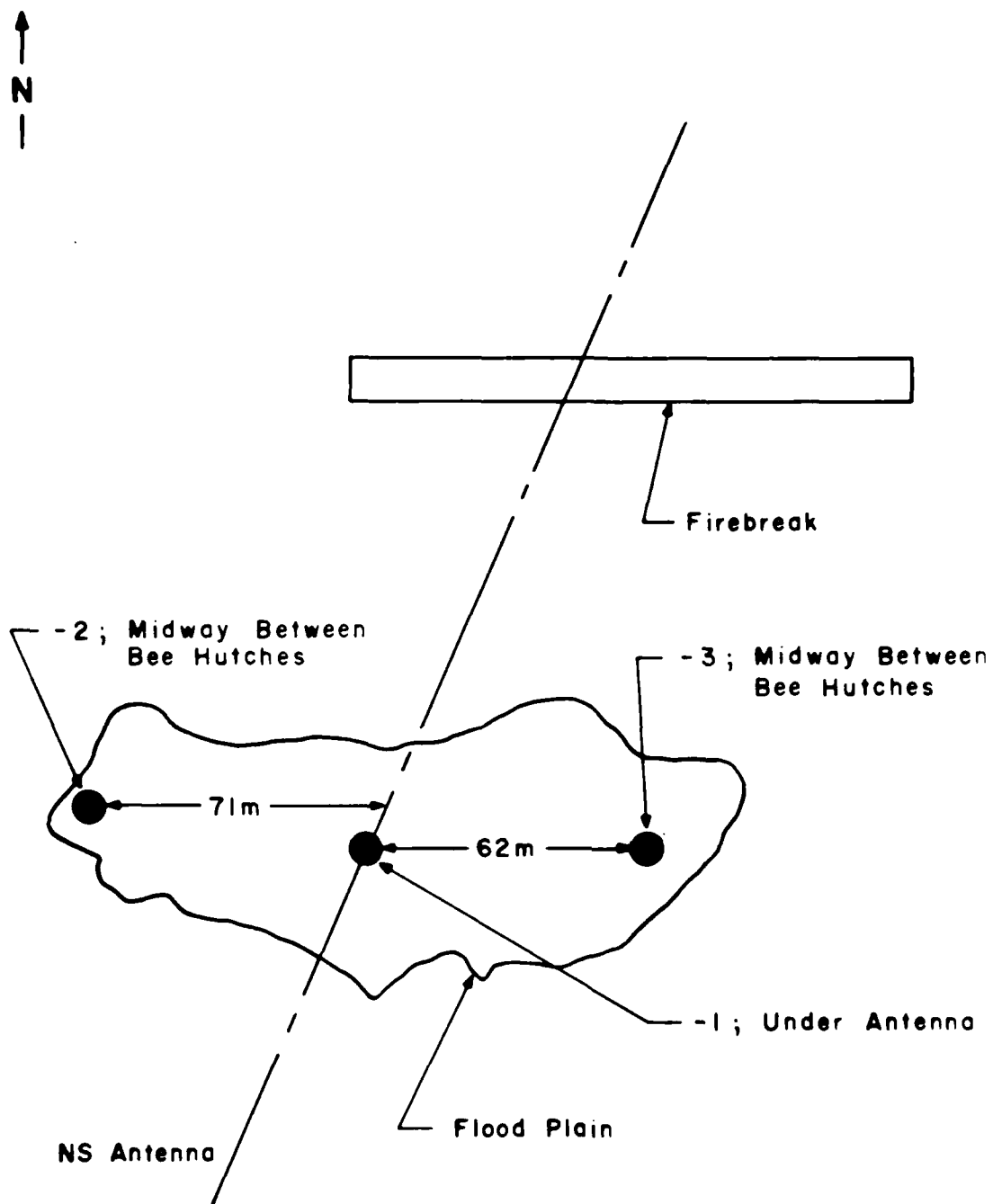


FIGURE B-4. MEASUREMENT POINTS AT FORD I (FI);
2TI - 1, 2, 3.

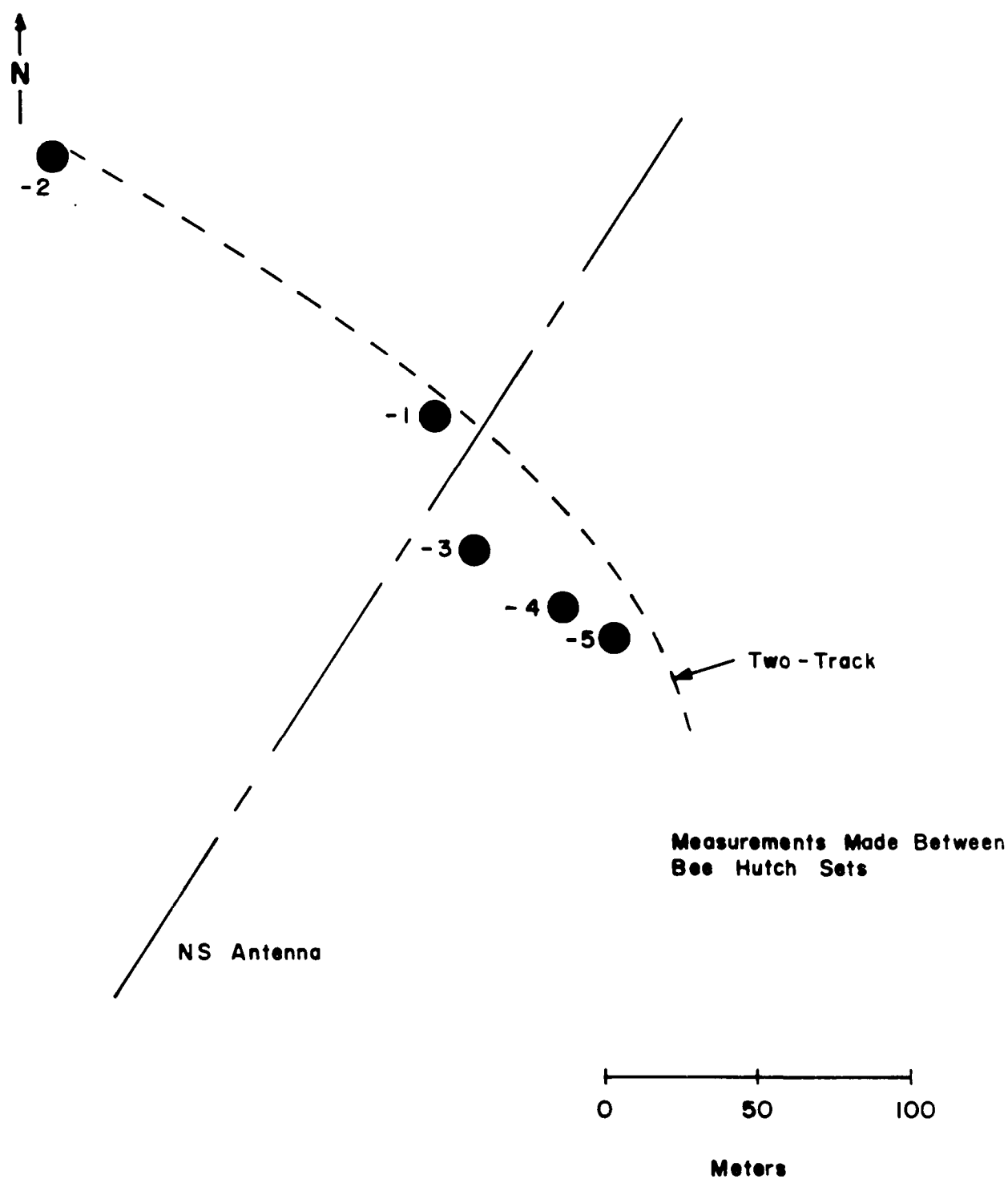


FIGURE B-5. MEASUREMENT POINTS AT FORD 2 (F2) ;
2T2-1 THROUGH 5.

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

TABLE B-2. SITE PAIRINGS AND STATUS
Native Bees Studies

Test Site	Control Site	EM Status
2T1	2C4	CA
2T1	2C5	CA
2T2	2C4	A
2T2	2C5	CA

A = Acceptable
CA = Conditionally Acceptable
U = Unacceptable

TABLE B-3. FIELD INTENSITY RATIOS
Native Bees Studies

Compared Sites	Transverse E-Field				Longitudinal E-Field (Earth)				Magnetic Flux Density			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
2T1/2C4	188	188	188	1.00	350	690	210	0.20 - 0.58	96	790	1600	1.33 - 12.7
2T1/2C5	188	188	188	1.00	80	690	90	0.086 - 0.86	1600	790	2400	2.0 - 38
2T2/2C4	188	188	188	1.00	510	700	300	0.37 - 1.73	48	770	800	1.00 - 6.7
2T2/2C5	188	188	188	1.00	116	700	131	0.159 - 2.6	800	770	1200	1.50 - 20

installation of the antenna. All other criteria were met, and all of the test/control site pairs for the native bees studies fell into either the acceptable or conditionally acceptable categories, as shown in Table B-2.

EM field measurements for 1986 and previous years are found in Tables B-4 through B-12. Tables B-4, B-5, and B-6 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables B-7, B-8, and B-9 present 76 Hz data for these three fields at 1986 MTF operating currents. Tables B-10, B-11, and B-12 present 76 Hz data extrapolated to a full power condition of 150 amperes as well as pre-operation estimates for comparison. (See Section 3.5.2.)

While several measurement points were added at the sites in 1986 to better define the spatial variations of the 76 Hz fields, all 1985 measurement points were retained. The 1986 60 Hz EM fields can be compared with values from previous years. The presence of the ELF antenna caused the 60 Hz magnetic flux densities to increase by up to an order of magnitude in 1986, while the longitudinal electric field densities decreased by less than an order of magnitude at the test sites. The 60 Hz magnetic flux densities and the transverse and longitudinal electric fields at the control sites remained consistent with data taken in previous years. The 76 Hz EM field measurements in 1986 compared well with the pre-antenna operation estimates. At test sites 2T2-1, 3, and 5 the measured longitudinal electric fields were 1.5X to 2.5X higher than predicted, and probably indicate localized variations in soil conductivity.

**TABLE B-4. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Native Bees Studies**

Site No., Meas. Pt.	Measurement Year			
	1983	1984	1985	1986
2C4-1	<0.001	<0.001	-	-
2C4-2	-	-	-	-
2C5-1	-	<0.001	-	-
2C5-2	-	<0.001	-	-
2C5-4	-	-	-	-
2T1-1	0.004	<0.001	-	-
2T1-2	-	-	-	-
2T1-3	-	-	-	-
2T2-1	<0.001	<0.001, 0.001	-	-
2T2-2	-	-	-	-
2T2-3	-	-	-	-
2T2-4	-	-	-	-
2T2-5	-	-	-	-

- = site measurement point not established.

- = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.

**TABLE B-5. 60 Hz. LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Native Bees Studies**

Site No., Meas. Pt.	Measurement Year			
	1983	1984	1985	1986
2C4-1	0.011	0.102, 0.138, 0.160	0.104	0.133
2C4-2	-	-	0.21	0.21
2C5-1	-	0.64, 0.50, 0.93	0.69	0.49
2C5-2	-	0.23	0.40	0.160
2C5-4	-	-	0.148	0.090
2T1-1	0.23	0.26	0.22	0.042
2T1-2	-	-	-	0.051
2T1-3	-	-	-	0.077
2T2-1	0.071	0.65, 0.88	0.86, 0.88	0.23
2T2-2	-	-	-	0.092
2T2-3	-	-	-	0.123
2T2-4	-	-	-	0.078
2T2-5	-	-	-	0.120

- = site measurement point not established.

**TABLE B-6. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Native Bees Studies**

Site No., Meas. Pt.	Measurement Year			
	1983	1984	1985	1986
2C4-1	0.004	0.003, 0.004	0.003	0.003
2C4-2	-	-	0.003	0.003
2C5-1	-	0.001, 0.002	0.002	0.001
2C5-2	-	<0.001	0.002	0.001
2C5-4	-	-	0.002	0.002
2T1-1	0.001	0.002	0.001	0.038
2T1-2	-	-	-	0.004
2T1-3	-	-	-	0.005
2T2-1	0.002	0.001	0.001	0.020
2T2-2	-	-	-	0.003
2T2-3	-	-	-	0.015
2T2-4	-	-	-	0.006
2T2-5	-	-	-	0.005

- = site measurement point not established.

**TABLE B-7. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Native Bees Studies
Measured (M) and Extrapolated (Ex) Data**

Site No., Meas. Pt.	Antenna Current and Element			
	(4 Amps)	(6 Amps)		(10 Amps)
	NS (M)	NEW (M)	SEW (M)	SEW (Ex)
2C4-1	-	-	-	--
2C4-2	-	-	-	--
2C5-1	-	-	-	--
2C5-2	-	-	-	--
2C5-4	-	-	-	--
2T1-1	0.59	-	-	--
2T1-2	0.009	-	-	--
2T1-3	0.005	-	-	--
2T2-1	0.182	-	-	--
2T2-2	0.005	-	-	--
2T2-3	0.123	-	-	--
2T2-4	0.021	-	-	--
2T2-5	0.012	-	-	--

- = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

TABLE B-8. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Native Bees Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	Antenna Current and Element			
	(4 Amps) NS (M)	(6 Amps) NEW (M)	SEW (M)	(10 Amps) SEW (Ex)
2C4-1	/	/	/	/
2C4-2	0.002	0.001	0.001	0.002
2C5-1	0.008	0.004	0.006	0.010
2C5-2	/	/	/	/
2C5-4	/	/	/	/
2T1-1	1.97	0.064	0.108	0.180
2T1-2	1.08	0.037	0.070	0.117
2T1-3	1.31	0.051	0.101	0.168
2T2-1	5.4	0.159	0.086	0.143
2T2-2	1.63	0.054	0.067	0.112
2T2-3	3.0	0.087	0.063	0.105
2T2-4	1.93	0.053	0.071	0.118
2T2-5	3.6	0.101	0.096	0.160

/ = data not taken.

TABLE B-9. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Native Bees Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	Antenna Current and Element			
	(4 Amps) NS (M)	(6 Amps) NEW (M)	SEW (M)	(10 Amps) SEW (Ex)
2C4-1	/	/	/	/
2C4-2	<0.001	<0.001	<0.001	--
2C5-1	<0.001	<0.001	<0.001	--
2C5-2	/	/	/	/
2C5-4	/	/	/	/
2T1-1	0.77	0.024	0.004	0.007
2T1-2	0.125	0.004	<0.001	--
2T1-3	0.131	0.004	0.001	0.002
2T2-1	0.40	0.013	0.002	0.003
2T2-2	0.06	0.002	<0.001	--
2T2-3	0.35	0.011	0.002	0.003
2T2-4	0.158	0.005	0.001	0.002
2T2-5	0.124	0.004	0.001	0.002

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

/ = data not taken.

TABLE B-10. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Native Bees Studies

Site No., Meas. Pt.	Data Extrapolated to 150 Amperes				Pre-Antenna Estimates
	NS	NEW	SEW	NS+NEW+SEW	
2C4-1	--	--	--	--	<0.001
2C4-2	--	--	--	--	<0.001
2C5-1	--	--	--	--	<0.001
2C5-2	--	--	--	--	<0.001
2C5-4	--	--	--	--	<0.001
2T1-1	22	--	--	22	0.1 - 150
2T1-2	0.34	--	--	0.34	0.1 - 150
2T1-3	0.188	--	--	0.188	0.1 - 150
2T2-1	6.8	--	--	6.8	0.1 - 150
2T2-2	0.188	--	--	0.188	0.1 - 150
2T2-3	4.6	--	--	4.6	0.1 - 150
2T2-4	0.79	--	--	0.79	0.1 - 150
2T2-5	0.45	--	--	0.45	0.1 - 150

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

TABLE B-11. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Native Bees Studies

Site No., Meas. Pt.	Data Extrapolated to 150 Amperes				Pre-Antenna Estimates
	NS	NEW	SEW	NS+NEW+SEW	
2C4-1	/	/	/	/	1.00
2C4-2	0.075	0.025	0.025	0.125	1.00
2C5-1	0.30	0.100	0.150	0.55	1.00
2C5-2	/	/	/	/	1.00
2C5-4	/	/	/	/	1.00
2T1-1	74	1.60	2.7	78	55 - 80
2T1-2	41	0.93	1.75	44	55 - 80
2T1-3	49	1.28	2.5	53	55 - 80
2T2-1	200	4.0	2.2	210	45 - 80
2T2-2	61	1.35	1.68	64	45 - 80
2T2-3	113	2.2	1.58	117	45 - 80
2T2-4	72	1.33	1.78	75	45 - 80
2T2-5	135	2.5	2.4	140	45 - 80

/ = data not taken.

TABLE B-12. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Native Bees Studies

Site No., Meas. Pt.	Data Extrapolated to 150 Amperes				Pre-Antenna Estimates
	NS	NEW	SEW	NS+NEW+SEW	
2C4-1	/	/	/	/	<0.050
2C4-2	--	--	--	--	<0.050
2C5-1	--	--	--	--	0.003
2C5-2	/	/	/	/	0.003
2C5-4	/	/	/	/	0.003
2T1-1	29	0.60	0.100	30	1.5 - 30
2T1-2	4.7	0.100	--	4.8	1.5 - 30
2T1-3	4.9	0.100	0.025	5.0	1.5 - 30
2T2-1	15.0	0.33	0.050	15.4	1.5 - 30
2T2-2	2.3	0.050	--	2.4	1.5 - 30
2T2-3	13.1	0.28	0.050	13.4	1.5 - 30
2T2-4	5.9	0.125	0.025	6.1	1.5 - 30
2T2-5	4.7	0.100	0.025	4.8	1.5 - 30

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

/ = data not taken.

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APPENDIX C
SOIL ARTHROPODS AND EARTHWORMS STUDIES

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SOIL ARTHROPODS AND EARTHWORMS STUDIES

On 2 and 7 October 1986, IITRI field crews made ELF electromagnetic (EM) field measurements at eight measurement points at one test and one control site for the soil arthropods and earthworms studies. The test and control sites measured in 1986 are the same as those measured in 1985. The Michigan Transmitting Facility (MTF) was operational for the first time in 1986. Therefore, 76 Hz field measurements were possible for the first time, and measurement points were added within sites to better define the spatial variations of the 76 Hz EM fields at the sites.

The position 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. Details of measurement locations within sites are shown in Figures C-2 and C-3. Table C-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites.

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. Table C-2 shows the test/control site pairing (only one possible) of interest to the investigator and the site pair status.

The field ratios for the site pair given in Table C-2 were recalculated using the measured values of the 76 Hz fields extrapolated to a 150 ampere antenna current; Table C-3 shows the results. All of the criteria were met, and the test/control site pair fell into the acceptable category.

Electromagnetic field measurements for 1986 and previous years are found in Tables C-4 through C-12. Tables C-4, C-5, and C-6 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables C-7, C-8, and C-9 present 76 Hz data for these fields at 1986 MTF operating currents. Tables C-10, C-11, and C-12 present 76 Hz data extrapolated to a full power condition of 150 amperes as well as pre-operation estimates for comparison. (See Section 3.5.2.)

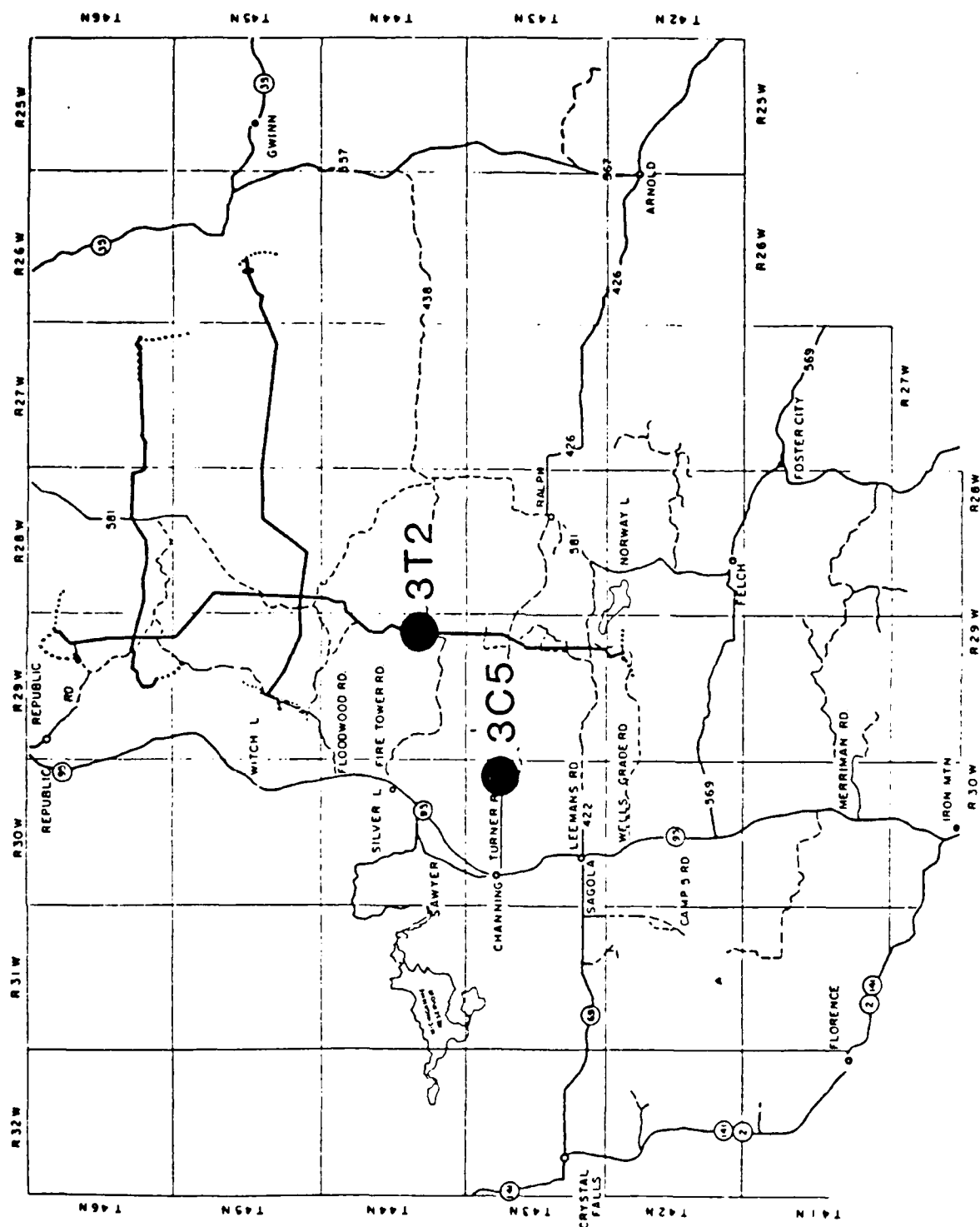
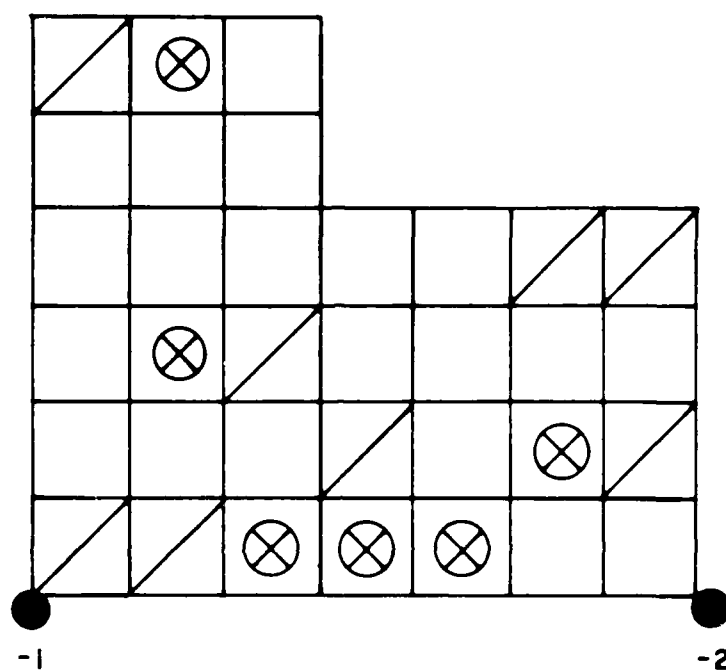


FIGURE C-1. POSITIONS OF SOIL ARTHROPODS AND EARTHWORMS STUDY SITES RELATIVE TO MICHIGAN TRANSMITTING FACILITY ANTENNA ELEMENTS.



Road

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

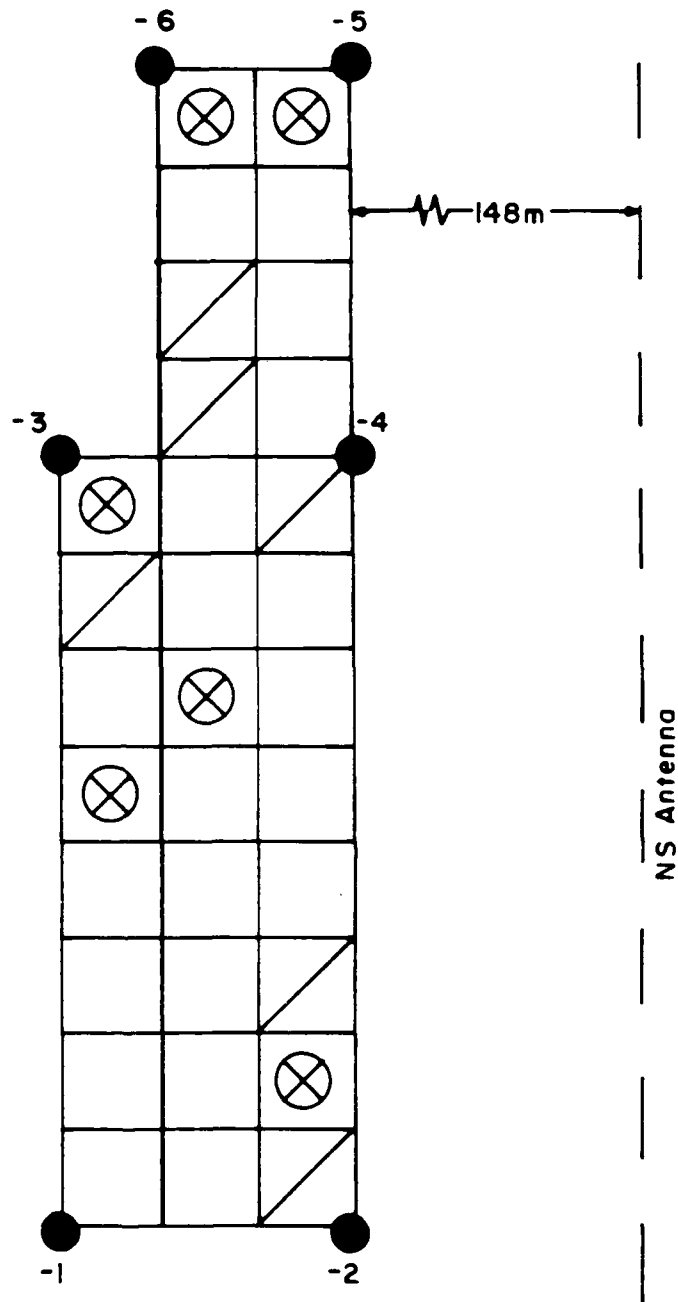


FIGURE C-3. MEASUREMENT POINTS AT SOUTH SILVER LAKE;
3T2 - 1 THROUGH 6.

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

TABLE C-2. SITE PAIRINGS AND STATUS
Soil Arthropods and Earthworms Studies

Test Site	Control Site	EM Status
3T2	3C5	A

A = Acceptable
CA = Conditionally Acceptable
U = Unacceptable

TABLE C-3. FIELD INTENSITY RATIOS
Soil Arthropods and Earthworms studies

Compared Sites	Transverse E-Field				Longitudinal E-Field (Earth)				Magnetic Flux Density			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
3T2/3C5	75	75	75	1.00	116	1060	1890	1.41 - 2.5	59	370	1780	4.0 - 6.0

While several measurement points were added at the sites in 1986 to better define spatial variations of the 76 Hz fields, all 1985 measurement points were retained. The 1986 60 Hz fields can be compared with values from previous years. The presence of the ELF antenna caused the 60 Hz magnetic flux densities at the test site to increase by roughly a factor of five in 1986, while the longitudinal electric field intensities decreased by about a factor of five. All other 60 Hz data remained consistent between 1986 and previous years.

All of the 76 Hz EM field measurements compare quite well with pre-operation estimates.

TABLE C-4. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Soil Arthropods and Earthworms Studies

Site No., Meas. Pt.	Measurement Year			
	1983	1984	1985	1986
3C5-1	<0.001	<0.001	-	-
3C5-2	-	-	-	-
3T2-1	<0.001	<0.001	-	-
3T2-2	-	-	-	-
3T2-3	-	-	-	-
3T2-4	-	-	-	-
3T2-5	-	-	-	-
3T2-6	-	-	-	-

- = site measurement point not established.

- = measurement is expected to be <0.001 V/m based on the longitudinal electric field measurement.

TABLE C-5. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Soil Arthropods and Earthworms Studies

Site No., Meas. Pt.	Measurement Year			
	1983	1984	1985	1986
3C5-1	0.063	0.018, 0.032	0.036	0.027
3C5-2	-	-	-	0.027
3T2-1	0.106	0.129, 0.27	0.194	0.045
3T2-2	-	-	-	0.068
3T2-3	-	-	-	0.038
3T2-4	-	-	-	0.045
3T2-5	-	-	-	0.044
3T2-6	-	-	-	0.048

- = site measurement point not established.

**TABLE C-6. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Arthropods and Earthworms Studies**

Site No., Meas. Pt.	Measurement Year			
	1983	1984	1985	1986
3C5-1	0.001	0.001	0.001	0.001
3C5-2	-	-	-	<0.001
3T2-1	<0.001	<0.001	0.001	0.005
3T2-2	-	-	-	0.006
3T2-3	-	-	-	0.004
3T2-4	-	-	-	0.005
3T2-5	-	-	-	0.005
3T2-6	-	-	-	0.004

- = site measurement point not established.

**TABLE C-7. 76 Hz. TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Soil Arthropods and Earthworms Studies
Measured (M) and Extrapolated (Ex) Data**

Site No., Meas. Pt.	Antenna Current and Element			
	(4 Amps)	(6 Amps)		(10 Amps)
	NS (M)	NEW (M)	SEW (M)	SEW (Ex)
3C5-1	-	-	-	--
3C5-2	-	-	-	--
3T2-1	0.002	-	-	--
3T2-2	0.002	-	-	--
3T2-3	0.002	-	-	--
3T2-4	0.002	-	-	--
3T2-5	0.002	-	-	--
3T2-6	0.002	-	-	--

- = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

TABLE C-8. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Soil Arthropods and Earthworms Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	Antenna Current and Element			
	(4 Amps)	(6 Amps)		(10 Amps)
	NS (M)	NEW (M)	SEW (M)	SEW (Ex)
3C5-1	0.005	0.001	0.002	0.003
3C5-2	0.009	0.001	0.003	0.005
3T2-1	1.33	0.057	0.188	0.31
3T2-2	1.46	0.064	0.24	0.40
3T2-3	1.19	0.047	0.149	0.25
3T2-4	1.47	0.060	0.20	0.33
3T2-5	1.56	0.070	0.23	0.38
3T2-6	1.20	0.056	0.180	0.30

TABLE C-9. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Arthropods and Earthworms Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	Antenna Current and Element			
	(4 Amps)	(6 Amps)		(10 Amps)
	NS (M)	NEW (M)	SEW (M)	SEW (Ex)
3C5-1	<0.001	<0.001	<0.001	--
3C5-2	<0.001	<0.001	<0.001	--
3T2-1	0.048	0.001	0.001	0.002
3T2-2	0.060	0.002	0.001	0.002
3T2-3	0.046	0.001	0.001	0.002
3T2-4	0.055	0.002	0.001	0.002
3T2-5	0.057	0.002	0.001	0.002
3T2-6	0.049	0.001	0.001	0.002

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

TABLE C-10. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Soil Arthropods and Earthworms Studies

Site No., Meas. Pt.	Data Extrapolated to 150 Amperes				Pre-Antenna Estimates
	NS	NEW	SEW	NS+NEW+SEW	
3C5-1	--	--	--	--	<0.001
3C5-2	--	--	--	--	<0.001
3T2-1	0.075	--	--	0.075	0.38 - 0.55
3T2-2	0.075	--	--	0.075	0.38 - 0.55
3T2-3	0.075	--	--	0.075	0.38 - 0.55
3T2-4	0.075	--	--	0.075	0.38 - 0.55
3T2-5	0.075	--	--	0.075	0.38 - 0.55
3T2-6	0.075	--	--	0.075	0.38 - 0.55

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

TABLE C-11. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Soil Arthropods and Earthworms Studies

Site No., Meas. Pt.	Data Extrapolated to 150 Amperes				Pre-Antenna Estimates
	NS	NEW	SEW	NS+NEW+SEW	
3C5-1	0.188	0.025	0.050	0.26	4.0
3C5-2	0.34	0.025	0.075	0.44	4.0
3T2-1	50	1.43	4.7	56	45 - 47
3T2-2	55	1.60	6.0	63	45 - 47
3T2-3	45	1.18	3.7	50	45 - 47
3T2-4	55	1.50	5.0	62	45 - 47
3T2-5	59	1.75	5.8	67	45 - 47
3T2-6	45	1.40	4.5	51	45 - 47

TABLE C-12. 76 Hz. MAGNETIC FLUX DENSITIES (mG)
Soil Arthropods and Earthworms Studies

Site No., Meas. Pt.	Data Extrapolated to 150 Amperes				Pre-Antenna Estimates
	NS	NEW	SEW	NS+NEW+SEW	
3C5-1	--	--	--	--	0.030
3C5-2	--	--	--	--	0.030
3T2-1	1.80	0.025	0.025	1.85	1.70 - 2.0
3T2-2	2.3	0.050	0.025	2.4	1.70 - 2.0
3T2-3	1.73	0.025	0.025	1.78	1.70 - 2.0
3T2-4	2.1	0.050	0.025	2.2	1.70 - 2.0
3T2-5	2.1	0.050	0.025	2.2	1.70 - 2.0
3T2-6	1.84	0.025	0.025	1.89	1.70 - 2.0

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

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APPENDIX D
UPLAND FLORA AND SOIL MICROFLORA STUDIES

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UPLAND FLORA AND SOIL MICROFLORA STUDIES

On 1, 2, and 14 October 1986, IITRI field crews made ELF electromagnetic (EM) field measurements at 29 measurement points at a total of two test sites and one control site for the upland flora and soil microflora studies. The test and control sites measured in 1986 are the same as those measured in 1985. The Michigan Transmitting Facility (MTF) was operational for the first time in 1986. Therefore, 76 Hz EM field measurements were possible for the first time. The site measurement points used in 1985 were sufficient to define the spatial variations of the 76 Hz EM fields, and with one exception (4T4-12), no measurement points were added in 1986.

The positions of the three 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. Details of measurement locations within sites are diagrammed in Figures D-2 through D-4. Table D-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites.

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, and is arranged in a manner similar to the test sites. The antenna test site and the control site each consist 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 reserve were established at the grounding 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 exposure.

The major themes of the upland flora and microflora studies are the functional and structural aspects of organic material cycling. These studies will 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

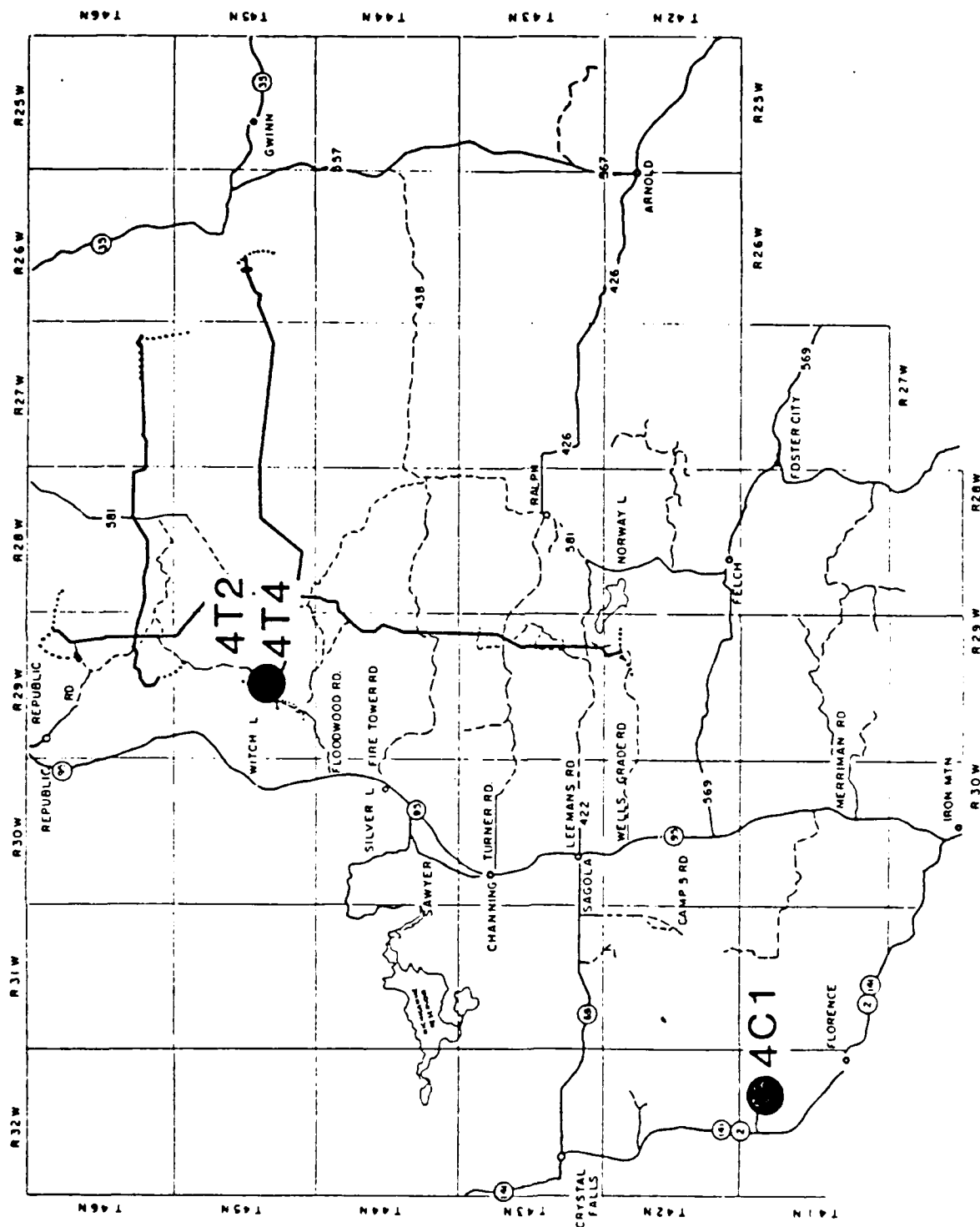


FIGURE D-1. POSITIONS OF UPLAND FLORA AND SOIL MICROFLORA STUDY SITES RELATIVE TO MICHIGAN TRANSMITTING FACILITY ANTENNA ELEMENTS.

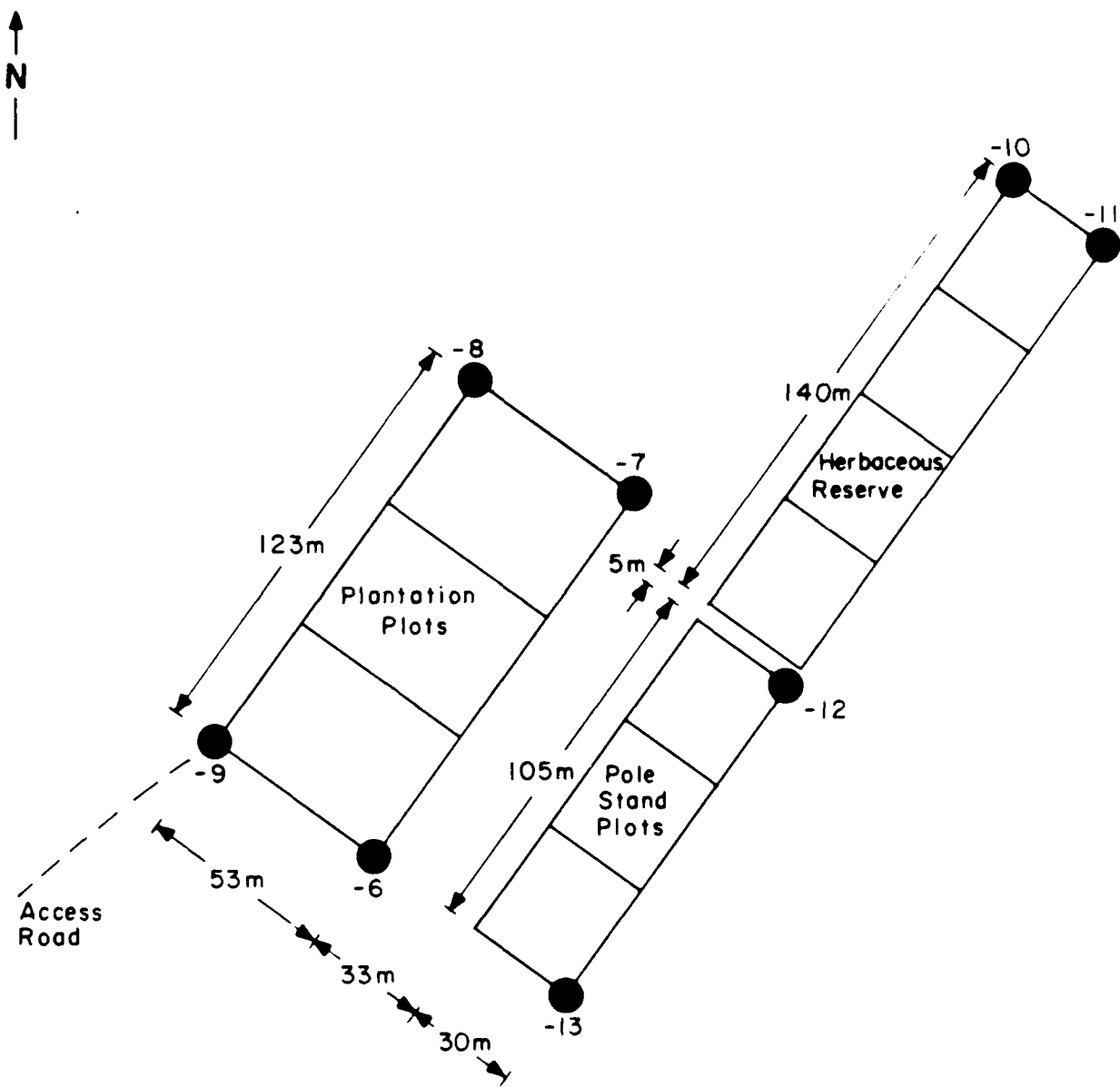


FIGURE D-2. MEASUREMENT POINTS AT PAINT POND ROAD CONTROL; 4C1-6 THROUGH 13.

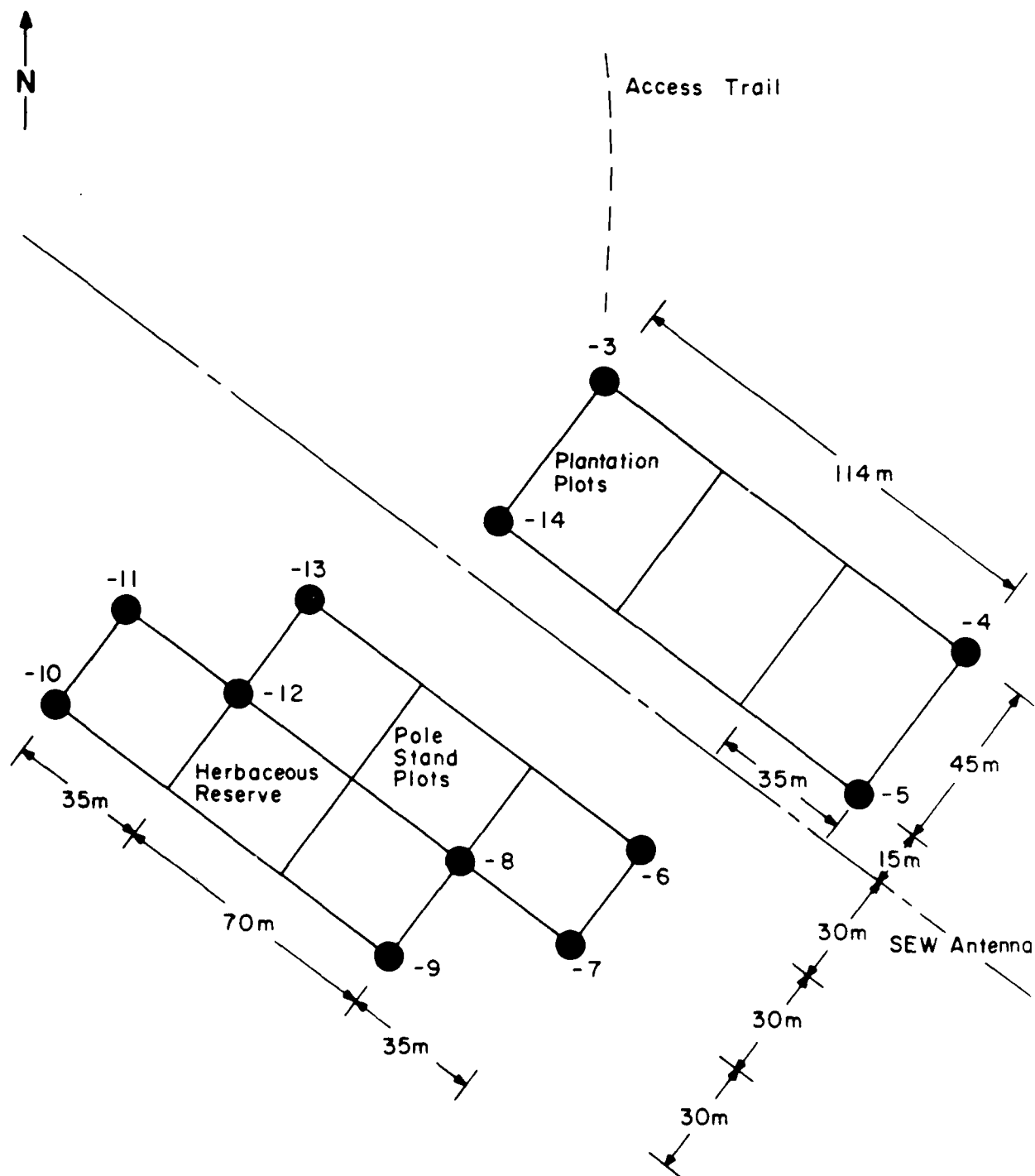


FIGURE D - 3. MARTELL'S LAKE (OVERHEAD): ML;
4T2 - 3 THROUGH 14.

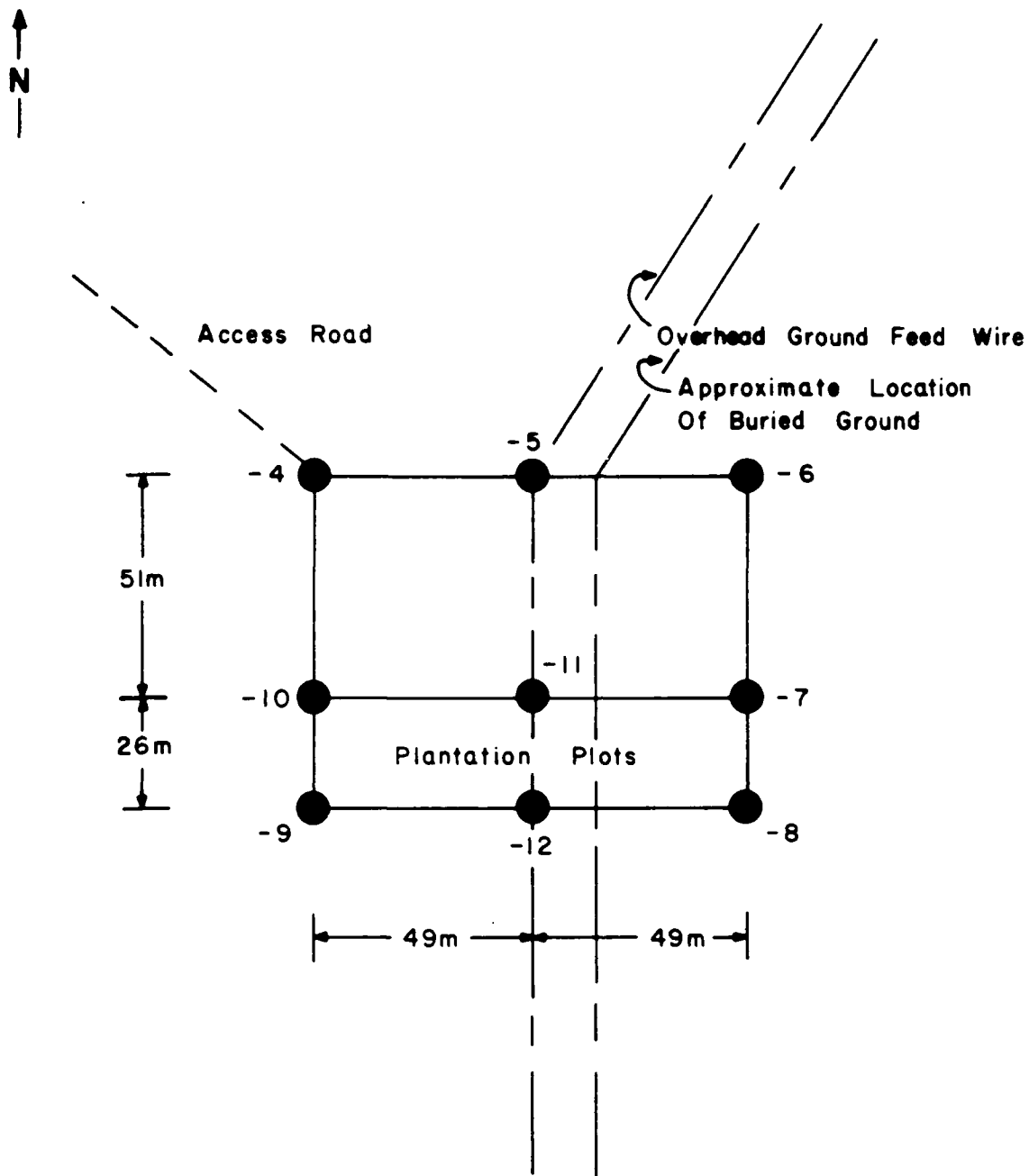


FIGURE D-4. MARTELL'S LAKE (BURIED) : EP;
4T4-4 THROUGH 12.

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

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 the plot.

Table D-2 shows the test/control site pairings of interest to the investigator, the corresponding study parameters, and site pair status. The pairings are done slightly differently in this study: each of three substudies (pole stands, plantations, and reserves) at test sites is compared only to similar substudies at the control site instead of comparing the entire site. The substudies for comparison are denoted by the site number followed by a three letter abbreviation of the substudy. These substudies and the measurement points of which they are comprised are shown in Table D-3.

The field ratios for the site pairs given in Table D-2 were recalculated using the measured values of the 76 Hz fields extrapolated to an antenna current of 150 amperes; Table D-4 shows the results. All of the ratio criteria were met except for the R4 ratio (T(60)/C(60) for the longitudinal electric field and magnetic flux densities at some site pairs. The R4 magnetic flux density ratio did not meet criteria at one site pair (4T2PIN/4C1PIN). This was the result of an increase in the 60 Hz magnetic flux at the test site due to coupling to the antenna wire. The R4 longitudinal electric field ratio did not meet criteria at three site pairs (4T2PIN/4C1PIN, 4T4PIN/4C1PIN, 4T2HDW/4C1HDW). In spite of a reduced longitudinal electric field at the test site, the R4 ratio (T60/C60) was >10 at these three site pairs. The 60 Hz longitudinal field at measurement point 4C1-6 (a pine plantation point) decreased by a factor of 3.2 between 1985 and 1986, causing

TABLE D-2. SITE PAIRINGS AND STATUS
Upland Flora and Soil Microflora Studies

Test Site	Control Site	EM Status
4T2PIN	4C1PIN	CA
4T4PIN	4C1PIN	CA
4T2HDW	4C1HDW	CA
4T2HER	4C1HER	A

A = Acceptable
CA = Conditionally Acceptable
U = Unacceptable

TABLE D-3. SUBSTUDY DEFINITION
Upland Flora and Soil Microflora Studies

Substudy	Measurement Points	Activity
4T2PIN	4T2-3, 4, 5, 14	Plantation
4T2HDW	4T2-6, 7, 8, 12, 13	Pole Stands
4T2HER	4T2-8, 9, 10, 11, 12	Reserve
4T4PIN	4T4-4, 5, 6, 7, 8, 9, 10, 11, 12	Plantation
4C1PIN	4C1-6, 7, 8, 9	Plantation
4C1HDW	4C1-12, 13	Pole Stands
4C1HER	4C1-12, 14, 15	Reserve

TABLE D-4. FIELD INTENSITY RATIOS
Upland Flora and Soil Microflora Studies

Compared Sites	Transverse E-Field				Longitudinal E-Field (Earth)				Magnetic Flux Density			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
4T2PIN/ 4C1PIN	100	100	100	1.00	4500	570	2200	2.5 - 64	7300	3100	2400	0.33 - 11.0
4T4PIN/ 4C1PIN	150	150	150	1.00	1240	220	610	2.1 - 150	3100	3100	1030	0.33 - 6.0
4T2HDW/ 4C1HDW	50	50	50	1.00	5200	350	1510	1.88 - 17.3	7200	1030	2400	0.67 - 2.0
4T2HER/ 4C1HER	50	50	50	1.00	5200	400	1360	1.78 - 5.9	4600	3600	1530	0.67 - 2.0

the 4T2PIN/4C1PIN and 4T2PIN/4C1PIN longitudinal R4 ratios to be greater than 10. The 4T2HDW/4C1HDW R4 longitudinal electric field ratio did not meet the established criteria in 1985 or 1986.

All other criteria were met for this study, and all of the test/control site pairs fell into either the acceptable or conditionally acceptable categories, as shown in Table D-3.

EM field measurements for 1986 and previous years are found in Tables D-5 through D-13. Tables D-5, D-6, and D-7 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables D-8, D-9, and D-10 present 76 Hz data for these three fields at 1986 MTF operating currents. Tables D-11, D-12, and D-13 present 76 Hz data extrapolated to a full power condition of 150 amperes as well as pre-operation estimates for comparison. (See Section 3.5.2.)

All the points measured in 1985 were remeasured in 1986. The 1986 60 Hz data can therefore be compared with previous years in Tables D-5, D-6, and D-7. The 60 Hz transverse electric field was not detectable at any measurement point. The 60 Hz magnetic flux densities increased slightly at the antenna site (4T2) due to coupling of ambient fields to the antenna, and typically decreased slightly or remained the same at the ground site (4T4) and the control site (4C1). The 60 Hz longitudinal electric field intensities decreased at the antenna site in 1986. These fields also decreased at the ground site at all points except 4T4-5 and 4T4-11, which are directly beneath the overhead ground feed. The 60 Hz longitudinal electric field remained fairly consistent at the control site between 1985 and 1986.

The 76 Hz fields fall within the estimates made for the magnetic flux densities and the transverse electric field. The longitudinal electric fields measured at the test sites were typically greater than the estimates. This is likely the result of low soil conductivities at these sites, and is advantageous, since it is intended for the 76 Hz fields to dominate at the test sites. The longitudinal electric fields are especially high at sites 4T4-5, 11, and 12 as these sites are very near the buried ground wire, the effects of which were not included in the estimates.

EM field intensities from Tables D-5 through D-13 can be entered beside each measurement point on the maps in Figures D-2 through D-4. Several

phenomena become evident when this is done. The fields at the test sites vary with distance from the antenna and remain relatively stable at equal distances from the antenna. At the ground site, the 76 Hz longitudinal electric fields on the east side of the overhead feed wire are four times greater than at points an equal distance to the west of the overhead feed wire. This is due to the ground wire being buried on the east side of the overhead wire. This buried ground will have its greatest effect on the longitudinal electric field, a significant but lesser effect on the magnetic flux density measured in the air, and little effect on the measured transverse electric field.

No 76 Hz EM fields were detectable at the control site for this study, presumably because of the very low antenna currents in 1986.

TABLE D-5. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Upland Flora and Soil Microflora Studies

Site No., Meas. Pt.	Measurement Year			
	1983	1984	1985	1986
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	-	-
4T2-4	-	-	-	-
4T2-5	-	-	-	-
4T2-6	-	-	-	-
4T2-7	-	-	-	-
4T2-8	-	-	-	-
4T2-9	-	-	-	-
4T2-10	-	-	-	-
4T2-11	-	-	-	-
4T2-12	-	-	-	-
4T2-13	-	-	-	-
4T2-14	-	-	-	-
4T4-4	-	0.003	-	-
4T4-5	-	-	-	-
4T4-6	-	-	-	-
4T4-7	-	-	-	-
4T4-8	-	-	-	-
4T4-9	-	-	-	-
4T4-10	-	-	-	-
4T4-11	-	-	-	-
4T4-12	-	-	-	-

- = site measurement point not established.

- = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.

TABLE D-6. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Studies

Site No., Meas. Pt.	Measurement Year			
	1983	1984	1985	1986
4C1-6	-	0.022	0.016	0.005
4C1-7	-	0.143	0.123	0.077
4C1-8	-	0.104	0.117	0.077
4C1-9	-	0.011	0.019	0.024
4C1-10	-	-	0.090	0.068
4C1-11	-	-	0.160	0.107
4C1-12	-	-	0.104	0.101
4C1-13	-	-	0.040	0.030
4T2-3	-	0.51	0.39	0.194
4T2-4	-	-	0.27	0.24
4T2-5	-	-	0.43	0.32
4T2-6	-	-	0.66	0.46
4T2-7	-	-	0.42	0.52
4T2-8	-	-	0.47	0.190
4T2-9	-	-	0.49	0.31
4T2-10	-	-	0.44	0.32
4T2-11	-	-	0.51	0.40
4T2-12	-	-	0.47	0.38
4T2-13	-	-	0.76	0.31
4T2-14	-	-	0.61	0.29
4T4-4	-	0.72	0.42	0.185
4T4-5	-	-	0.58	0.58
4T4-6	-	-	0.22	0.16
4T4-7	-	-	0.44	0.29
4T4-8	-	-	0.42	0.193
4T4-9	-	-	0.50	0.21
4T4-10	-	-	0.42	0.22
4T4-11	-	-	0.40	0.60
4T4-12	-	-	-	0.75

- = site measurement point not established.

TABLE D-7. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Upland Flora and Soil Microflora Studies

Site No., Meas. Pt.	Measurement Year			
	1983	1984	1985	1986
4C1-6	-	0.003	0.003	0.003
4C1-7	-	0.003	0.002	0.001
4C1-8	-	0.003	0.003	0.002
4C1-9	-	0.003	0.003	0.002
4C1-10	-	-	0.002	0.002
4C1-11	-	-	0.002	0.002
4C1-12	-	-	0.002	0.003
4C1-13	-	-	0.002	0.003
4T2-3	-	0.002	0.001	0.001
4T2-4	-	-	0.001	0.001
4T2-5	-	-	0.001	0.007
4T2-6	-	-	0.001	0.006
4T2-7	-	-	0.001	0.004
4T2-8	-	-	0.001	0.002
4T2-9	-	-	0.001	0.003
4T2-10	-	-	0.001	0.003
4T2-11	-	-	0.001	0.004
4T2-12	-	-	0.002	0.004
4T2-13	-	-	0.001	0.005
4T2-14	-	-	0.002	0.011
4T4-4	-	0.004	0.002	0.001
4T4-5	-	-	0.002	0.006
4T4-6	-	-	0.002	0.001
4T4-7	-	-	0.001	0.001
4T4-8	-	-	0.002	0.001
4T4-9	-	-	0.002	0.001
4T4-10	-	-	0.001	0.001
4T4-11	-	-	0.002	0.002
4T4-12	-	-	-	0.002

- = site measurement point not established.

TABLE D-8. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Upland Flora and Soil Microflora Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	Antenna Current and Element			
	(4 Amps) NS (M)	(6 Amps) NEW (M)	(6 Amps) SEW (M)	(10 Amps) SEW (Ex)
4C1-6	-	-	-	--
4C1-7	-	-	-	--
4C1-8	-	-	-	--
4C1-9	-	-	-	--
4C1-10	-	-	-	--
4C1-11	-	-	-	--
4C1-12	-	-	-	--
4C1-13	-	-	-	--
4T2-3	-	-	0.004	0.007
4T2-4	-	-	0.005	0.008
4T2-5	0.018	-	0.092	0.153
4T2-6	-	-	0.005	0.008
4T2-7	-	-	0.007	0.012
4T2-8	-	-	0.004	0.007
4T2-9	-	-	0.005	0.008
4T2-10	-	-	0.004	0.007
4T2-11	-	-	0.003	0.005
4T2-12	-	-	0.002	0.003
4T2-13	-	-	0.005	0.008
4T2-14	0.030	-	0.155	0.26
4T4-4	-	-	0.006	0.010
4T4-5	0.033	0.008	0.20	0.33
4T4-6	0.005	-	0.023	0.038
4T4-7	-	-	0.006	0.010
4T4-8	-	-	0.008	0.013
4T4-9	-	-	0.009	0.015
4T4-10	-	-	0.007	0.012
4T4-11	-	0.005	0.38	0.63
4T4-12	0.055	0.005	0.43	0.72

- = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

TABLE D-9. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	Antenna Current and Element			
	(4 Amps) NS (M)	(6 Amps) NEW (M)	SEW (M)	(10 Amps) SEW (Ex)
4C1-6	-	-	-	--
4C1-7	-	-	-	--
4C1-8	-	-	-	--
4C1-9	<0.001	<0.001	<0.001	--
4C1-10	-	-	-	--
4C1-11	-	-	-	--
4C1-12	-	-	-	--
4C1-13	-	-	-	--
4T2-3	1.31	0.22	6.3	10.5
4T2-4	1.05	0.22	5.0	8.3
4T2-5	1.18	0.24	5.3	8.8
4T2-6	1.11	0.27	4.4	7.3
4T2-7	1.13	0.23	5.3	8.8
4T2-8	1.32	0.25	5.7	9.5
4T2-9	1.17	0.21	5.1	8.5
4T2-10	0.97	0.22	4.1	6.8
4T2-11	1.14	0.21	5.0	8.3
4T2-12	1.06	0.21	4.3	7.2
4T2-13	1.12	0.64	5.4	9.0
4T2-14	1.07	0.175	5.1	8.5
4T4-4	0.33	0.181	1.46	2.4
4T4-5	13.8	2.0	81	135
4T4-6	1.22	0.22	6.2	10.3
4T4-7	0.94	0.175	5.5	9.2
4T4-8	0.91	0.188	5.3	8.8
4T4-9	0.29	0.130	1.32	2.2
4T4-10	0.29	0.169	1.63	2.7
4T4-11	0.59	1.82	89	148
4T4-12	21	2.2	118	197

- = measurement expected to be <0.001 mV/m based on nearby measurements and distance to antenna.

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

TABLE D-10. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Upland Flora and Soil Microflora Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	Antenna Current and Element			
	(4 Amps) NS (M)	(6 Amps) NEW (M)	(10 Amps) SEW (M)	(10 Amps) SEW (Ex)
4C1-6	-	-	-	--
4C1-7	-	-	-	--
4C1-8	-	-	-	--
4C1-9	<0.001	<0.001	<0.001	--
4C1-10	-	-	-	--
4C1-11	-	-	-	--
4C1-12	-	-	-	--
4C1-13	-	-	-	--
4T2-3	0.047	0.001	0.22	0.37
4T2-4	0.049	0.001	0.24	0.40
4T2-5	0.197	<0.001	1.00	1.67
4T2-6	0.058	0.001	0.44	0.73
4T2-7	0.046	0.001	0.22	0.37
4T2-8	0.045	0.001	0.22	0.37
4T2-9	0.029	0.001	0.138	0.23
4T2-10	0.033	0.001	0.149	0.25
4T2-11	0.043	0.001	0.21	0.35
4T2-12	0.047	0.001	0.23	0.38
4T2-13	0.086	<0.001	0.43	0.72
4T2-14	0.21	<0.001	1.03	1.72
4T4-4	0.019	<0.001	0.096	0.160
4T4-5	0.114	0.001	0.57	0.95
4T4-6	0.045	0.001	0.22	0.37
4T4-7	0.038	0.001	0.186	0.31
4T4-8	0.035	0.001	0.179	0.30
4T4-9	0.025	0.21	0.118	0.197
4T4-10	0.022	<0.001	0.116	0.193
4T4-11	0.161	0.001	0.80	1.33
4T4-12	0.115	0.001	0.58	0.97

- = measurement expected to be <0.001 mG based on nearby measurements and distance to antenna.

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

TABLE D-11. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Upland Flora and Soil Microflora Studies

Site No., Meas. Pt.	Data Extrapolated to 150 Amperes				Pre-Antenna Estimates
	NS	NEW	SEW	NS+NEW+SEW	
4C1-6	--	--	--	--	<0.001
4C1-7	--	--	--	--	<0.001
4C1-8	--	--	--	--	<0.001
4C1-9	--	--	--	--	<0.001
4C1-10	--	--	--	--	<0.001
4C1-11	--	--	--	--	<0.001
4C1-12	--	--	--	--	<0.001
4C1-13	--	--	--	--	<0.001
4T2-3	--	--	0.100	0.100	0.075 - 35
4T2-4	--	--	0.125	0.125	0.075 - 35
4T2-5	0.68	--	2.3	3.0	0.075 - 35
4T2-6	--	--	0.125	0.125	0.075 - 35
4T2-7	--	--	0.175	0.175	0.075 - 35
4T2-8	--	--	0.100	0.100	0.075 - 35
4T2-9	--	--	0.125	0.125	0.075 - 35
4T2-10	--	--	0.100	0.100	0.075 - 35
4T2-11	--	--	0.075	0.075	0.075 - 35
4T2-12	--	--	0.050	0.050	0.075 - 35
4T2-13	--	--	0.125	0.125	0.075 - 35
4T2-14	1.13	--	3.9	5.0	0.075 - 35
4T4-4	--	--	0.150	0.150	0.060 - 35
4T4-5	1.24	0.20	5.0	6.4	0.060 - 35
4T4-6	0.188	--	0.58	0.77	0.060 - 35
4T4-7	--	--	0.150	0.150	0.060 - 35
4T4-8	--	--	0.20	0.20	0.060 - 35
4T4-9	--	--	0.23	0.23	0.060 - 35
4T4-10	--	--	0.175	0.175	0.060 - 35
4T4-11	--	0.125	9.5	9.6	0.060 - 35
4T4-12	2.1	0.125	10.8	13.0	0.060 - 35

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

TABLE D-12. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Studies

Site No., Meas. Pt.	Data Extrapolated to 150 Amperes				Pre-Antenna Estimates
	NS	NEW	SEW	NS+NEW+SEW	
4C1-6	--	--	--	--	0.20
4C1-7	--	--	--	--	0.20
4C1-8	--	--	--	--	0.20
4C1-9	--	--	--	--	0.20
4C1-10	--	--	--	--	0.20
4C1-11	--	--	--	--	0.20
4C1-12	--	--	--	--	0.20
4C1-13	--	--	--	--	0.20
4T2-3	49	5.5	158	210	60 - 75
4T2-4	39	5.5	125	170	60 - 75
4T2-5	44	6.0	133	183	60 - 75
4T2-6	42	6.8	110	159	60 - 75
4T2-7	42	5.8	133	181	60 - 75
4T2-8	50	6.3	143	199	60 - 75
4T2-9	44	5.3	128	177	60 - 75
4T2-10	36	5.5	103	145	60 - 75
4T2-11	43	5.3	125	173	60 - 75
4T2-12	40	5.3	108	153	60 - 75
4T2-13	42	16.0	135	193	60 - 75
4T2-14	40	4.4	128	172	60 - 75
4T4-4	12.4	4.5	37	54	60 - 75
4T4-5	520	50	2000	2600	60 - 75
4T4-6	46	5.5	155	210	60 - 75
4T4-7	35	4.4	138	177	60 - 75
4T4-8	34	4.7	133	172	60 - 75
4T4-9	10.9	3.3	33	47	60 - 75
4T4-10	10.9	4.2	41	56	60 - 75
4T4-11	22	46	2200	2300	60 - 75
4T4-12	790	55	3000	3800	60 - 75

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

TABLE D-13. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Upland Flora and Soil Microflora Studies

Site No., Meas. Pt.	Data Extrapolated to 150 Amperes				Pre-Antenna Estimates
	NS	NEW	SEW	NS+NEW+SEW	
4C1-6	--	--	--	--	0.001
4C1-7	--	--	--	--	0.001
4C1-8	--	--	--	--	0.001
4C1-9	--	--	--	--	0.001
4C1-10	--	--	--	--	0.001
4C1-11	--	--	--	--	0.001
4C1-12	--	--	--	--	0.001
4C1-13	--	--	--	--	0.001
4T2-3	1.76	0.025	5.5	7.3	5.0 - 20
4T2-4	1.84	0.025	6.0	7.9	5.0 - 20
4T2-5	7.4	--	25	32	5.0 - 20
4T2-6	2.2	0.025	11.0	13.2	5.0 - 20
4T2-7	1.73	0.025	5.5	7.3	5.0 - 20
4T2-8	1.69	0.025	5.5	7.2	5.0 - 20
4T2-9	1.09	0.025	3.5	4.6	5.0 - 20
4T2-10	1.24	0.025	3.7	5.0	5.0 - 20
4T2-11	1.61	0.025	5.3	6.9	5.0 - 20
4T2-12	1.76	0.025	5.8	7.6	5.0 - 20
4T2-13	3.2	--	10.8	14.0	5.0 - 20
4T2-14	7.9	--	26	34	5.0 - 20
4T4-4	0.71	--	2.4	3.1	5.0 - 20
4T4-5	4.3	0.025	14.3	18.6	5.0 - 20
4T4-6	1.69	0.025	5.5	7.2	5.0 - 20
4T4-7	1.43	0.025	4.7	6.2	5.0 - 20
4T4-8	1.31	0.025	4.5	5.8	5.0 - 20
4T4-9	0.94	5.3	3.0	9.2	5.0 - 20
4T4-10	0.83	--	2.9	3.7	5.0 - 20
4T4-11	6.0	0.025	20	26	5.0 - 20
4T4-12	4.3	0.025	14.5	18.8	5.0 - 20

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

APPENDIX E
AQUATIC ECOSYSTEMS STUDIES

[illegible]

AQUATIC ECOSYSTEMS STUDIES

On 8-10 October 1986, IITRI field crews made ELF electromagnetic (EM) field measurements at 17 measurement points at a total of six test and four control sites for the aquatic ecosystems studies. The measurement points were those used in 1985 plus three additional points, including one newly established site. The new site, 5T7-1, is a stream monitoring point and a possible future weir net site. The Michigan Transmitting Facility (MTF) was operational for the first time in 1986. Therefore, 76 Hz EM field measurements were possible for the first time.

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. Details of measurement locations within sites are given in Figures E-2 through E-7. Table E-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites.

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. Table E-2 shows the test/control site pairings of interest to the investigator, the corresponding study parameters, and site pair status.

The field ratios for the site pairs given in Table E-2 were recalculated using the measured values of the 76 Hz fields extrapolated to a 150 ampere antenna current; Table E-3 shows the results. All of the ratio criteria were met except for the R1 ratio (T76/C76) for the longitudinal field intensity at 10 compared measurement points (5T2-1/5C1-1, 5T2-2/5C1-1, 5T2-3/5C1-3, 5T1-2/5C1-1, 5T3-1/5C1-4, 5T1-1/5C1-2, 5T4-1/5C1-2, 5T4-1/5C3-2, 5T6-1/5C1-2, and 5T6-1/5C3-2) and the R4 ratio (T60/C60) for the magnetic flux density at one measurement point pair (5T2-2/5C1-1). The R1 ratio criteria were not met because of physical limitations in the positioning of test sites and control

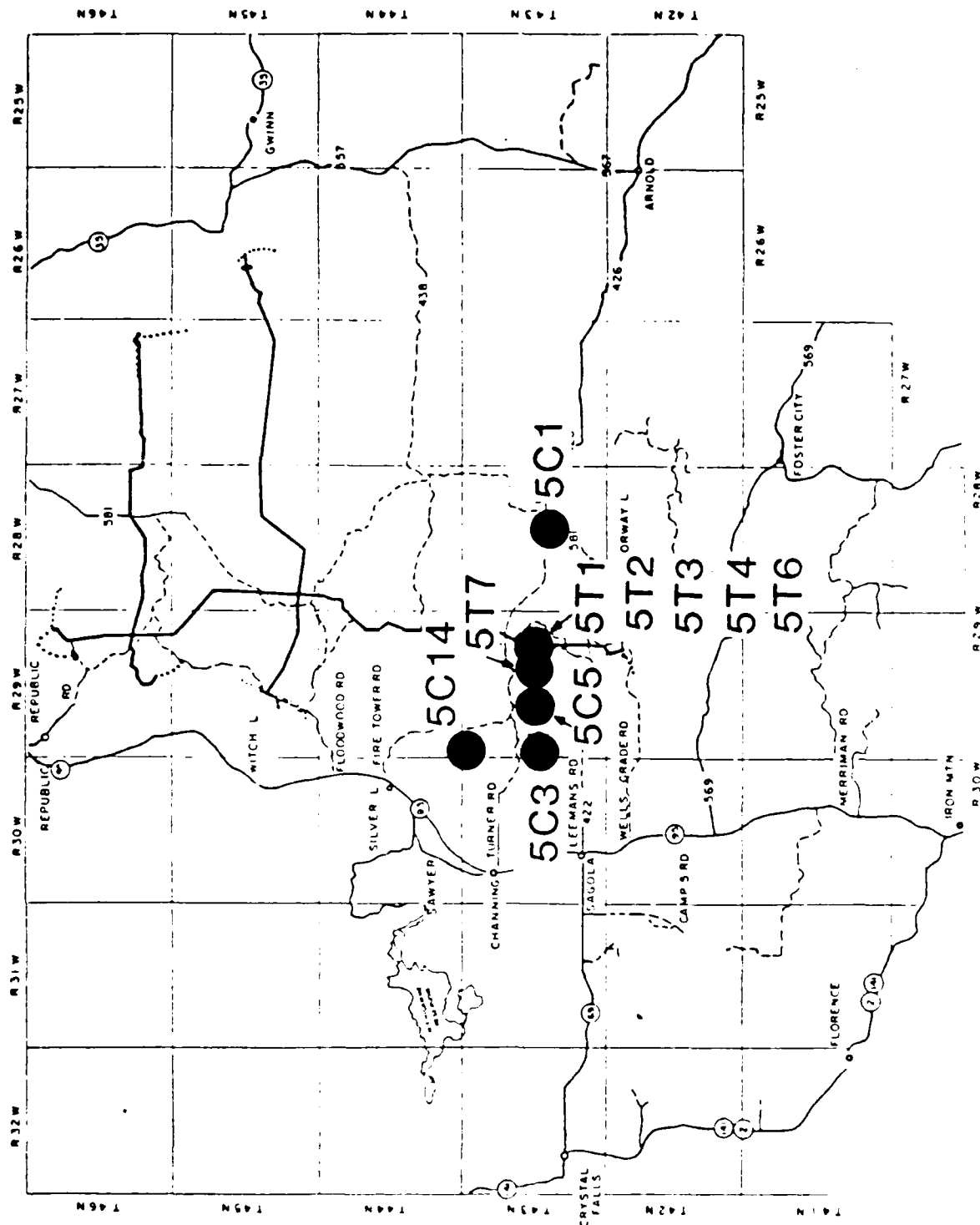
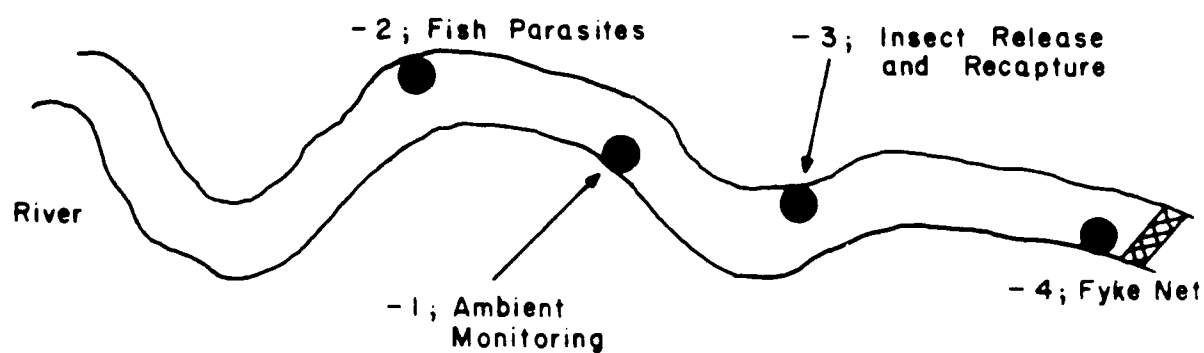


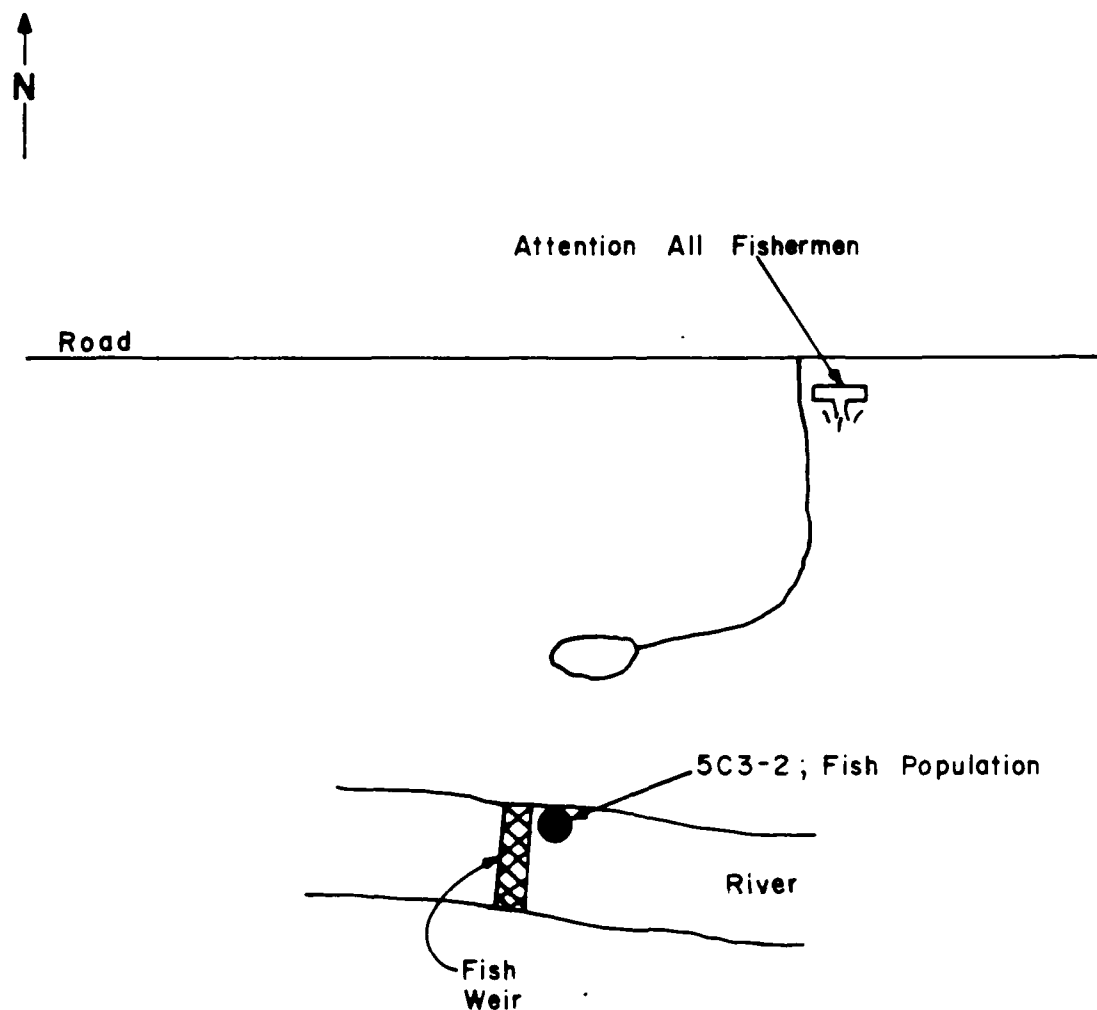
FIGURE E-1. POSITIONS OF AQUATIC ECOSYSTEMS STUDY SITES RELATIVE TO MICHIGAN TRANSMITTING FACILITY ANTENNA ELEMENTS.

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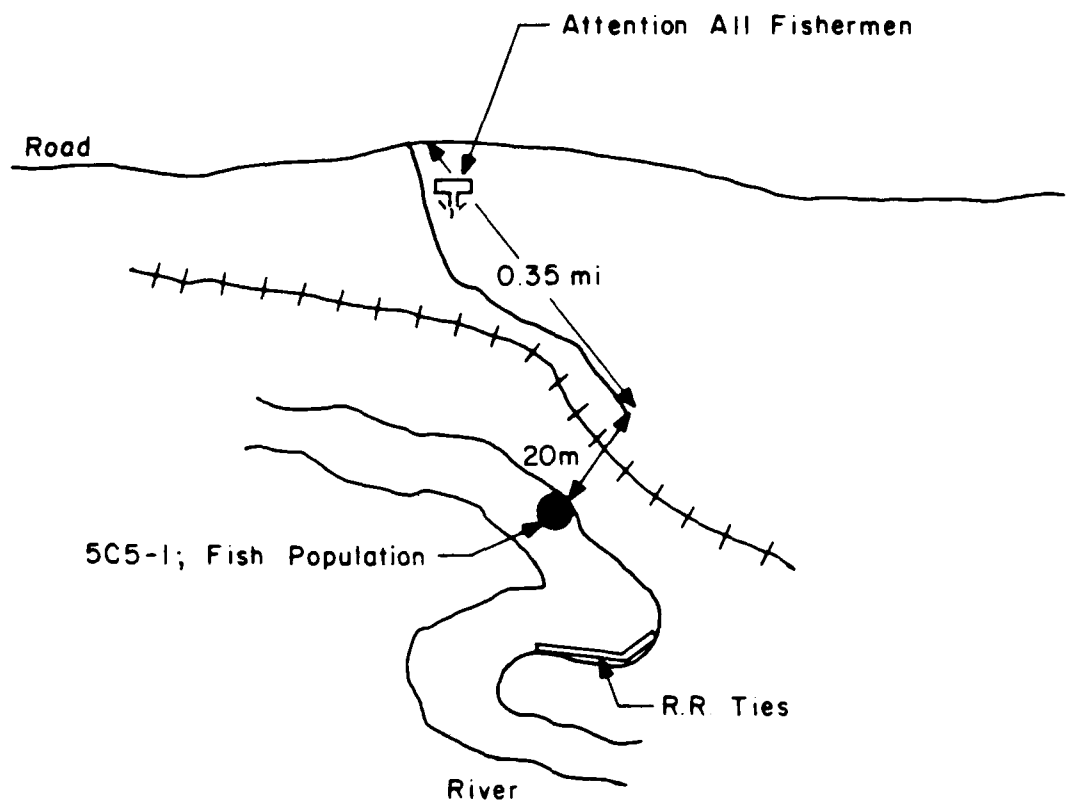
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FIGURE E-2. MEASUREMENT POINTS AT FCD;
5CI-1 THROUGH 4.



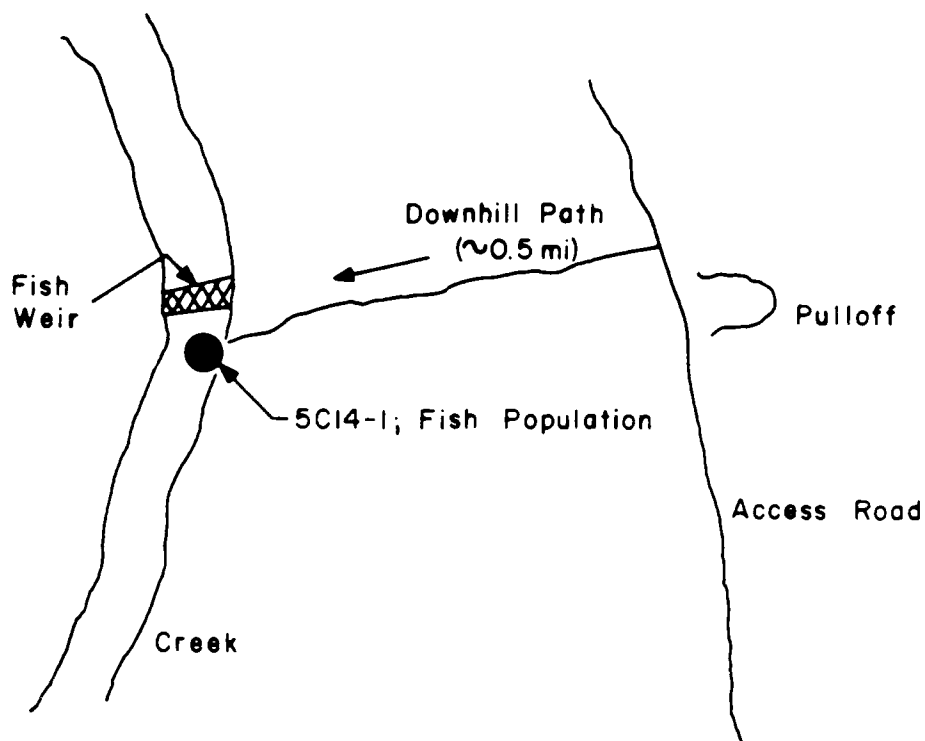
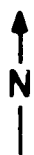
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FIGURE E-3. MEASUREMENT POINT AT FCU; 5C3-2.



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



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

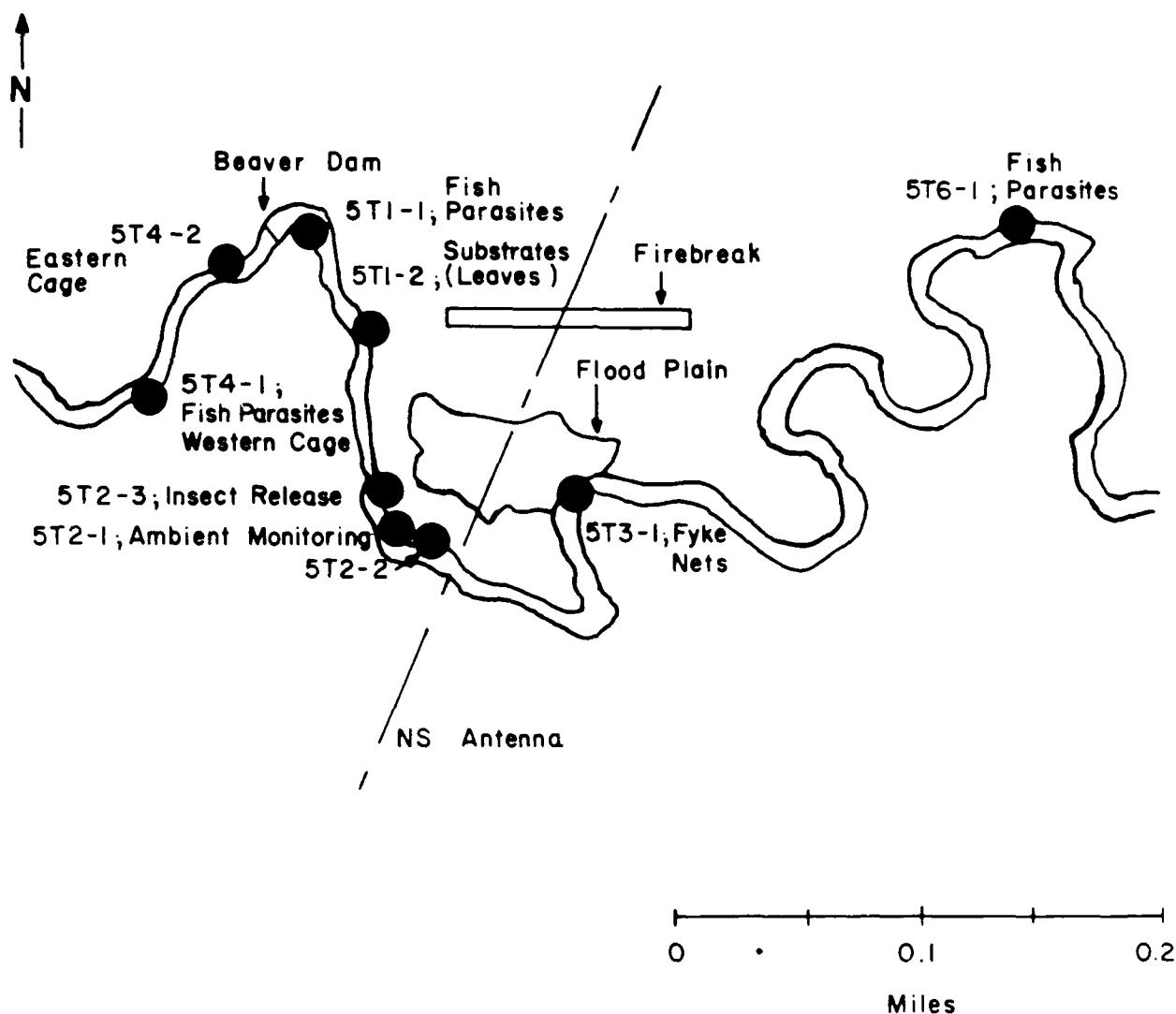
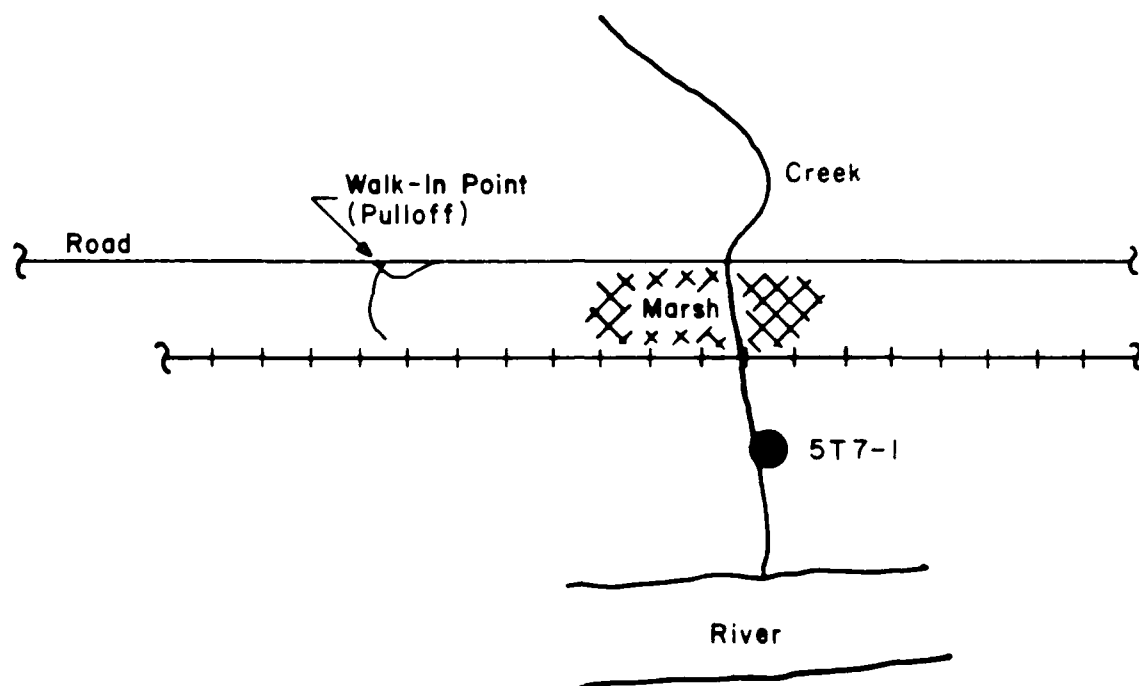


FIGURE E-6. MEASUREMENT POINTS AT FEX 1, FEX 2, FEX 3, FEX 4, FEX 6; 5T1-1,2; 5T2-1,2,3; 5T3-1; 5T4-1,2; 5T6-1.



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

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
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

TABLE E-2. SITE PAIRINGS
Aquatic Ecosystems Studies

Test Site	Control Site	Study Parameters	EM Status
5T2-1	5C1-1	Ambient Monitoring	CA
5T2-2	5C1-1	Periphyton	CA
5T2-3	5C1-3	Insect Movement	CA
5T1-2	5C1-1	Insect Substrates/Leaf Litter	CA
5T3-1	5C1-4	Fish Population	CA
5T3-1	5C3-2	Fish Population	A
5T3-1	5C5-1	Fish Population	A
5T3-1	5C14-1	Fish Population	A
5T1-1	5C1-2	Fish Parasites	CA
5T1-1	5C3-2	Fish Parasites	A
5T4-1	5C1-2	Fish Parasites	CA
5T4-1	5C3-2	Fish Parasites	CA
5T6-1	5C1-2	Fish Parasites	CA
5T6-1	5C3-2	Fish Parasites	CA

A = Acceptable

CA = Conditionally Acceptable

U = Unacceptable

**TABLE E-3. FIELD INTENSITY RATIOS
Aquatic Ecosystems Studies**

Compared Sites	Transverse E-Field				Longitudinal E-Field (Earth)				Magnetic Flux Density			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
5T2-1/5C1-1	38	38	38	1.00	3.7	930	240	0.26	129	980	4900	5.0
5T2-2/5C1-1	410	410	410	1.00	4.5	780	290	0.37	310	850	11900	14.0
5T2-3/5C1-3	38	38	38	1.00	5.4	940	370	0.40	111	1050	4200	4.0
5T1-2/5C1-1	38	38	38	1.00	2.3	860	145	0.168	66	630	2500	4.0
5T3-1/5C1-4	300	300	300	1.00	4.1	1070	280	0.26	137	1040	5200	5.0
5T3-1/5C3-2	300	300	300	1.00	10.0	1070	410	0.39	137	1040	1040	1.00
5T3-1/5C5-1	300	300	300	1.00	31	1070	640	0.60	38	1040	5200	5.0
5T3-1/5C14-1	300	300	300	1.00	23	1070	260	0.25	137	1040	310	0.29
5T1-1/5C1-2	38	38	38	1.00	9.3	790	640	0.81	45	860	1720	2.0
5T1-1/5C3-2	38	38	38	1.00	20	790	830	1.05	45	860	340	0.40
5T4-1/5C1-2	38	38	38	1.00	2.8	940	194	0.21	28	1080	1080	1.00
5T4-1/5C3-2	38	38	38	1.00	6.1	940	250	0.27	28	1080	220	0.20
5T6-1/5C1-2	38	38	38	1.00	4.4	1000	300	0.30	30	1140	1140	1.00
5T6-1/5C3-2	38	38	38	1.00	9.6	1000	390	0.39	30	1140	230	0.20

sites in the river. The R4 ratio criteria were not met at the 5T2-2/5C1-1 site pair because of an increase in the magnetic flux density at the test site in 1986 due to coupling of nearby 60 Hz ambient fields to the ELF antenna. All other criteria were met, and all of the test/control site pairs for the aquatic ecosystems studies fell into either the acceptable or conditionally acceptable categories, as shown in Table E-2.

EM field measurements for 1986 and previous years are found in Tables E-4 through E-12. Tables E-4, E-5, and E-6 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables E-7, E-8, and E-9 present 76 Hz data for these three fields at 1986 MTF operating currents. Tables E-10, E-11, and E-12 present 76 Hz data extrapolated to a full power condition of 150 amperes as well as pre-operation estimates for comparison. (See Section 3.5.2.)

The 60 Hz longitudinal electric field intensities decreased at all test sites. The 60 Hz magnetic flux densities increased at all test sites except for 5T4 and 5T6 as a result of coupling of nearby 60 Hz fields to the ELF

antenna. Sites 5T4 and 5T6 were unaffected by 60 Hz coupling because of their distance from the antenna (>300 meters).

The measured 76 Hz fields match reasonably well with the pre-operation estimates. Some measurements of particular interest are those at points 5T1-1, 5T4-2, and 5T6-1. These measurement points are 200 to 300 meters from the antenna, but have longitudinal electric field intensities greater than points only 80 meters from the antenna (5T2-3). The commonality of the three points is that they are near the E. and L.S. Railroad tracks, which may be coupling to the ELF EM fields and perturbing local field gradients.

TABLE E-4. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Aquatic Ecosystems Studies

Site No., Meas. Pt.	Measurement Year			
	1983	1984	1985	1986
5C1-1	0.002	<0.001	-	-
5C1-2	<0.001	-	-	-
5C1-3	<0.001	-	-	-
5C1-4	-	<0.001	-	-
5C3-2	<0.001	0.003	-	-
5C5-1	0.001	<0.001	-	-
5C14-1	-	0.033	-	-
5T1-1	<0.001	-	-	-
5T1-2	<0.001	-	-	-
5T2-1	-	-	-	-
5T2-2	-	-	-	-
5T2-3	-	-	-	-
5T3-1	-	-	-	-
5T4-1	-	-	-	-
5T4-2	-	-	-	-
5T6-1	-	<0.001	-	-
5T7-1	-	-	-	-

- = site measurement point not established.

- = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.

TABLE E-5. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Aquatic Ecosystems Studies

Site No., Meas. Pt.	Measurement Year			
	1983	1984	1985	1986
5C1-1	1.47, 1.73	2.7	2.6	0.22
5C1-2	1.8	/	/	0.155
5C1-3	1.3	3.0	/	0.126
5C1-4	-	2.5, 2.7	2.2	0.174
5C3-2	0.049	0.045	0.060	0.119
5C5-1	0.076	0.062	0.059	0.077
5C14-1	-	0.174, 0.24	0.22	0.187
5T1-1	0.38	0.38	/	0.125
5T1-2	0.184	0.154, 0.22	0.175	0.037
5T2-1	-	0.22, 0.31	0.23	0.057
5T2-2	-	0.26	0.165	0.082
5T2-3	-	-	-	0.050
5T3-1	-	0.22, 0.26	0.23	0.046
5T4-1	-	0.170, 0.195	/	0.032
5T4-2	-	-	-	0.073
5T6-1	-	0.37, 0.42	0.34	0.047
5T7-1	-	-	-	0.040

- = site measurement point not established.

/ = data not taken.

TABLE E-6. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Aquatic Ecosystems Studies

Site No., Meas. Pt.	Measurement Year			
	1983	1984	1985	1986
5C1-1	0.008	0.008	0.003	0.001
5C1-2	0.006	/	/	0.001
5C1-3	0.004	0.011	/	0.001
5C1-4	-	0.007, 0.008	0.007	0.001
5C3-2	0.003	0.003	0.003	0.005
5C5-1	0.002	0.002	0.002	0.001
5C14-1	-	0.013, 0.021	0.020	0.017
5T1-1	<0.001	<0.001	/	0.002
5T1-2	<0.001	0.001	0.001	0.004
5T2-1	-	0.001, 0.002	0.001	0.005
5T2-2	-	0.002	0.001	0.014
5T2-3	-	-	-	0.004
5T3-1	-	0.001, 0.002	0.001	0.005
5T4-1	-	0.001	/	<0.001
5T4-2	-	-	-	0.001
5T6-1	-	0.001	0.001	0.001
5T7-1	-	-	-	0.001

- = site measurement point not established.

/ = data not taken.

TABLE E-7. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Aquatic Ecosystems Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	Antenna Current and Element			
	(4 Amps)	(6 Amps)		(10 Amps)
	NS (M)	NEW (M)	SEW (M)	SEW (Ex)
5C1-1	-	-	-	--
5C1-2	-	-	-	--
5C1-3	-	-	-	--
5C1-4	-	-	-	--
5C3-2	-	-	-	--
5C5-1	-	-	-	--
5C14-1	-	-	-	--
5T1-1	-	-	-	--
5T1-2	-	-	-	--
5T2-1	0.001	-	-	--
5T2-2	0.011	-	-	--
5T2-3	-	-	-	--
5T3-1	0.008	-	-	--
5T4-1	-	-	-	--
5T4-2	-	-	-	--
5T6-1	-	-	-	--
5T7-1	-	-	-	--

- = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

TABLE E-8. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Aquatic Ecosystems Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	Antenna Current and Element			
	(4 Amps) NS (M)	(6 Amps) NEW (M)	SEW (M)	(10 Amps) SEW (Ex)
5C1-1	0.33	0.020	0.052	0.087
5C1-2	0.24	0.016	0.053	0.088
5C1-3	0.191	0.013	0.047	0.078
5C1-4	0.26	0.014	0.075	0.125
5C3-2	0.126	0.002	0.007	0.012
5C5-1	0.034	0.002	0.009	0.015
5C14-1	0.042	0.004	0.015	0.025
5T1-1	2.5	0.080	0.108	0.180
5T1-2	0.77	0.034	0.097	0.162
5T2-1	1.33	0.045	0.077	0.128
5T2-2	1.62	0.052	0.067	0.112
5T2-3	1.17	0.042	0.079	0.132
5T3-1	1.22	0.045	0.082	0.137
5T4-1	0.75	0.026	0.061	0.102
5T4-2	1.91	0.056	0.077	0.128
5T6-1	1.21	0.030	0.066	0.110
5T7-1	0.76	0.033	0.072	0.120

TABLE E-9. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Aquatic Ecosystems Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	Antenna Current and Element			
	(4 Amps) NS (M)	(6 Amps) NEW (M)	(6 Amps) SEW (M)	(10 Amps) SEW (Ex)
5C1-1	0.001	<0.001	<0.001	--
5C1-2	0.001	<0.001	<0.001	--
5C1-3	0.001	<0.001	<0.001	--
5C1-4	0.001	<0.001	<0.001	--
5C3-2	0.001	<0.001	<0.001	--
5C5-1	0.003	<0.001	0.001	0.002
5C14-1	0.001	<0.001	<0.001	--
5T1-1	0.045	0.001	<0.001	--
5T1-2	0.063	0.002	<0.001	--
5T2-1	0.129	0.004	0.001	0.002
5T2-2	0.31	0.009	0.001	0.002
5T2-3	0.110	0.003	<0.001	--
5T3-1	0.137	0.004	0.001	0.002
5T4-1	0.028	0.001	<0.001	--
5T4-2	0.033	0.001	<0.001	--
5T6-1	0.029	0.001	0.001	0.002
5T7-1	0.011	<0.001	0.001	0.002

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

TABLE E-10. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Aquatic Ecosystems Studies

Site No., Meas. Pt.	Data Extrapolated to 150 Amperes				Pre-Antenna Estimates
	NS	NEW	SEW	NS+NEW+SEW	
5C1-1	--	--	--	--	<0.001
5C1-2	--	--	--	--	<0.001
5C1-3	--	--	--	--	<0.001
5C1-4	--	--	--	--	<0.001
5C3-2	--	--	--	--	<0.001
5C5-1	--	--	--	--	<0.001
5C14-1	--	--	--	--	<0.001
5T1-1	--	--	--	--	0.30
5T1-2	--	--	--	--	1.00
5T2-1	0.038	--	--	0.038	1.00
5T2-2	0.41	--	--	0.41	1.00
5T2-3	--	--	--	--	*
5T3-1	0.30	--	--	0.30	3.5
5T4-1	--	--	--	--	0.100
5T4-2	--	--	--	--	*
5T6-1	--	--	--	--	0.150
5T7-1	--	--	--	--	*

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

* = measurement point established after antenna construction.

TABLE E-11. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Aquatic Ecosystems Studies

Site No., Meas. Pt.	Data Extrapolated to 150 Amperes				Pre-Antenna Estimates
	NS	NEW	SEW	NS+NEW+SEW	
5C1-1	12.4	0.50	1.30	14.2	5.8
5C1-2	9.0	0.40	1.33	10.7	5.8
5C1-3	7.2	0.33	1.18	8.7	5.8
5C1-4	9.8	0.35	1.88	12.0	5.8
5C3-2	4.7	0.050	0.175	4.9	5.7
5C5-1	1.28	0.050	0.23	1.56	12.3
5C14-1	1.58	0.100	0.38	2.1	7.1
5T1-1	94	2.0	2.7	99	47
5T1-2	29	0.85	2.4	32	47
5T2-1	50	1.13	1.93	53	60
5T2-2	61	1.30	1.68	64	68
5T2-3	44	1.05	1.98	47	*
5T3-1	46	1.13	2.1	49	60
5T4-1	28	0.65	1.53	30	36
5T4-2	72	1.40	1.93	75	*
5T6-1	45	0.75	1.65	47	38
5T7-1	29	0.83	1.80	32	*

* = measurement point established after antenna construction.

TABLE E-12. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Aquatic Ecosystems Studies

Site No., Meas. Pt.	Data Extrapolated to 150 Amperes				Pre-Antenna Estimates
	NS	NEW	SEW	NS+NEW+SEW	
5C1-1	0.038	--	--	0.038	0.047
5C1-2	0.038	--	--	0.038	0.047
5C1-3	0.038	--	--	0.038	0.047
5C1-4	0.038	--	--	0.038	0.047
5C3-2	0.038	--	--	0.038	0.037
5C5-1	0.113	--	0.025	0.138	0.070
5C14-1	0.038	--	--	0.038	0.047
5T1-1	1.69	0.025	--	1.72	2.0
5T1-2	2.4	0.050	--	2.5	2.0
5T2-1	4.8	0.100	0.025	4.9	5.0
5T2-2	11.6	0.23	0.025	11.9	10
5T2-3	4.1	0.075	--	4.2	*
5T3-1	5.1	0.100	0.025	5.2	5.0
5T4-1	1.05	0.025	--	1.08	0.95
5T4-2	1.24	0.025	--	1.27	*
5T6-1	1.09	0.025	0.025	1.14	1.10
5T7-1	0.41	--	0.025	0.44	*

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

* = measurement point established after antenna construction.

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APPENDIX F
SOIL AMOEBA STUDIES

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SOIL AMOEBA STUDIES

On 3, 10, and 16 October 1986, 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 amoeba studies. The test and control sites measured in 1986 were all established in previous years. The Michigan Transmitting Facility (MTF) was operational for the first time in 1986. Therefore, 76 Hz EM field measurements were possible for the first time, and measurement points were added within sites to better define the spatial variations of the 76 Hz EM fields at the sites.

The positions of the three 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. Details of measurement locations within sites are shown in Figures F-2 through F-4. Table F-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites.

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.

Several of the above objectives require the use of buried culture chambers at the study sites. The chambers are used to match the internal EM fields of the cultures to those present in the surrounding earth.

The field ratios for the site pairs given in Table F-2 were recalculated using the measured values of the 76 Hz fields extrapolated to a 150 ampere antenna current; Table F-3 shows the results. All of the ratio criteria were met.

Electromagnetic field measurements for 1986 and previous years are found in Tables F-4 through F-12. Tables F-4, F-5, and F-6 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables F-7, F-8, and F-9 present 76 Hz data for these three fields at 1986 MTF operating currents. Tables F-10, F-11, and F-12

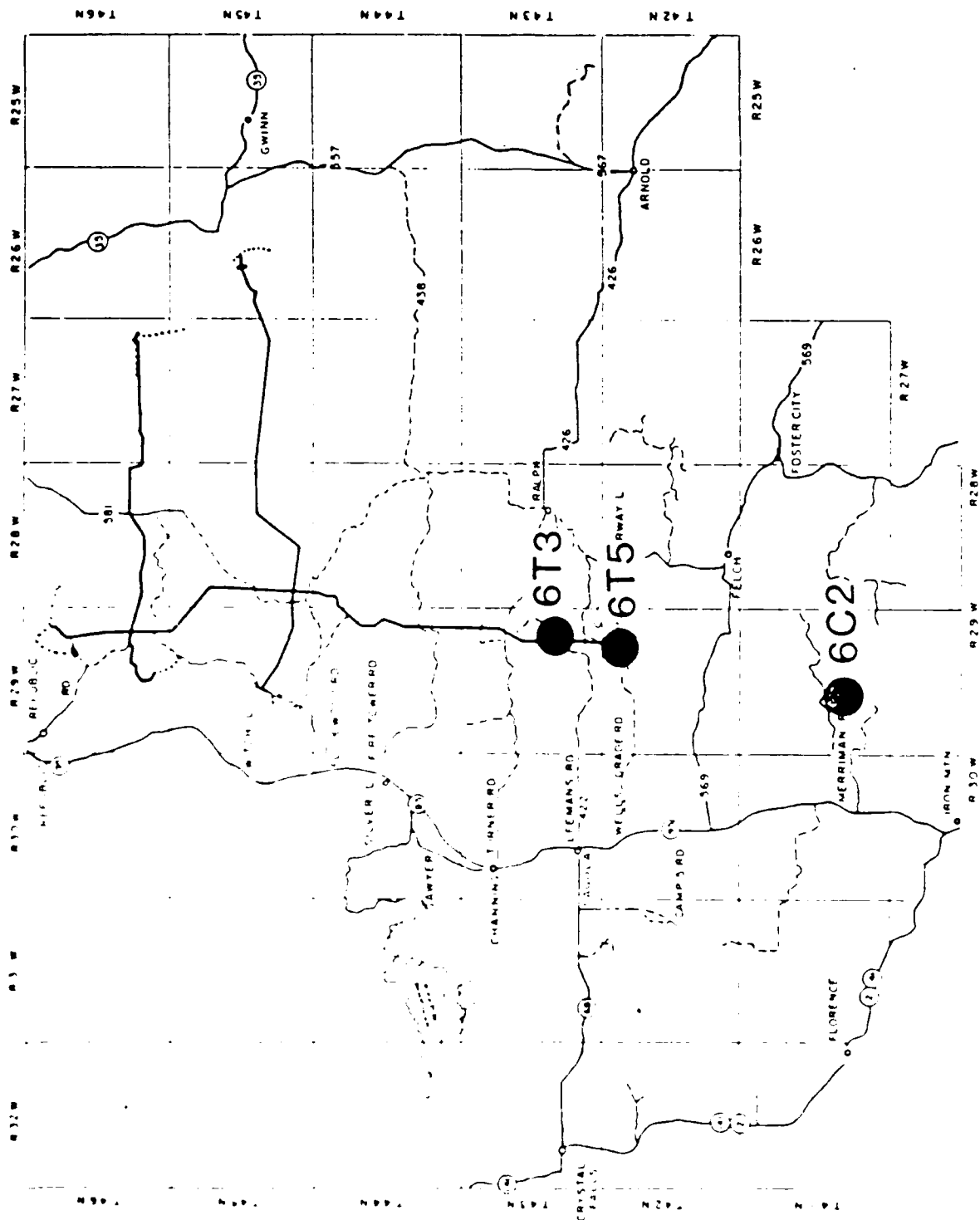


FIGURE F-1. POSITIONS OF SOIL AMOEBA STUDY SITES RELATIVE TO MICHIGAN TRANSMITTING FACILITY ANTENNA ELEMENTS.

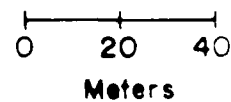
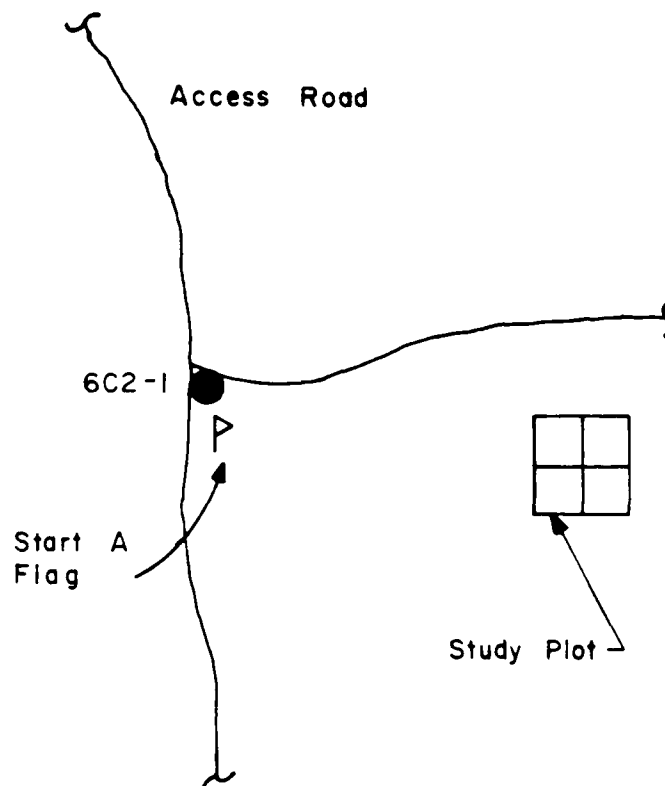
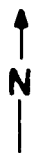


FIGURE F-2. MEASUREMENT POINT AT MERRIMAN
TRUCK TRAIL CONTROL; 6C2-1.

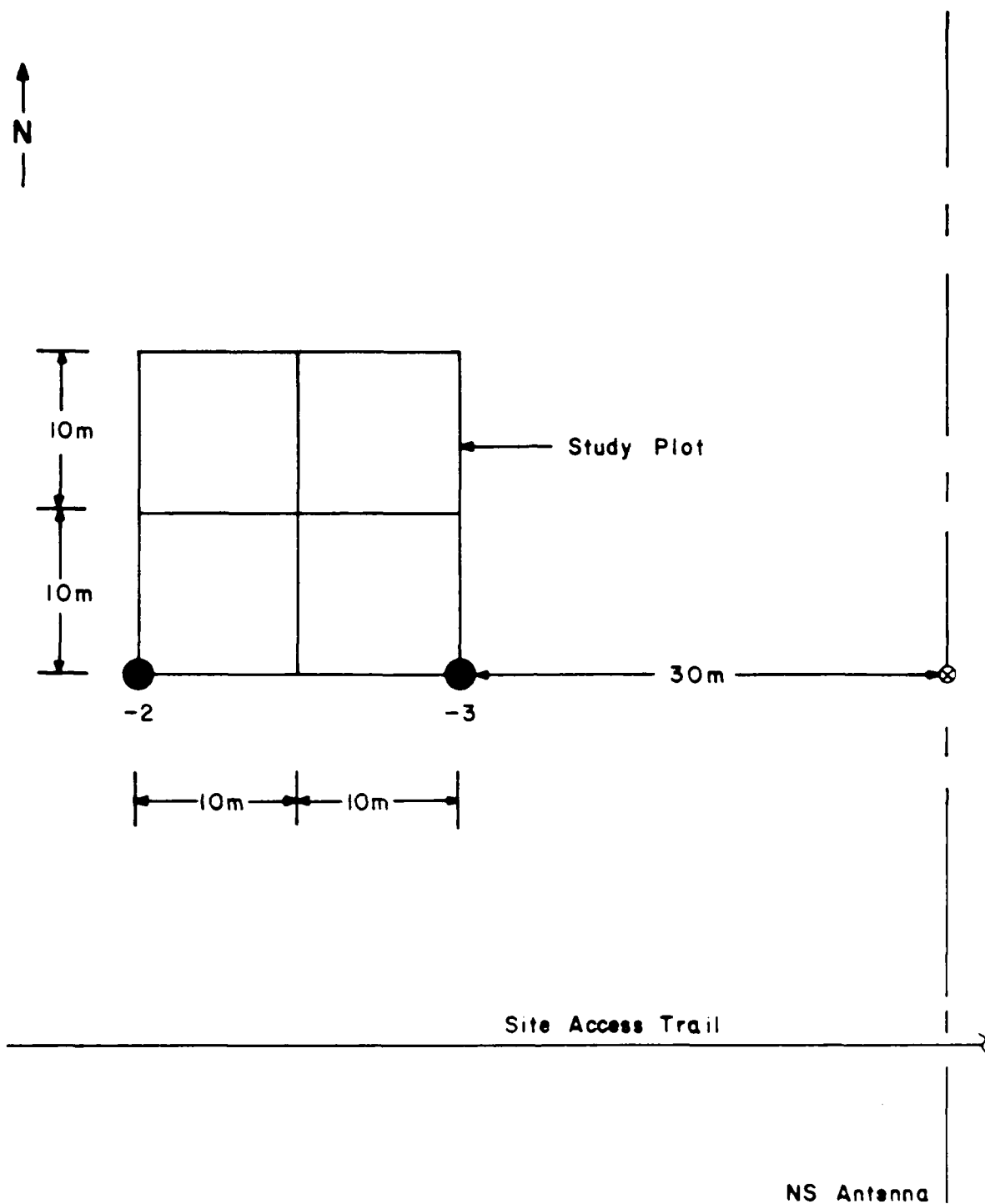


FIGURE F-3. MEASUREMENT POINTS AT LEEMAN'S ROAD;
6T3 - 2,3.

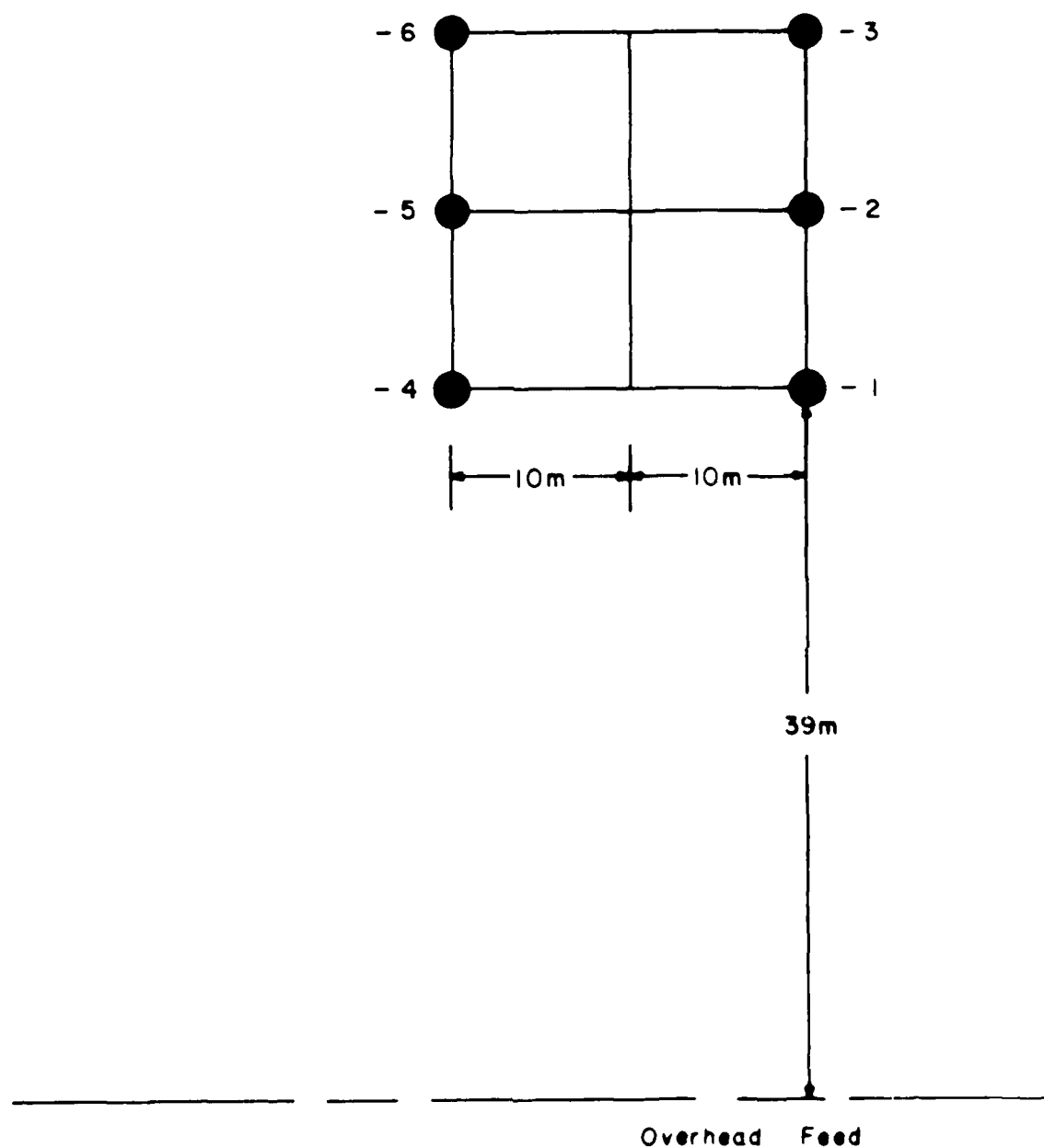


FIGURE F-4. MEASUREMENT POINTS AT WELLS GRADE GROUND;
6T4-1 THROUGH 6.

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

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

TABLE F-2. SITE PAIRINGS
Soil Amoeba Studies

Test Site	Control Site	EM Status
6T3	6C2	A
6T4	6C2	A

A = Acceptable
CA = Conditionally Acceptable
U = Unacceptable

TABLE F-3. FIELD INTENSITY RATIOS
Soil Amoeba Studies

Compared Sites	Transverse Field				Longitudinal Field				Magnetic Field			
	RT	RT	RT	RT	RT	RT	RT	RT	RT	RT	RT	RT
6T3/6C2	38	38	38	1,100	33	610	900	1,34	1,41	31	31	1,100
6T4/6C2	38	38	38	1,000	12,2	500	480	0.64	1,69	1	52	1,100

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present 76 Hz data extrapolated to a full power condition of 150 amperes as well as pre-operation estimates for comparison. (See Section 3.5.2.)

Several measurement points were added at the sites in 1986 to better define the spatial variations of the 76 Hz fields, while measurement points at these sites that were used for the previous year's 60 Hz measurements were retained. Tables F-4, F-5, and F-6 include this history of measurements so that temporal comparisons can be easily made. The Wells Grade ground site (6T4) was relocated in 1985 and labelled 6T5. It was then moved back to the original 6T4 site in 1986. This move is the reason for the lack of data for site 6T4 in 1985 in the 60 Hz data tables.

The 76 Hz EM field measurements for 1986 match the pre-operation estimates reasonably well.

TABLE F-4. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Soil Amoeba Studies

Site No., Meas. Pt.	Measurement Year			
	1983	1984	1985	1986
6C2-1	<0.001	-	-	-
6T3-2	-	-	-	-
6T3-3	-	-	-	-
6T4-1	-	-	/	-
6T4-2	-	-	-	-
6T4-3	-	-	-	-
6T4-4	-	-	-	-
6T4-5	-	-	-	-
6T4-6	-	-	-	-

- = site measurement point not established.

= measurement expected to be <0.001 v/m based on the longitudinal electric field measurement.

/ = data not taken.

**TABLE F-5. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Soil Amoeba Studies**

Site No., Meas. Pt.	Measurement Year			
	1983	1984	1985	1986
6C2-1	0.32	0.61	0.194, 0.28	0.058
6T3-2	-	0.130	/	0.085
6T3-3	-	-	0.134	0.078
6T4-1	-	0.48, 0.52	/	0.072
6T4-2	-	-	-	0.046
6T4-3	-	-	-	0.065
6T4-4	-	-	-	0.037
6T4-5	-	-	-	0.053
6T4-6	-	-	-	0.098

- = site measurement point not established.

/ = data not taken.

**TABLE F-6. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Amoeba Studies**

Site No., Meas. Pt.	Measurement Year			
	1983	1984	1985	1986
6C2-1	0.004	0.008	0.001, 0.003	0.002
6T3-2	-	0.002	/	0.020
6T3-3	-	-	0.003	0.013
6T4-1	-	0.005, 0.007	/	0.005
6T4-2	-	-	-	0.005
6T4-3	-	-	-	0.004
6T4-4	-	-	-	0.002
6T4-5	-	-	-	0.003
6T4-6	-	-	-	0.005

- = site measurement point not established.

/ = data not taken.

TABLE F-7. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Soil Amoeba Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	Antenna Current and Element			
	(4 Amps)	(6 Amps)		(10 Amps)
	NS (M)	NEW (M)	SEW (M)	SEW (Ex)
6C2-1	-	-	-	--
6T3-2	-	-	-	--
6T3-3	-	-	-	--
6T4-1	-	-	-	--
6T4-2	-	-	-	--
6T4-3	-	-	-	--
6T4-4	-	-	-	--
6T4-5	-	-	-	--
6T4-6	-	-	-	--

- = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

TABLE F-8. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Soil Amoeba Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	Antenna Current and Element			
	(4 Amps)	(6 Amps)		(10 Amps)
	NS (M)	NEW (M)	SEW (M)	SEW (Ex)
6C2-1	0.028	0.010	0.011	0.018
6T3-2	1.34	0.041	0.030	0.050
6T3-3	1.45	0.046	0.040	0.067
6T4-1	1.73	0.059	0.007	0.012
6T4-2	0.72	0.023	0.009	0.015
6T4-3	1.14	0.035	0.018	0.030
6T4-4	1.31	0.042	0.006	0.010
6T4-5	0.78	0.027	0.012	0.020
6T4-6	1.27	0.040	0.015	0.025

TABLE F-9. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Amoeba Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	Antenna Current and Element			
	(4 Amps) NS (M)	(6 Amps) NEW (M)	(10 Amps) SEW (M)	(10 Amps) SEW (Ex)
6C2-1	<0.001	<0.001	<0.001	--
6T3-2	0.170	0.006	0.001	0.002
6T3-3	0.28	0.009	0.001	0.002
6T4-1	0.100	0.003	0.001	0.002
6T4-2	0.082	0.003	0.001	0.002
6T4-3	0.071	0.002	<0.001	--
6T4-4	0.090	0.003	0.001	0.002
6T4-5	0.078	0.002	<0.001	--
6T4-6	0.067	0.002	<0.001	--

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

TABLE F-10. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Soil Amoeba Studies

Site No., Meas. Pt.	Data Extrapolated to 150 Amperes				Pre-Antenna Estimates
	NS	NEW	SEW	NS+NEW+SEW	
6C2-1	--	--	--	--	<0.001
6T3-2	--	--	--	--	15
6T3-3	--	--	--	--	15
6T4-1	--	--	--	--	15
6T4-2	--	--	--	--	15
6T4-3	--	--	--	--	15
6T4-4	--	--	--	--	15
6T4-5	--	--	--	--	15
6T4-6	--	--	--	--	15

-- = data cannot be extrapolated from measurement lower than the probe's minimum sensitivity.

TABLE F-11. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Soil Amoeba Studies

Site No., Meas. Pt.	Data Extrapolated to 150 Amperes				Pre-Antenna Estimates
	NS	NEW	SEW	NS+NEW+SEW	
6C2-1	1.05	0.25	0.28	1.58	0.50
6T3-2	50	1.03	0.75	52	65
6T3-3	54	1.15	1.00	56	65
6T4-1	65	1.48	0.175	67	65
6T4-2	27	0.58	0.23	28	65
6T4-3	43	0.88	0.45	44	65
6T4-4	49	1.05	0.150	50	65
6T4-5	29	0.68	0.30	30	65
6T4-6	48	1.00	0.38	49	65

TABLE F-12. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Amoeba Studies

Site No., Meas. Pt.	Data Extrapolated to 150 Amperes				Pre-Antenna Estimates
	NS	NEW	SEW	NS+NEW+SEW	
6C2-1	--	--	--	--	0.020
6T3-2	6.4	0.150	0.025	6.6	10
6T3-3	10.5	0.23	0.025	10.8	10
6T4-1	3.8	0.075	0.025	3.9	10
6T4-2	3.1	0.075	0.025	3.3	10
6T4-3	2.7	0.050		2.7	10
6T4-4	3.4	0.075	0.025	3.6	10
6T4-5	2.9	0.050		3.0	10
6T4-6	2.5	0.050		2.6	10

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

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APPENDIX G
SLIME MOLD STUDIES

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ELF (EXTREMELY LOW FREQUENCY) COMMUNICATIONS SYSTEM
ECOLOGICAL MONITORING. (U) IIT RESEARCH INST CHICAGO IL
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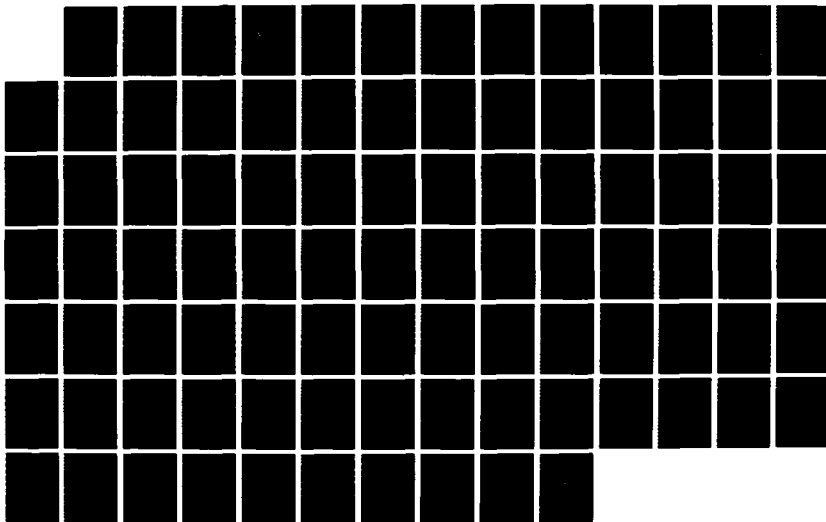
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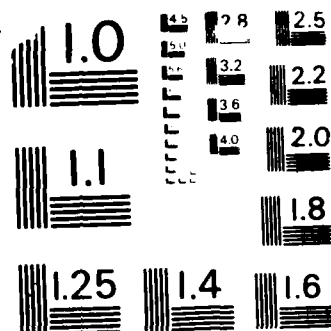
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SLIME MOLD STUDIES

On 12 and 14 August 1986, 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 slime mold studies. The test and control sites measured in 1986 were the same as those measured in 1985. Measurement points were added such that a measurement was made at each culture chamber, instead of at only the center chamber as was done previously. The measurement point numbers are designated with C, N, and S to denote measurements taken at the center, northernmost, and southernmost chambers, respectively.

The positions of the three sites relative to the WTF are shown on the composite map in Figure G-1. The site numbers listed on the map are those used by IITRI. Table G-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites.

The slime mold studies have been designed to monitor for ELF EM field exposure effects on the respiration and mitosis of the slime mold, Physarum polycephalum. The electric and magnetic fields in the earth are considered 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.

TABLE G-1. SITE NO. CROSS-REFERENCE
Slime Mold Studies

IITRI Site No.	Investigator's Site Name	Location		
		Township	: Range	: Section(s)
7A2	Antenna No. 2	T42N	: R5W	: 7
7C1	Control No. 1	T43N	: R2W	: 31
7G3	Ground No. 3	T42N	: R5W	: 7

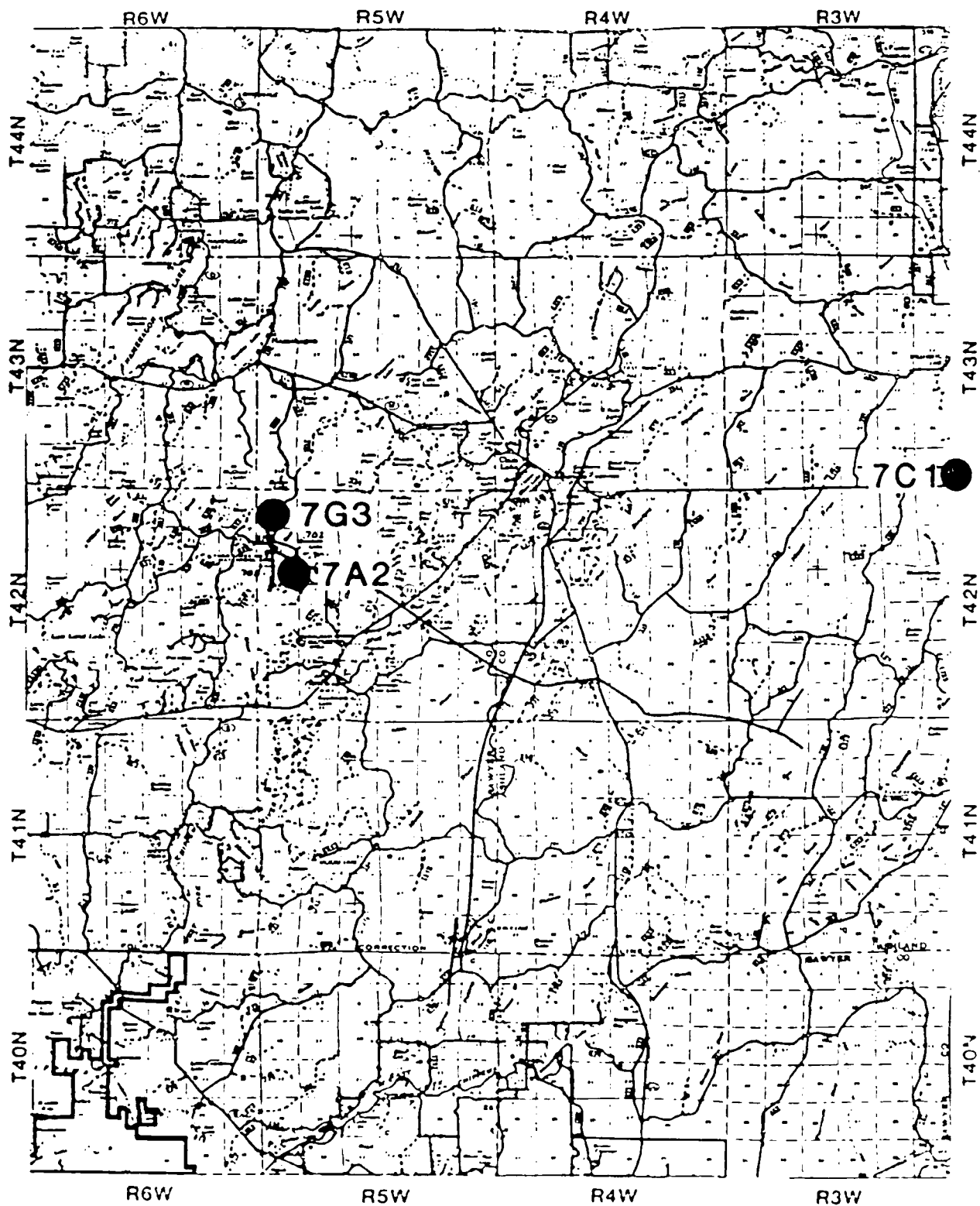


FIGURE G-1. POSITIONS OF SLIME MOLD STUDY SITES RELATIVE TO WISCONSIN TRANSMITTING FACILITY ANTENNA ELEMENTS.

Tables G-2, G-3, and G-4 present a summary of transverse electric field intensities, longitudinal electric field intensities, and magnetic flux densities, respectively, as measured at 76 Hz. Data for 1986 are given for each of the three currently active sites. Where available, data from previous years are presented for reference.

Tables G-3 and G-4 indicate that no significant changes occurred in the 76 Hz longitudinal electric fields or the magnetic fields at either the antenna or control site in 1986. At the ground site, however, the electric field nearly doubled from 1985 values, and the magnetic field levels increased about 25%. These changes are believed to be the result of current rebalancing in the various segments of the west ground terminal by the prime contractor for the Wisconsin Transmitting Facility (WTF).

Measurements of 60 Hz ambient EM fields could not be conducted at the WTF in 1986 as a result of its full-time operation status and modulated signal. Previous 60 Hz measurements are given in the 1985 measurement report.*

*ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1985. IIT Research Institute Technical Report E06549-24, September 1986, 48 pp. plus appendixes.

TABLE G-2. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Slime Mold Studies

Site No., Meas. Pt.	1982		1983		1984		1985		B(-75°)	1986 B(-75°)
	NS	EW	NS	EW	NS	EW	NS	EW		
7A2-C	-	-	-	-	0.004	0.031	/	/	/	/
7A2-N	-	-	-	-	-	-	/	/	/	/
7A2-S	-	-	-	-	-	-	/	/	/	/
7C1-C	/	/	/	/	/	/	/	/	/	/
7C1-N	-	-	-	-	-	-	/	/	/	/
7C1-S	-	-	-	-	-	-	/	/	/	/
7G3-C	-	-	/	/	0.014	1.49	/	/	/	/
7G3-N	-	-	-	-	-	-	/	/	/	/
7G3-S	-	-	-	-	-	-	/	/	/	/

NS = north-south antenna element

EW = east-west antenna element

B = both antenna elements

- = site not established

/ = data not taken

TABLE G-3. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Slime Mold Studies

Site No., Meas. Pt.	1982		1983		1984		1985		B(-75°)	1986 B(-75°)
	NS	EW	NS	EW	NS	EW	NS	EW		
7A2-C	-	-	-	-	3.9, 4.1	200, 240	/	189, 210	200, 220	240
7A2-N	-	-	-	-	-	-	/	210	/	220
7A2-S	-	-	-	-	-	-	/	200	/	156
7C1-C	0.95	0.97	0.96	0.96	1.11	1.13	0.90	/	1.17	1.20
7C1-N	-	-	-	-	-	-	1.03	/	/	1.38
7C1-S	-	-	-	-	-	-	1.00	/	/	1.35
7G3-C	-	-	18	1840	13.3	1460	/	610, 780	570	1000
7G3-N	-	-	-	-	-	-	/	910	/	960
7G3-S	-	-	-	-	-	-	/	980	/	1170

NS = north-south antenna element

EW = east-west antenna element

B = both antenna elements

- = site not established

/ = data not taken

TABLE G-4. 76 Hz Magnetic Flux Densities (mG)
Slime Mold Studies

Site No., Meas. Pt.	1982		1983		1984		1985		B(-75°)	1986 B(-75°)
	NS	EW	NS	EW	NS	EW	NS	EW		
7A2-C	-	-	-	-	0.045,0.051	44	/	44	44	40
7A2-N	-	-	-	-	-	-	/	/	/	42
7A2-S	-	-	-	-	-	-	/	/	/	39
7C1-C	0.012	0.014	0.012	0.013	0.011	0.013	/	/	0.016	0.016
7C1-N	-	-	-	-	-	-	/	/	/	0.016
7C1-S	-	-	-	-	-	-	/	/	/	0.016
7G3-C	-	-	0.060	5.2	0.078	5.6	/	3.2	3.1	3.9
7G3-N	-	-	-	-	-	-	/	/	/	4.0
7G3-S	-	-	-	-	-	-	/	/	/	3.9

NS = north-south antenna element

EW = east-west antenna element

B = both antenna elements

- = site not established

/ = data not taken

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APPENDIX H
WETLANDS STUDIES

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WETLANDS STUDIES

On 11, 13, 15, and 16 August 1986, IITRI field crews made ELF electro-magnetic (EM) field measurements at 66 measurement points at a total of three antenna, two ground, three control, and three intermediate sites for the wetlands studies. All sites measured in 1985 were remeasured in 1986.

The positions of the 11 sites relative to the Wisconsin Transmitting Facility (WTF) are shown on the composite map in Figure H-1. The site numbers listed on the map are those used by IITRI. Table H-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites.

The wetlands studies will examine the competitive ability of three types of wetlands plants (herbs, shrubs, and trees) by examining the organismal characteristics of leaf diffusion and cation transport. The functional operation of the decomposer community will also be assessed by studying the decomposition rate of standardized cellulose material. The electric and magnetic fields in the earth are considered important EM factors influencing wetlands biota and processes. The electric and magnetic fields in the air can influence any object extending above the surface; for this reason, these fields are also considered important factors influencing wetland biota and processes. The specific design of the study plots (long and narrow) and their orientation (parallel to the antenna) diminish the need for field gradient measurements across their width (4 m). However, data were taken at measurement points along the length (60 m) of the plots.

For 1986, measurements were conducted at all six subplots within each study site. Measurement data are presented in Tables H-2 and H-4. Longitudinal (earth) electric field and magnetic field measurements were taken by straddling the water sampling well with the two orthogonal legs of the longitudinal electric field probe.

The transverse (air) electric fields were also measured at each site when possible. The air electric fields are highly influenced by nearby vegetation, which can cause significant localized field shielding or enhancement. Therefore, every attempt was made to locate the air electric field probe in nearby areas that are generally clear of trees or large shrubs, in order to

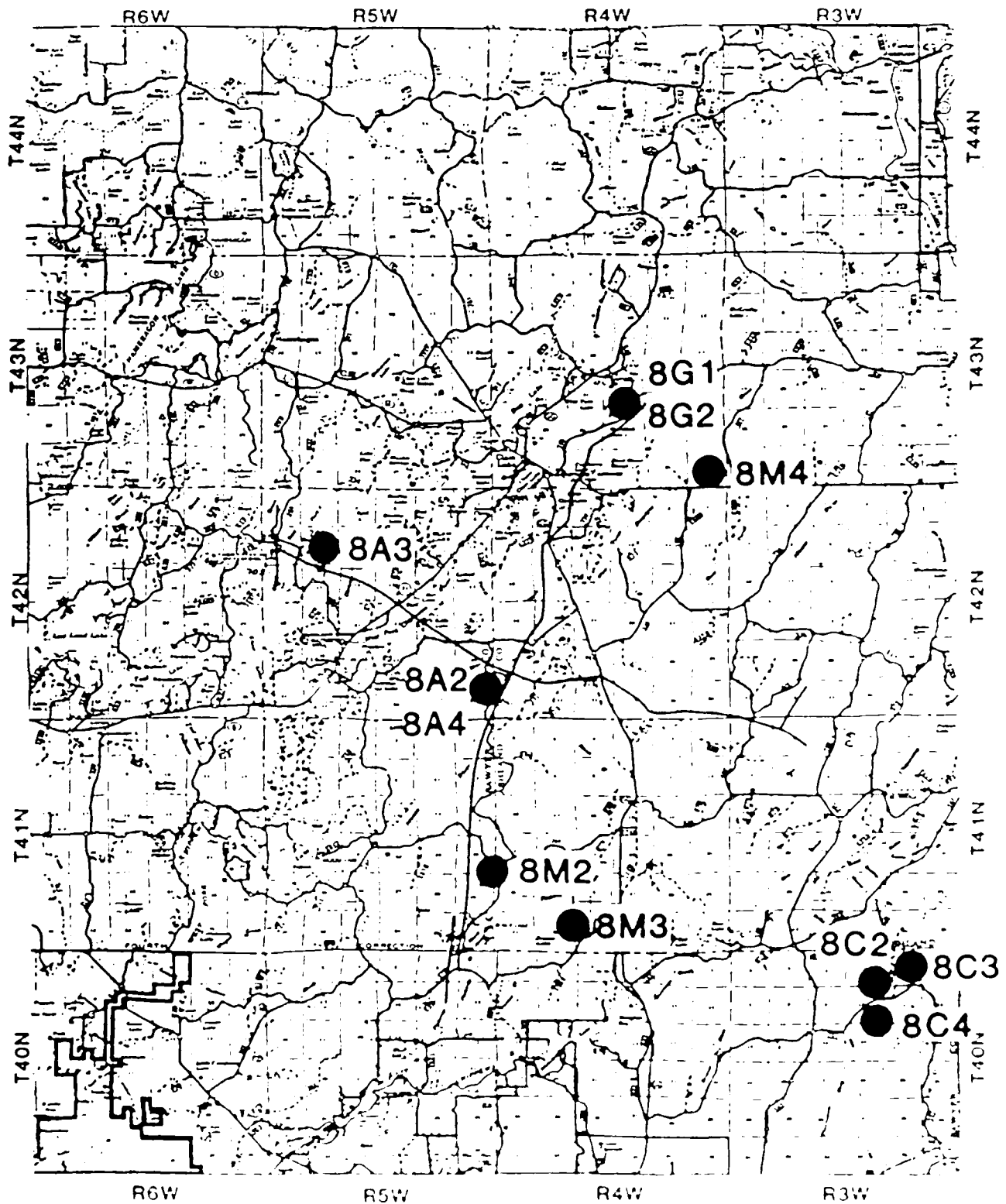


FIGURE H-1. POSITIONS OF WETLAND STUDY SITES RELATIVE TO WISCONSIN TRANSMITTING FACILITY ANTENNA ELEMENTS.

TABLE H-1. SITE NO. CROSS-REFERENCE
Wetlands Studies

IITRI Site No.	Investigator's Site Name	Location		
		Township	: Range	: Section(s)
8A2	UW Site 22 Antenna	T42N	: R4W	: 31
8A3	UW Site 40 Antenna	T42N	: R5W	: 8
8A4	UW Site 21.2 Antenna	T41N	: R5W	: 1
8G1	UW Site 10.1 Ground	T43N	: R4W	: 22
8G2	UW Site 10.2 Ground	T43N	: R4W	: 22
8C2	UW Site 20 Control	T40N	: R3W	: 10
8C3	UW Site 41 Control	T40N	: R3W	: 2
8C4	UW Site 50 Control	T40N	: R3W	: 10
8M2	UW Site 2 Intermediate	T41N	: R4W	: 19
8M3	UW Site 7 Intermediate	T41N	: R4W	: 33
8M4	UW Site 11 Intermediate	T43N	: R4W	: 36

obtain a relatively unperturbed measurement of the air field. These areas were typically within a few meters of the wells. At all wetland sites, the air electric field is generated by the electric field in the earth, which is predominantly horizontal; the overhead antenna wire is too far away to measure a vertical field. The close relationship between the earth and air electric fields is easily seen in the data tables for the antenna, ground, and intermediate sites. For most measurement points, the two field values are within a factor of 1.5 or better. At the control sites, the air electric field intensities were estimated as less than 0.001 V/m, the air probe's limit of sensitivity. This was based on previous measurement attempts and the measured values of the earth electric fields.

Several comments on the measurement data are in order. At sites 8A2-6 through 8A2-6, a significant change in the earth electric field occurred between August 1985 and August 1986. At first glance it appears that the 1986 electric field intensities increased by about 50%. However, measurements taken in May 1985 at site 8A2-6 to document EM field magnitudes versus antenna phasing, and reported in Appendix K of the 1985 measurement report (IITRI Technical Report E06549-24), closely match the August 1986 measurements. This

indicates that the change was due to a 33% decrease in the earth electric fields in August 1985. We have not been able to ascertain the cause of this decrease or its duration.

The ground test sites, 8G1 and 8G2, also experienced EM field changes from 1985 to 1986. Earth electric fields at 8G1 and 8G2 decreased by an average of 12.2% and 16.8%, respectively, and magnetic fields decreased by 50% and 33% respectively. These EM magnitude changes were the result of a redistribution of the currents in this ground segment.

The earth electric fields at intermediate site 8M4 were given incorrectly in the 1985 measurement report. The electric fields at that site are influenced by both antenna elements, and a correction factor obtained from 1985 antenna phase measurements (Appendix K of the 1985 measurement report) must be applied to the normal vector sum field magnitude to obtain the true magnitude. This factor was not applied to the data for 8M4 given in the 1985 report, but has been accounted for in the tables in this appendix.

Measurements of 60 Hz ambient EM fields could not be conducted at the WTF in 1986 as a result of its full-time operation status and modulated signal. Previous 60 Hz measurements are given in the 1985 measurement report.

TABLE H-2. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Wetlands Studies (page 1 of 3)

Site No., Meas. Pt.	1983		1984		1985	1986
	NS	EW	NS	EW	B(-75)	B(-75)
8A2-A	0.174	0.015	--	--	--	--
8A2-B	0.127	0.023	--	--	--	--
8A2-C	0.104	0.011	--	--	--	--
8A2-1	-	-	0.155	0.051	/	0.141
8A2-2	-	-	0.142	0.047	/	0.104
8A2-3	-	-	0.124	0.045	/	0.114
8A2-4	-	-	0.29	0.088	/	0.177
8A2-5	-	-	0.55	0.116	/	0.35
8A2-6	-	-	0.31	0.066	/	0.175
8A3-A	0.009	0.116	--	--	--	--
8A3-B	0.010	0.139	--	--	--	--
8A3-C	0.011	0.163	--	--	--	--
8A3-1	-	-	0.008	0.144	/	0.130
8A3-2	-	-	0.008	0.186	/	0.151
8A3-3	-	-	0.010	0.161	/	0.115
8A3-4	-	-	0.006	0.160	/	0.137
8A3-5	-	-	0.007	0.185	/	0.125
8A3-6	-	-	0.008	0.137	/	0.144
8A3-7	-	-	0.007	0.153	--	--
8A4-1	-	-	0.161	0.007	/	0.066
8A4-2	-	-	0.155	0.006	/	0.087
8A4-3	-	-	0.145	0.007	/	0.106
8A4-4	-	-	0.118	0.005	/	0.095
8A4-5	-	-	0.089	0.005	/	0.079
8A4-6	-	-	0.096	0.005	/	0.098
8C2-A	<0.001	<0.001	--	--	--	--
8C2-B	<0.001	<0.001	--	--	--	--
8C2-1	-	-	-	-	-	-
8C2-2	-	-	-	-	-	-
8C2-3	-	-	-	-	-	-
8C2-4	-	-	-	-	-	-
8C2-5	-	-	-	-	-	-
8C2-6	-	-	-	-	-	-
8C3-A	<0.001	<0.001	--	--	--	--
8C3-B	<0.001	<0.001	--	--	--	--
8C3-C	<0.001	<0.001	--	--	--	--

TABLE H-2. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Wetlands Studies (page 2 of 3)

Site No., Meas. Pt.	1983		1984		1985	1986
	NS	EW	NS	EW	B(-75)	B(-75)
8C3-1	-	-	-	-	-	-
8C3-2	-	-	-	-	-	-
8C3-3	-	-	-	-	-	-
8C3-4	-	-	-	-	-	-
8C3-5	-	-	-	-	-	-
8C3-6	-	-	-	-	-	-
8C4-A	-	-	<0.001	<0.001	--	--
8C4-B	-	-	/	/	--	--
8C4-C	-	-	/	/	--	--
8C4-1	-	-	-	-	-	-
8C4-2	-	-	-	-	-	-
8C4-3	-	-	-	-	-	-
8C4-4	-	-	-	-	-	-
8C4-5	-	-	-	-	-	-
8C4-6	-	-	-	-	-	-
8G1-A	0.59	0.024	--	--	--	--
8G1-B	0.49	0.019	--	--	--	--
8G1-C	0.45	0.017	--	--	--	--
8G1-1	-	-	0.73	0.010	0.25	0.185
8G1-2	-	-	0.59	0.006	0.26	0.22
8G1-3	-	-	0.59	0.006	0.29	0.193
8G1-4	-	-	0.80	0.008	0.32	0.23
8G1-5	-	-	0.68	0.006	0.29	0.166
8G1-6	-	-	0.49	0.004	0.30	0.111
8G2-A	0.29	0.013	--	--	--	--
8G2-B	0.32	0.015	--	--	--	--
8G2-C	0.26	0.010	--	--	--	--
8G2-1	-	-	/	/	0.25	0.150
8G2-2	-	-	/	/	0.181	0.117
8G2-3	-	-	/	/	0.20	0.129
8G2-4	-	-	0.32	0.003	0.24	0.125
8G2-5	-	-	0.39	0.005	0.21	0.107
8G2-6	-	-	0.40	0.004	0.185	0.125
8M2-A	0.058	0.005	--	--	--	--
8M2-B	0.069	0.006	--	--	--	--
8M2-C	0.077	0.008	--	--	--	--

TABLE H-2. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Wetlands Studies (page 3 of 3)

Site No., Meas. Pt.	1983		1984		1985	1986
	NS	EW	NS	EW	B(-75)	B(-75)
8M2-1	-	-	0.054	0.005	0.062	0.047
8M2-2	-	-	0.059	0.005	/	0.054
8M2-3	-	-	0.056	0.006	0.066	0.050
8M2-4	-	-	0.062	0.005	/	0.051
8M2-5	-	-	0.067	0.006	/	0.057
8M2-6	-	-	0.074	0.006	0.065	0.058
8M3-A	0.013	0.005	--	--	--	--
8M3-B	0.013	0.007	--	--	--	--
8M3-C	0.013	0.005	--	--	--	--
8M3-1	-	-	0.016	0.008	0.010	0.006
8M3-2	-	-	0.018	0.008	/	0.010
8M3-3	-	-	0.015	0.006	0.009	0.010
8M3-4	-	-	0.018	0.006	/	0.012
8M3-5	-	-	0.015	0.005	/	0.010
8M3-6	-	-	0.013	0.007	0.011	0.009
8M4-A	/	/	--	--	--	--
8M4-B	/	/	--	--	--	--
8M4-C	/	/	--	--	--	--
8M4-1	-	-	0.010	0.003	/	0.012
8M4-2	-	-	0.008	0.004	/	0.012
8M4-3	-	-	0.008	0.004	/	0.008
8M4-4	-	-	0.007	0.005	/	0.007
8M4-5	-	-	0.010	0.004	/	0.007
8M4-6	-	-	0.010	0.003	/	0.008

NS = north-south antenna element

EW = east-west antenna element

B = both antenna elements

- = site not established

-- = site dropped

/ = data not taken

** 8G1 and 8G2 data for NS antenna element only

TABLE H-3. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Wetlands Studies (page 1 of 3)

Site No., Meas. Pt.	1983		1984		1985	1986
	NS	EW	NS	EW	B(-75)	B(-75)
8A2-A	138	11.4	--	--	--	--
8A2-B	79	13.5	--	--	--	--
8A2-C	45	4.1	--	--	--	--
8A2-1	-	-	116	36	77	118
8A2-2	-	-	98	32	62	100
8A2-3	-	-	96	42	60	106
8A2-4	-	-	176, 177	55, 57	111	182
8A2-5	-	-	360, 370	90, 91	264	340
8A2-6	-	-	151, 153	36	123	147
8A3-A	9.8	134	--	--	--	--
8A3-B	9.3	142	--	--	--	--
8A3-C	9.5	151	--	--	--	--
8A3-1	-	-	8.1	137	137	131
8A3-2	-	-	7.7	151	144	138
8A3-3	-	-	7.4	145	140	138
8A3-4	-	-	7.5	126	118	117
8A3-5	-	-	7.6	152	137	136
8A3-6	-	-	7.8	157	146	146
8A3-7	-	-	7.8	131	--	--
8A3-A	9.8	134	--	--	--	--
8A3-B	9.3	142	--	--	--	--
8A3-C	9.5	151	--	--	--	--
8A4-1	-	-	149	5.6	171	183
8A4-2	-	-	140	5.0	156	155
8A4-3	-	-	121	5.4	121	124
8A4-4	-	-	117	5.6	104	102
8A4-5	-	-	94	4.9	89	91
8A4-6	-	-	88	4.9	77	73
8C2-A	0.62	0.59	--	--	--	--
8C2-B	0.65	0.60	--	--	--	--
8C2-1	-	-	/	/	/	0.98
8C2-2	-	-	/	/	/	1.07
8C2-3	-	-	/	/	1.07	1.09
8C2-4	-	-	0.80	0.76	/	1.24
8C2-5	-	-	0.74	0.70	/	1.04
8C2-6	-	-	0.62	0.60	/	0.89

TABLE H-3. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Wetlands Studies (page 2 of 3)

Site No., Meas. Pt.	1983		1984		1985	1986
	NS	EW	NS	EW	B(-75)	B(-75)
8C3-A	0.81	0.86	--	--	--	--
8C3-B	0.77	0.83	--	--	--	--
8C3-C	0.85	0.91	--	--	--	--
8C3-1	-	-	0.81	0.88	/	1.24
8C3-2	-	-	0.82	0.97	/	1.26
8C3-3	-	-	0.84	0.90	1.32	1.30
8C3-4	-	-	0.85	0.92	/	1.32
8C3-5	-	-	0.84	0.91	/	1.37
8C3-6	-	-	0.79	0.85	/	1.22
8C4-A	-	-	0.93	0.69	--	--
8C4-B	-	-	0.72	0.73	--	--
8C4-C	-	-	0.72	0.70	--	--
8C4-1	-	-	0.83	0.72	/	1.20
8C4-2	-	-	0.84	0.72	/	1.19
8C4-3	-	-	0.74	0.73	/	1.13
8C4-4	-	-	0.85	0.72	1.15	1.15
8C4-5	-	-	0.82	0.69	/	1.10
8C4-6	-	-	0.85	0.72	/	1.10
8G1-A	430	15.9	--	--	--	--
8G1-B	490	18.1	--	--	--	--
8G1-C	410	14.8	--	--	--	--
8G1-1	-	-	420	4.0	195	184
8G1-2	-	-	470	4.6	220	200
8G1-3	-	-	460	4.5	230	230
8G1-4	-	-	470	4.5	230	200
8G1-5	-	-	430	4.1	220	185
8G1-6	-	-	460	4.4	240	176
8G2-A	280	10.9	--	--	--	--
8G2-B	310	12.1	--	--	--	--
8G2-C	230	9.3	--	--	--	--
8G2-1	-	-	280	3.3	184	145
8G2-2	-	-	270	3.0	162	134
8G2-3	-	-	280	3.3	158	130
8G2-4	-	-	260	3.1	143	125
8G2-5	-	-	280	3.4	146	121
8G2-6	-	-	300	3.7	155	132

TABLE H-3. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Wetlands Studies (page 3 of 3)

Site No., Meas. Pt.	1983		1984		1985	1986
	NS	EW	NS	EW	B(-75)	B(-75)
8M2-A	49	4.8	--	--	--	--
8M2-B	55	5.3	--	--	--	--
8M2-C	75	6.4	--	--	--	--
8M2-1	-	-	52	4.2	51	49
8M2-2	-	-	60	4.6	/	56
8M2-3	-	-	58	4.7	57	52
8M2-4	-	-	57	4.8	/	54
8M2-5	-	-	66	5.1	/	59
8M2-6	-	-	70	5.3	64	61
8M3-A	9.5	4.0	--	--	--	--
8M3-B	13.3	6.0	--	--	--	--
8M3-C	11.6	3.6	--	--	--	--
8M3-1	-	-	11.7	5.1	7.7	7.7
8M3-2	-	-	12.0	4.9	/	7.4
8M3-3	-	-	13.5	5.4	9.2	8.7
8M3-4	-	-	15.1	4.7	/	12.7
8M3-5	-	-	12.7	4.1	/	10.4
8M3-6	-	-	13.4	4.5	10	10.1
8M4-A	6.6	3.1	--	--	--	--
8M4-B	2.8	2.8	--	--	--	--
8M4-C	3.1	1.02	--	--	--	--
8M4-1	-	-	6.9	3.1	5.5	5.2
8M4-2	-	-	7.2	3.2	/	5.8
8M4-3	-	-	7.2	3.0	5.5	5.6
8M4-4	-	-	7.2	2.9	/	5.5
8M4-5	-	-	7.0	2.9	/	5.7
8M4-6	-	-	7.0	3.0	5.5	5.6

NS = north-south antenna element

EW = east-west antenna element

B = both antenna elements

- = site not established

-- = site dropped

/ = data not taken

** 8G1 and 8G2 data for NS antenna element only

TABLE H-4. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Wetlands Studies (page 1 of 3)

Site No., Meas. Pt.	1983		1984		1985	1986
	NS	EW	NS	EW	B(-75)	B(-75)
8A2-A	7.5	0.45	--	--	--	--
8A2-B	7.1	0.45	--	--	--	--
8A2-C	7.7	0.45	--	--	--	--
8A2-1	-	-	7.2	0.23	6.9	7.1
8A2-2	-	-	7.1	0.23	6.5	6.9
8A2-3	-	-	7.1	0.23	6.5	6.9
8A2-4	-	-	7.2	0.23	6.7	6.9
8A2-5	-	-	7.2	0.23	6.5	6.9
8A2-6	-	-	7.2	0.23	6.5	6.9
8A3-A	0.055	22	--	--	--	--
8A3-B	0.055	21	--	--	--	--
8A3-C	0.054	23	--	--	--	--
8A3-1	-	-	0.114	19.1	17.5	18.3
8A3-2	-	-	0.115	19.5	17.5	18.0
8A3-3	-	-	0.115	19.4	18.6	18.0
8A3-4	-	-	0.116	20	17.7	18.3
8A3-5	-	-	0.116	20	18.5	19.7
8A3-6	-	-	0.113	18.8	16.5	16.8
8A3-7	-	-	0.126	23	--	--
8A4-1	-	-	8.9	0.154	8.1	8.6
8A4-2	-	-	8.4	0.167	7.9	8.2
8A4-3	-	-	8.0	0.158	7.7	8.0
8A4-4	-	-	8.0	0.158	7.5	7.7
8A4-5	-	-	7.8	0.159	7.5	7.5
8A4-6	-	-	8.0	0.161	7.4	7.5
8C2-A	0.013	0.011	--	--	--	--
8C2-B	0.012	0.011	--	--	--	--
8C2-1	-	-	/	/	/	0.017
8C2-2	-	-	/	/	/	0.017
8C2-3	-	-	/	/	0.016	0.017
8C2-4	-	-	0.013	0.012	/	0.017
8C2-5	-	-	0.013	0.012	/	0.017
8C2-6	-	-	0.013	0.012	/	0.017
8C3-A	0.013	0.012	--	--	--	--
8C3-B	0.013	0.012	--	--	--	--
8C3-C	0.013	0.012	--	--	--	--

TABLE H-4. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Wetlands Studies (page 2 of 3)

Site No., Meas. Pt.	1983		1984		1985	1986
	NS	EW	NS	EW	B(-75)	B(-75)
8C3-1	-	-	0.011	0.011	/	0.015
8C3-2	-	-	0.011	0.011	/	0.015
8C3-3	-	-	0.012	0.011	0.015	0.015
8C3-4	-	-	0.012	0.011	/	0.016
8C3-5	-	-	0.011	0.010	/	0.016
8C3-6	-	-	0.012	0.011	/	0.015
8C4-A	-	-	0.012	0.011	--	--
8C4-B	-	-	0.013	0.011	--	--
8C4-C	-	-	0.013	0.011	--	--
8C4-1	-	-	0.012	0.010	/	0.015
8C4-2	-	-	0.012	0.010	/	0.015
8C4-3	-	-	0.012	0.010	/	0.015
8C4-4	-	-	0.012	0.010	0.015	0.015
8C4-5	-	-	0.011	0.010	/	0.015
8C4-6	-	-	0.011	0.010	/	0.015
8G1-A	2.3	0.083	--	--	--	--
8G1-B	2.3	0.083	--	--	--	--
8G1-C	2.2	0.081	--	--	--	--
8G1-1	-	-	2.1	0.036	1.44	0.74
8G1-2	-	-	2.2	0.036	1.43	0.76
8G1-3	-	-	2.2	0.037	1.39	0.74
8G1-4	-	-	2.1	0.036	1.39	0.74
8G1-5	-	-	2.1	0.036	1.37	0.74
8G1-6	-	-	2.0	0.036	1.26	0.66
8G2-A	0.63	0.038	--	--	--	--
8G2-B	0.68	0.054	--	--	--	--
8G2-C	0.66	0.039	--	--	--	--
8G2-1	-	-	0.64	0.031	0.33	0.22
8G2-2	-	-	0.64	0.032	0.32	0.22
8G2-3	-	-	0.67	0.032	0.33	0.23
8G2-4	-	-	0.68	0.032	0.33	0.23
8G2-5	-	-	0.69	0.030	0.34	0.22
8G2-6	-	-	0.72	0.032	0.32	0.22
8M2-A	0.48	0.074	--	--	--	--
8M2-B	0.49	0.077	--	--	--	--
8M2-C	0.48	0.076	--	--	--	--

TABLE H-4. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Wetlands Studies (page 3 of 3)

Site No., Meas. Pt.	1983		1984		1985	1986
	NS	EW	NS	EW	B(-75)	B(-75)
8M2-1	-	-	0.48	0.072	0.50	0.49
8M2-2	-	-	0.48	0.071	/	0.51
8M2-3	-	-	0.49	0.071	0.51	0.51
8M2-4	-	-	0.48	0.072	/	0.51
8M2-5	-	-	0.49	0.073	/	0.51
8M2-6	-	-	0.49	0.073	0.51	0.50
8M3-A	0.080	0.036	--	--	--	--
8M3-B	0.080	0.037	--	--	--	--
8M3-C	0.078	0.034	--	--	--	--
8M3-1	-	-	0.083	0.036	0.098	0.091
8M3-2	-	-	0.085	0.036	/	0.094
8M3-3	-	-	0.084	0.036	0.097	0.095
8M3-4	-	-	0.084	0.038	/	0.093
8M3-5	-	-	0.084	0.036	/	0.094
8M3-6	-	-	0.085	0.036	0.096	0.094
8M4-A	0.101	0.058	--	--	--	--
8M4-B	0.100	0.047	--	--	--	--
8M4-C	0.088	0.049	--	--	--	--
8M4-1	-	-	0.093	0.055	0.082	0.082
8M4-2	-	-	0.092	0.055	/	0.083
8M4-3	-	-	0.092	0.054	0.083	0.084
8M4-4	-	-	0.091	0.054	/	0.081
8M4-5	-	-	0.091	0.054	/	0.082
8M4-6	-	-	0.091	0.054	0.082	0.083

NS = north-south antenna element

EW = east-west antenna element

B = both antenna elements

- = site not established

-- = site dropped

/ = data not taken

** 8G1 and 8G2 data for NS antenna element only

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APPENDIX I
BIRD SPECIES AND COMMUNITIES STUDIES

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BIRD SPECIES AND COMMUNITIES STUDIES

On 12, 13, and 14 August 1986, IITRI field crews made ELF electromagnetic (EM) field measurements at 22 measurement points at a total of five test and five control sites for the bird species and communities studies in Wisconsin. All sites and measurement points were unchanged from those used for the 1985 measurements.

On 30 September and on 3, 6, 7, 13, and 16 October, IITRI field crews made ELF EM field measurements at a total of 24 measurement points at five test and five control sites for the bird species and communities studies in Michigan. These were the same test and control sites used in 1985. The 1986 measurement points consisted of all but four of those used in 1985, plus five new points at test transects. The Michigan Transmitting Facility (MTF) began testing in 1986, and 76 Hz EM field measurements were possible for the first time.

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

The bird species and communities studies will monitor migrating bird population using a census technique that involves variable-width transects. The study will involve monitoring both the total population of migrating birds in an area as a whole and as a 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.

Wisconsin field activities are described below, followed by those for Michigan.

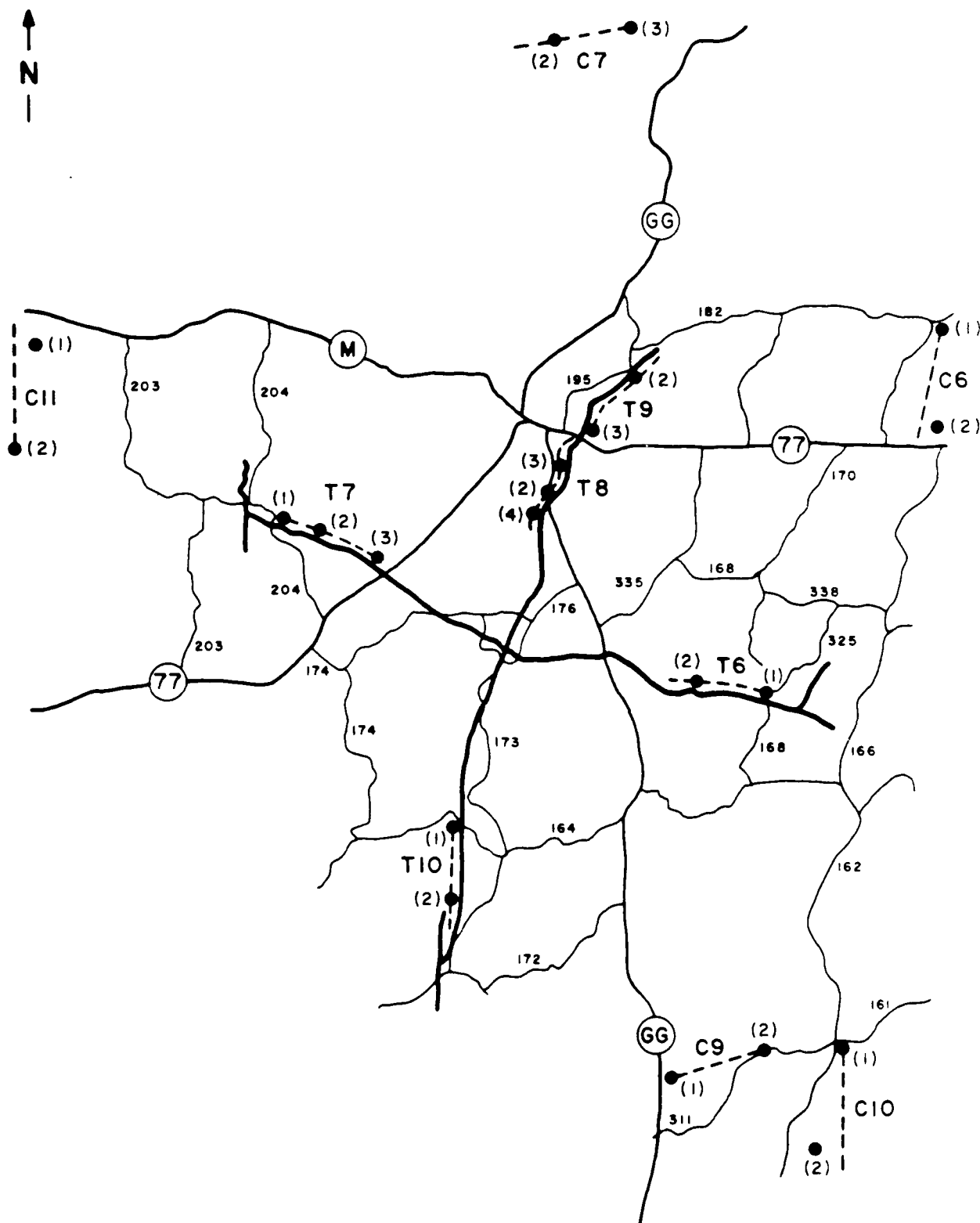


FIGURE I-1. POSITIONS OF BIRD SPECIES AND COMMUNITY STUDIES TRANSECTS RELATIVE TO WISCONSIN TRANSMITTING FACILITY ANTENNA ELEMENTS.

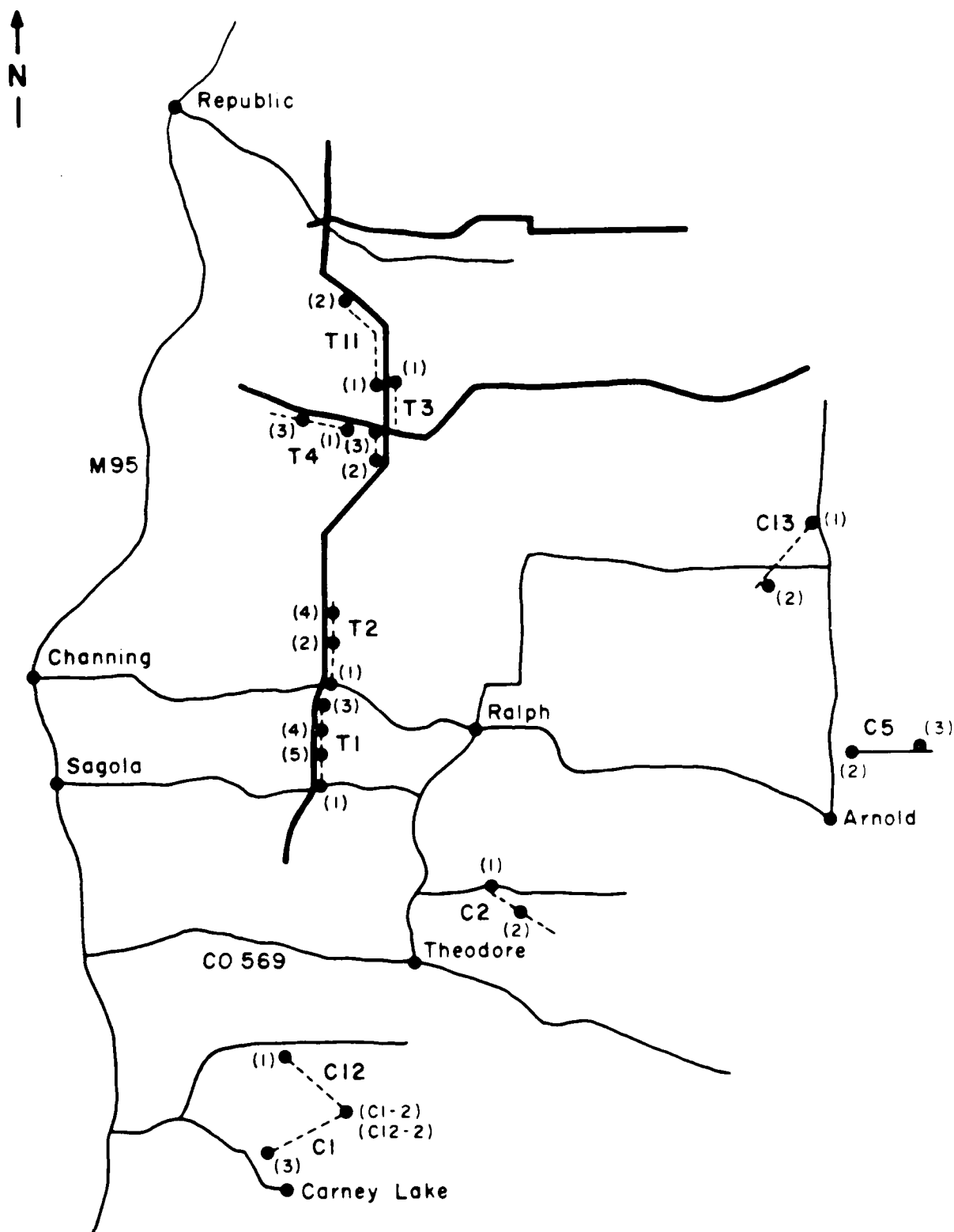


FIGURE I-2. POSITIONS OF BIRD SPECIES AND COMMUNITY STUDIES TRANSECTS RELATIVE TO MICHIGAN TRANSMITTING FACILITY ANTENNA ELEMENTS.

TABLE I-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

The measurement points at the Wisconsin bird species and communities sites were unchanged between 1985 and 1986. Results of the 76 Hz transverse, longitudinal, and magnetic field measurements are presented in Tables I-2, I-3, and I-4. These tables contain 1986 measurement results as well as previous years' measurements where applicable. Only measurements for the simultaneous phased operation of both antenna elements were taken in 1986. In years 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 Tables I-2, I-3, and I-4. Comparing 1986 data with the phased antenna operation data from 1985, one can see that there were no significant differences in any of the field measurements between the years.

Measurements of 60 Hz ambient EM fields could not be conducted at the WTF in 1986 as a result of its full-time operating status and modulated signal. Previous 60 Hz measurements are given in the 1985 report.

Michigan Measurements

The measurement points at the Michigan bird species and communities sites were modified slightly in 1986. Five new measurement points were added (10T1-4, 10T1-5, 10T2-2, 10T3-3, and 10T4-3) and four measurement points were dropped (10C2-3, 10T1-2, 10T2-3, and 10T4-2).

In Michigan, all test sites were compared to all control sites for calculations of the site pair ratio criteria. Table I-5 shows these test/control site pairings and site pair status. The field ratios for the site pairs given in Table I-5 were recalculated in 1986 using the measured values of the 76 Hz fields extrapolated to a 150 ampere antenna current; Table I-6 shows the results.

Two longitudinal R1 electric field ratios (T76/C76) did not satisfy the established criteria. These are at site pairs 10T1/10C13 and 10T2/10C13. At these pairs the longitudinal electric fields at the test sites were only 6.0 and 6.4 times that at the control sites, respectively, because of a higher than predicted field at this control site. Other criteria not met were the R4

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

Site No., Meas. Pt.	1984		1985		B(-75)	1986 B(-75)
	NS	EW	NS	EW		
10C6-1	-	-	/	/	-	-
10C6-2	-	-	/	/	-	-
10C7-2	-	-	-	/	-	-
10C7-3	-	-	-	-	-	-
10C9-1	-	-	/	/	-	-
10C9-2	-	-	/	/	-	-
10C10-1	-	-	/	/	-	-
10C10-2	-	-	/	/	-	-
10C11-1	-	-	-	-	-	-
10C11-2	-	-	-	-	-	-
10T6-1	0.006	0.195	/	/	/	0.166
10T6-2	0.014	0.107	/	/	/	0.090
10T7-1	/	/	/	/	/	0.20
10T7-2	0.014	0.156	/	/	/	0.117
10T7-3	0.015	0.183	/	/	/	0.129
10T8-2	0.089	0.013	/	/	/	0.067
10T8-3	-	-	/	/	/	0.107
10T8-4	-	-	/	/	/	0.078
10T9-2	0.47	0.004	/	/	0.48	0.41
10T9-3	-	-	/	/	/	0.092
10T10-1	0.094	0.007	/	/	0.146	0.07
10T10-2	0.195	0.006	/	/	0.163	0.091

NS = north-south antenna element

EW = east-west antenna element

B = both antenna elements

- = site not established

/ = data not taken

- = measurement expected to be <0.002 V/m based on
longitudinal E-field measurements.

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

Site No., Meas. Pt.	1984		1985		B(-75)	1986 B(-75)
	NS	EW	NS	EW		
10C6-1	1.60	1.08	/	/	1.20	1.12
10C6-2	1.89	1.61	/	/	2.7	2.3
10C7-2	0.47	0.43	0.48	/	0.64	0.59
10C7-3	-	-	0.25, 0.34	0.36	0.59	0.62
10C9-1	1.16	0.44	/	/	0.95	1.12
10C9-2	1.44	1.08	/	/	1.77	2.0
10C10-1	1.40	1.12	/	/	1.98	1.55
10C10-2	0.30	0.31	/	/	0.48	0.55
10C11-1	-	-	0.67	0.59	1.44	1.63
10C11-2	-	-	0.98	0.91	2.0	1.91
10T6-1	6.0	130	/	/	157	184
10T6-2	12.8	88	14.1	95	75	80
10T7-1	20	180	/	/	210	210
10T7-2	13.2	142	/	/	137	99
10T7-3	18.7	159	/	/	104	101
10T8-2	102	15.2	/	/	81	90
10T8-3	-	-	150	13.2	121	114
10T8-4	-	-	73, 85	23, 24	81	66
10T9-2	470	3.5	/	/	350	470
10T9-3	-	-	81	7.8	71	88
10T10-1	73	11.0	77	10.5	104	91
10T10-2	150	6.5	130	11.2	158	94

NS = north-south antenna element

EW = east-west antenna element

B = both antenna elements

- = site not established

/ = data not taken

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

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

NS = north-south antenna element

EW = east-west antenna element

B = both antenna elements

- = site not established

/ = data not taken

**TABLE I-5. SITE PAIRINGS AND STATUS
Bird Species and Communities Studies**

Test Site	Control Site	EM Status
10T1	10C1	A
10T1	10C2	A
10T1	10C5	A
10T1	10C12	A
10T1	10C13	CA
10T2	10C1	A
10T2	10C2	A
10T2	10C5	A
10T2	10C12	A
10T2	10C13	CA
10T3	10C1	CA
10T3	10C2	A
10T3	10C5	CA
10T3	10C12	CA
10T3	10C13	CA
10T4	10C1	A
10T4	10C2	A
10T4	10C5	A
10T4	10C12	A
10T4	10C13	A
10T11	10C1	CA
10T11	10C2	CA
10T11	10C5	A
10T11	10C12	A
10T11	10C13	A

A = Acceptable
CA = Conditionally Acceptable
U = Unacceptable

**TABLE I-6. FIELD INTENSITY RATIOS FOR MICHIGAN TRANSECTS
Bird Species and Communities Studies**

Compared Transects	Transverse E-Field (Air)				Longitudinal E-Field (Earth)				Magnetic Flux Density			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
10T1/10C1	50	38	50	1.00	39	340	250	0.34 - 2.2	41	340	1030	2.0 - 3.0
10T1/10C2	50	38	50	1.00	29	340	450	0.62 - 2.9	29	340	1030	2.0 - 3.0
10T1/10C5	50	38	50	1.00	51	340	100	0.136 - 0.62	114	340	172	0.33 - 1.50
10T1/10C12	50	38	50	1.00	15.8	340	250	0.34 - 2.1	30	340	520	1.00 - 3.0
10T1/10C13	50	38	50	1.00	6.0	340	180	0.24 - 0.40	27	340	147	0.29 - 3.0
10T2/10C1	75	75	75	1.00	42	500	270	0.50 - 1.05	41	520	1030	1.00 - 3.0
10T2/10C2	75	75	75	1.00	31	500	490	0.91 - 1.41	29	520	1030	1.00 - 3.0
10T2/10C5	75	75	75	1.00	55	500	108	0.20 - 0.30	114	520	172	0.167 - 1.50
10T2/10C12	75	75	75	1.00	17.1	500	270	0.50 - 1.00	30	520	520	0.50 - 3.0
10T2/10C13	75	75	75	1.00	6.4	500	194	0.36 - 0.193	27	520	147	0.143 - 3.0
10T3/10C1	150	62	150	1.00	81	360	510	0.68 - 2.6	54	220	1340	6.0 - 12.0
10T3/10C2	150	62	150	1.00	60	360	950	1.25 - 3.5	37	220	1340	6.0 - 12.0
10T3/10C5	150	62	150	1.00	106	360	210	0.28 - 0.75	149	220	220	1.00 - 6.0
10T3/10C12	150	62	150	1.00	33	360	510	0.68 - 2.5	39	220	670	3.0 - 12.0
10T3/10C13	150	62	150	1.00	12.4	360	370	0.50 - 0.48	35	220	191	0.86 - 12.0
10T4/10C1	75	75	75	1.00	108	590	680	1.11 - 2.3	120	1500	3000	1.00 - 2.0
10T4/10C2	75	75	75	1.00	79	590	1250	2.0 - 3.1	83	1500	3000	1.00 - 2.0
10T4/10C5	75	75	75	1.00	141	590	280	0.45 - 0.67	330	1500	500	0.167 - 1.00
10T4/10C12	75	75	75	1.00	44	590	680	1.11 - 2.2	88	1500	1500	0.50 - 2.0
10T4/10C13	75	75	75	1.00	16.4	590	500	0.81 - 0.43	79	1500	430	0.143 - 2.0
10T11/10C1	38	38	38	1.00	73	150	470	1.70 - 10.5	58	220	1440	6.0 - 8.0
10T11/10C2	38	38	38	1.00	54	150	850	3.1 - 14.1	40	220	1440	6.0 - 8.0
10T11/10C5	38	38	38	1.00	96	150	188	0.69 - 3.0	160	220	240	1.00 - 4.0
10T11/10C12	38	38	38	1.00	30	150	470	1.70 - 10.0	42	220	720	3.0 - 8.0
10T11/10C13	38	38	38	1.00	11.2	150	340	1.24 - 1.93	38	220	210	0.86 - 8.0

magnetic flux density ratio (T60/C60) at four site pairs involving 10T3 (10T3/10C1, 10T3/10C2, 10T3/10C12, and 10T3/10C13) and the R4 longitudinal fields at two pairs involving 10T11 (10T11/10C1 and 10T11/10C2). The magnetic flux R4 ratio increased because of an increased 60 Hz magnetic field, most likely due to coupling of power lines to the antenna at test site 10T3. The longitudinal electric field R4 ratio increased because the 60 Hz longitudinal electric field dropped by a factor of about 4 between 1985 and 1986 at control sites 10C1 and 10C2.

All other criteria were met, and all of the test/control site pairs for the bird species and communities studies fell into either the acceptable or conditionally acceptable categories, as shown in Table I-5.

EM measurements for Michigan in 1986 and previous years are found in Tables I-7 through I-15. Tables I-7, I-8, and I-9 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables I-10, I-11, and I-12 present 76 Hz data for these three fields at 1986 MTF operating currents. Tables I-13, I-14, and I-15 present 76 Hz data extrapolated to a full power condition of 150 amperes as well as pre-operation estimates for comparison.

The 60 Hz transverse electric field was not detectable at any of the Michigan measurement points either in 1986 or previous years. The 60 Hz longitudinal electric field and magnetic flux varied somewhat between 1986 and previous years, but not more than would be expected. The 76 Hz EM measurements made in 1986 matched well with pre-antenna operation estimates.

TABLE I-7. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Bird Species and Communities Studies
Michigan Transects

Site No., Meas. Pt.	Measurement Year			
	1983	1984	1985	1986
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	-	-	-	-
10T3-1	-	-	-	-
10T3-2	-	-	-	-
10T3-3	-	-	-	-
10T4-1	-	-	-	-
10T4-3	-	-	-	-
10T11-1	-	-	-	-
10T11-2	-	-	-	-

- = site measurement point not established.

- = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.

TABLE I-8. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Bird Species and Communities Studies
Michigan Transects

Site No., Meas. Pt.	Measurement Year			
	1983	1984	1985	1986
10C1-2	-	0.62	0.106, 0.141	0.101
10C1-3	-	-	0.26, 0.27	0.055
10C2-1	-	0.98	0.138	0.041
10C2-2	-	0.35	0.21	0.055
10C5-2	-	0.35	0.45	0.193
10C5-3	-	0.111	0.23	0.25
10C12-1	-	-	0.194, 0.28	0.058
10C12-2	-	-	0.106, 0.141	0.101
10C13-1	-	-	0.34, 0.52	0.30
10C13-2	-	-	0.143, 0.31	0.139
10T1-1	-	0.076	0.061	0.034
10T1-3	-	-	0.38	0.120
10T1-4	-	-	-	0.111
10T1-5	-	-	-	0.040
10T2-1	-	0.42	0.194	0.050
10T2-2	-	-	-	0.058
10T2-4	-	-	0.158	0.054
10T3-1	-	0.30	0.23	0.145
10T3-2	-	0.26	0.117	0.069
10T3-3	-	-	-	0.094
10T4-1	-	0.29	0.132	0.129
10T4-3	-	-	-	0.112
10T11-1	-	-	0.23	0.172
10T11-2	-	-	0.26, 0.50	0.58

- = site measurement point not established.

TABLE I-9. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Bird Species and Communities Studies
Michigan Transects

Site No., Meas. Pt.	Measurement Year			
	1983	1984	1985	1986
10C1-2	-	0.001	0.001	<0.001
10C1-3	-	-	0.001, 0.003	<0.001
10C2-1	-	0.005	0.004	<0.001
10C2-2	-	0.003	0.003	<0.001
10C5-2	-	0.008	0.009	0.006
10C5-3	-	0.001	0.002	0.002
10C12-1	-	-	0.001, 0.003	0.002
10C12-2	-	-	0.001	<0.001
10C13-1	-	-	0.007, 0.010	0.007
10C13-2	-	-	0.001, <0.001	0.001
10T1-1	-	0.006	0.004	0.002
10T1-3	-	-	0.002	0.003
10T1-4	-	-	-	0.003
10T1-5	-	-	-	0.003
10T2-1	-	0.002	0.002	0.003
10T2-2	-	-	-	<0.001
10T2-4	-	-	0.001	0.002
10T3-1	-	0.001	0.001	0.006
10T3-2	-	0.001	<0.001	0.008
10T3-3	-	-	-	0.012
10T4-1	-	0.001	<0.001	0.002
10T4-3	-	-	-	0.001
10T11-1	-	-	<0.001	0.006
10T11-2	-	-	0.001, <0.001	0.008

- = site measurement point not established.

TABLE I-10. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
 Bird Species and Communities Studies
 Michigan Transects
 Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	Antenna Current and Element			
	(4 Amps) NS (M)	(6 Amps) NEW (M)	SEW (M)	(10 Amps) SEW (Ex)
10C1-2	-	-	-	--
10C1-3	-	-	-	--
10C2-1	-	-	-	--
10C2-2	-	-	-	--
10C5-2	-	-	-	--
10C5-3	-	-	-	--
10C12-1	-	-	-	--
10C12-2	-	-	-	--
10C13-1	-	-	-	--
10C13-2	-	-	-	--
10T1-1	-	-	-	--
10T1-3	0.002	-	-	--
10T1-4	-	-	-	--
10T1-5	-	-	-	--
10T2-1	0.002	-	-	--
10T2-2	0.002	-	-	--
10T2-4	0.002	-	-	--
10T3-1	0.004	-	-	--
10T3-2	0.004	-	0.001	0.002
10T3-3	0.005	-	0.017	0.028
10T4-1	0.002	-	0.003	0.005
10T4-3	-	-	0.003	0.005
10T11-1	-	-	-	--
10T11-2	-	-	-	--

- = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

TABLE I-11. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
 Bird Species and Communities Studies
 Michigan Transects
 Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	Antenna Current and Element			
	(4 Amps) NS (M)	(6 Amps) NEW (M)	SEW (M)	(10 Amps) SEW (Ex)
10C1-2	0.004	0.003	0.004	0.007
10C1-3	0.013	0.004	0.002	0.003
10C2-1	0.017	0.002	0.007	0.012
10C2-2	0.011	0.003	0.007	0.012
10C5-2	0.001	0.003	0.007	0.012
10C5-3	0.005	0.003	0.009	0.015
10C12-1	0.028	0.010	0.011	0.018
10C12-2	0.004	0.003	0.004	0.007
10C13-1	0.024	0.027	0.104	0.173
10C13-2	0.024	0.023	0.098	0.163
10T1-1	0.85	0.028	0.008	0.013
10T1-3	2.2	0.068	0.077	0.128
10T1-4	0.96	0.030	0.031	0.052
10T1-5	0.65	0.020	0.006	0.010
10T2-1	1.42	0.043	0.077	0.128
10T2-2	1.69	0.056	0.107	0.178
10T2-4	0.59	0.056	0.158	0.26
10T3-1	0.82	0.23	0.60	1.00
10T3-2	1.24	0.133	1.05	1.75
10T3-3	1.36	<0.001	3.6	6.0
10T4-1	0.88	0.137	1.58	2.6
10T4-3	0.46	0.139	1.92	3.2
10T11-1	0.67	0.27	0.59	0.98
10T11-2	1.38	0.93	0.44	0.73

TABLE I-12. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Bird Species and Communities Studies
Michigan Transects
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	Antenna Current and Element			
	(4 Amps) NS (M)	(6 Amps) NEW (M)	SEW (M)	(10 Amps) SEW (Ex)
10C1-2	<0.001	<0.001	<0.001	--
10C1-3	<0.001	<0.001	<0.001	--
10C2-1	<0.001	<0.001	<0.001	--
10C2-2	<0.001	<0.001	<0.001	--
10C5-2	<0.001	<0.001	<0.001	--
10C5-3	<0.001	<0.001	<0.001	--
10C12-1	<0.001	<0.001	<0.001	--
10C12-2	<0.001	<0.001	<0.001	--
10C13-1	<0.001	<0.001	<0.001	--
10C13-2	<0.001	<0.001	<0.001	--
10T1-1	0.044	0.001	<0.001	--
10T1-3	0.047	0.001	0.007	0.012
10T1-4	0.026	0.001	0.001	0.002
10T1-5	0.034	0.001	0.001	0.002
10T2-1	0.066	0.002	0.001	0.002
10T2-2	0.043	0.001	0.001	0.002
10T2-4	0.026	0.001	0.001	0.002
10T3-1	0.029	0.003	0.007	0.012
10T3-2	0.081	0.002	0.013	0.022
10T3-3	0.116	0.40	0.58	0.97
10T4-1	0.025	0.001	0.081	0.135
10T4-3	0.025	0.001	0.119	0.198
10T11-1	0.033	0.002	0.006	0.010
10T11-2	0.042	0.003	0.003	0.005

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

TABLE I-13. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Bird Species and Communities Studies
Michigan Transects

Site No., Meas. Pt.	Data Extrapolated to 150 Amperes				Pre-Antenna Estimates
	NS	NEW	SEW	NS+NEW+SEW	
10C1-2	--	--	--	--	<0.001
10C1-3	--	--	--	--	<0.001
10C2-1	--	--	--	--	<0.001
10C2-2	--	--	--	--	<0.001
10C5-2	--	--	--	--	<0.001
10C5-3	--	--	--	--	<0.001
10C12-1	--	--	--	--	<0.001
10C12-2	--	--	--	--	<0.001
10C13-1	--	--	--	--	<0.001
10C13-2	--	--	--	--	<0.001
10T1-1	--	--	--	--	0.050 - 0.50
10T1-3	0.075	--	--	0.075	0.050 - 0.50
10T1-4	--	--	--	--	0.050 - 0.50
10T1-5	--	--	--	--	0.050 - 0.50
10T2-1	0.075	--	--	0.075	0.050 - 0.50
10T2-2	0.075	--	--	0.075	0.050 - 0.50
10T2-4	0.075	--	--	0.075	0.050 - 0.50
10T3-1	0.150	--	--	0.150	0.050 - 0.50
10T3-2	0.150	--	0.025	0.175	0.050 - 0.50
10T3-3	0.188	--	0.43	0.62	0.050 - 0.50
10T4-1	0.075	--	0.075	0.150	0.050 - 0.50
10T4-3	--	--	0.075	0.075	0.050 - 0.50
10T11-1	--	--	--	--	0.050 - 0.50
10T11-2	--	--	--	--	0.050 - 0.50

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

TABLE I-14. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Bird Species and Communities Studies
Michigan Transects

Site No., Meas. Pt.	Data Extrapolated to 150 Amperes				Pre-Antenna Estimates
	NS	NEW	SEW	NS+NEW+SEW	
10C1-2	0.150	0.075	0.100	0.33	0.50
10C1-3	0.49	0.100	0.050	0.64	0.50
10C2-1	0.64	0.050	0.175	0.87	2.0
10C2-2	0.41	0.075	0.175	0.66	1.00
10C5-2	0.038	0.075	0.175	0.29	0.50
10C5-3	0.188	0.075	0.23	0.49	0.50
10C12-1	1.05	0.25	0.28	1.58	1.00
10C12-2	0.150	0.075	0.100	0.33	1.00
10C13-1	0.90	0.68	2.6	4.2	1.00
10C13-2	0.90	0.58	2.5	4.0	1.00
10T1-1	32	0.70	0.20	33	48
10T1-3	83	1.70	1.93	87	48
10T1-4	36	0.75	0.78	38	48
10T1-5	24	0.50	0.150	25	48
10T2-1	53	1.08	1.93	56	48
10T2-2	63	1.40	2.7	67	48
10T2-4	22	1.40	4.0	27	48
10T3-1	31	5.8	15.0	52	48
10T3-2	47	3.3	26	76	48
10T3-3	5	--	90	141	48
10T4-1	33	3.4	40	76	48
10T4-3	17.3	3.5	48	69	48
10T11-1	25	6.8	14.8	47	48
10T11-2	52	23	11.0	86	48

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

TABLE I-15. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Bird Species and Communities Studies
Michigan Transects

Site No.- Meas. Pt.	Data Extrapolated to 150 Amperes				Pre-Antenna Estimates
	NS	NEW	SEW	NS+NEW+SEW	
10C1-2	--	--	--	--	0.025
10C1-3	--	--	--	--	0.025
10C2-1	--	--	--	--	0.036
10C2-2	--	--	--	--	0.028
10C5-2	--	--	--	--	0.009
10C5-3	--	--	--	--	0.008
10C12-1	--	--	--	--	0.034
10C12-2	--	--	--	--	0.025
10C13-1	--	--	--	--	0.040
10C13-2	--	--	--	--	0.036
10T1-1	1.65	0.025	--	1.68	2.5
10T1-3	1.76	0.025	0.175	1.96	2.5
10T1-4	0.98	0.025	0.025	1.03	2.5
10T1-5	1.28	0.025	0.025	1.33	2.5
10T2-1	2.5	0.050	0.025	2.6	2.5
10T2-2	1.61	0.025	0.025	1.66	2.5
10T2-4	0.98	0.025	0.025	1.03	2.5
10T3-1	1.09	0.075	0.175	1.34	2.5
10T3-2	3.0	0.050	0.33	3.4	2.5
10T3-3	4.4	10.0	14.5	29	
10T4-1	0.94	0.025	2.0	3.0	2.5
10T4-3	0.94	0.025	3.0	4.0	
10T11-1	1.24	0.050	0.150	1.44	2.5
10T11-2	1.58	0.075	0.075	1.73	2.5

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

APPENDIX J

EM EXPOSURE CRITERIA AND SITE PAIR RATIO CALCULATIONS

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EM EXPOSURE CRITERIA AND SITE PAIR RATIO CALCULATIONS

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 fields at the test site, and the 60 Hz 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:

- (1) $T (76 \text{ Hz}) / C (76 \text{ Hz}) > 10$
- (2) $T (76 \text{ Hz}) / T (60 \text{ Hz}) > 10$
- (3) $T (76 \text{ Hz}) / C (60 \text{ Hz}) > 10$
- (4) $0.1 < T (60 \text{ Hz}) / C (60 \text{ Hz}) < 10$

where: $T (76 \text{ Hz})$ = Test site exposure due to ELF system

$T (60 \text{ Hz})$ = Test site exposure due to power lines

$C (76 \text{ Hz})$ = Control site exposure due to ELF system

$C (60 \text{ Hz})$ = Control site exposure due to power lines.

Test and control site pairings were assessed for acceptability using the exposure criteria for each of the three EM fields produced by the ELF Communications System. This assessment has been completed for study sites in Wisconsin. Prior to 1986, site pair ratios were computed for Michigan study sites based on estimates of the 76 Hz EM fields. Since the Michigan Transmitting Facility (MTF) began operating at low currents in 1986, 76 Hz measurements were possible for the first time, and Michigan site pair ratios were recalculated on the basis of these 76 Hz low current measurements. At most sites, however, the 76 Hz EM field contributions from some antenna elements were lower than the sensitivity of the measurement probes (.001 V/m, .001 mV/m, and .001 mG for the transverse electric, longitudinal electric, and magnetic fields, respectively). Therefore, the 76 Hz measurement data were

extrapolated to a full power antenna current of 150 amperes for the ratio calculations according to the following guidelines:

- Actual field measurement data for each antenna element were linearly extrapolated to an antenna current of 150 amperes.
- Where the field level from an antenna element was below the probe's sensitivity, the probe sensitivity level was taken as the measured value and extrapolated to 150 amperes. This calculated value was compared to the earlier field estimate, and the lesser of the two was used as the field contribution.
- For each of the three EM field types, the contributions from each antenna element were algebraically summed. This gives the maximum field level that could be produced by the simultaneous operation of all antenna elements. These field maximums were used for 76 Hz ratio calculations.

In cases where the 60 Hz EM fields were below probe sensitivity, the probe sensitivity levels were used for the ratio calculation. This is a conservative approach for computations of R2 and R3, but a generally liberal approach for the R4 calculation.

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 greater 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.

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APPENDIX K
EM MEASUREMENTS VS. WTF ANTENNA PHASE

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EM MEASUREMENTS VS. WTF ANTENNA PHASE

Tables K-1 through K-6 document EM field measurements as a function of the Wisconsin Transmitting Facility (WTF) antenna current phase angle for study sites 8A2, 8M3, 8M4, 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 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 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° , as this is the most commonly used WTF condition.

TABLE K-1. EM MEASUREMENTS VS. ANTENNA PHASE FOR 8A2-6

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 $B_{VERT.}$
8A2-6	NS only	189	195	1.03	7.1	7.1
	EW only	66	67	1.02	0.27	0.26
	0	137	138	1.01	7.3	7.3
	-30	131	131	1.00	7.3	7.3
	-60	147	143	0.97	7.2	7.2
	-75			1.01		
	-90	160	168	1.05	7.2	7.2
	-120	210	210	1.00	7.1	7.1
	-150	230	240	1.04	7.0	6.9
	-180	250	250	1.00	6.8	6.7
	-210	250	250	1.00	6.9	6.8
	-240	240	250	1.04	6.9	6.8
	-270	220	230	1.04	7.0	6.9
	-300	190	195	1.03	7.1	7.1
	-330	160	168	1.05	7.2	7.2

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

TABLE K-2. EM MEASUREMENTS VS. ANTENNA PHASE FOR 8M3-1

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.}
8M3-1	NS only	10.6	10.5	0.99	0.079	0.051
	EW only	4.8	5.0	1.04	0.035	0.0167
	0	9.2	8.5	0.92	0.106	0.064
	-30	7.7	7.8	1.01	0.109	0.068
	-60	7.3	7.6	1.04	0.103	0.066
	-75			1.01		
	-90	8.4	8.3	0.99	0.094	0.062
	-120	10.2	10.2	1.00	0.082	0.056
	-150	12.3	12.0	0.98	0.069	0.047
	-180	13.5	13.6	1.01	0.060	0.038
	-210	14.7	14.6	0.99	0.059	0.035
	-240	14.9	14.5	0.97	0.068	0.037
	-270	14.2	13.6	0.96	0.080	0.046
	-300	13.0	12.0	0.92	0.093	0.054
	-330	11.2	10.2	0.91	0.101	0.060

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

TABLE K-3. EM MEASUREMENTS VS. ANTENNA PHASE FOR 8M4-1

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 $B_{Vert.}$
8M4-1	NS only	6.6	6.5	0.98	0.095	0.051
	EW only	3.0	3.0	1.00	0.058	0.022
	0	5.2	5.2	1.00	0.062	0.034
	-30	5.0	4.6	0.92	0.061	0.027
	-60	5.9	5.0	0.85	0.078	0.032
	-75			0.88		
	-90	6.8	6.1	0.90	0.102	0.042
	-120	7.8	7.3	0.94	0.121	0.053
	-150	8.5	8.4	0.99	0.136	0.060
	-180	8.9	8.8	0.99	0.144	0.065
	-210	8.8	8.9	1.01	0.145	0.069
	-240	8.4	8.5	1.01	0.135	0.066
	-270	7.6	7.2	0.95	0.122	0.062
	-300	6.7	6.7	1.00	0.099	0.052
	-330	5.7	5.7	1.00	0.076	0.041

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

TABLE K-4. EM MEASUREMENTS VS. ANTENNA PHASE FOR 10T6-2

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.}	
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 K-5. 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 K-6. EM MEASUREMENTS VS. ANTENNA PHASE FOR 10T10-1

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.}
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.

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APPENDIX L
EM EXPOSURE SETUP PROTOCOLS FOR SOIL AMOEBA
AND SLIME MOLD STUDIES

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EM EXPOSURE SETUP PROTOCOLS FOR SOIL AMOEBA AND SLIME MOLD STUDIES

This appendix documents the protocols written by IITRI to assist the soil amoeba and slime mold study investigators in setting up their study sites using the culture cell exposure hardware fabricated by IITRI. These protocols also provide guidelines for proper adjustment of the EM exposures and monitoring of the exposure parameters using this equipment.

Figures L-1 and L-4 illustrate the test setups used for determining the electrode spacing required to produce the proper exposure chamber drive voltages for matched electric field sites. Figures L-2 and L-5 are schematics of the exposure chamber and test cell hookup for the matched electric field scenarios. Figures L-3 and L-6 show the circuit for matched current density exposure.

EXPOSURE SETUP PROTOCOLS FOR SOIL AMOEBA STUDIES

MATCHED ELECTRIC FIELD PROTOCOL

- (1) Measure maximum electric field in soil using 1 meter probe, E.
- (2) Multiply electric field value by 0.15 to determine the minimum required drive voltage, V_{DR} (min).

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

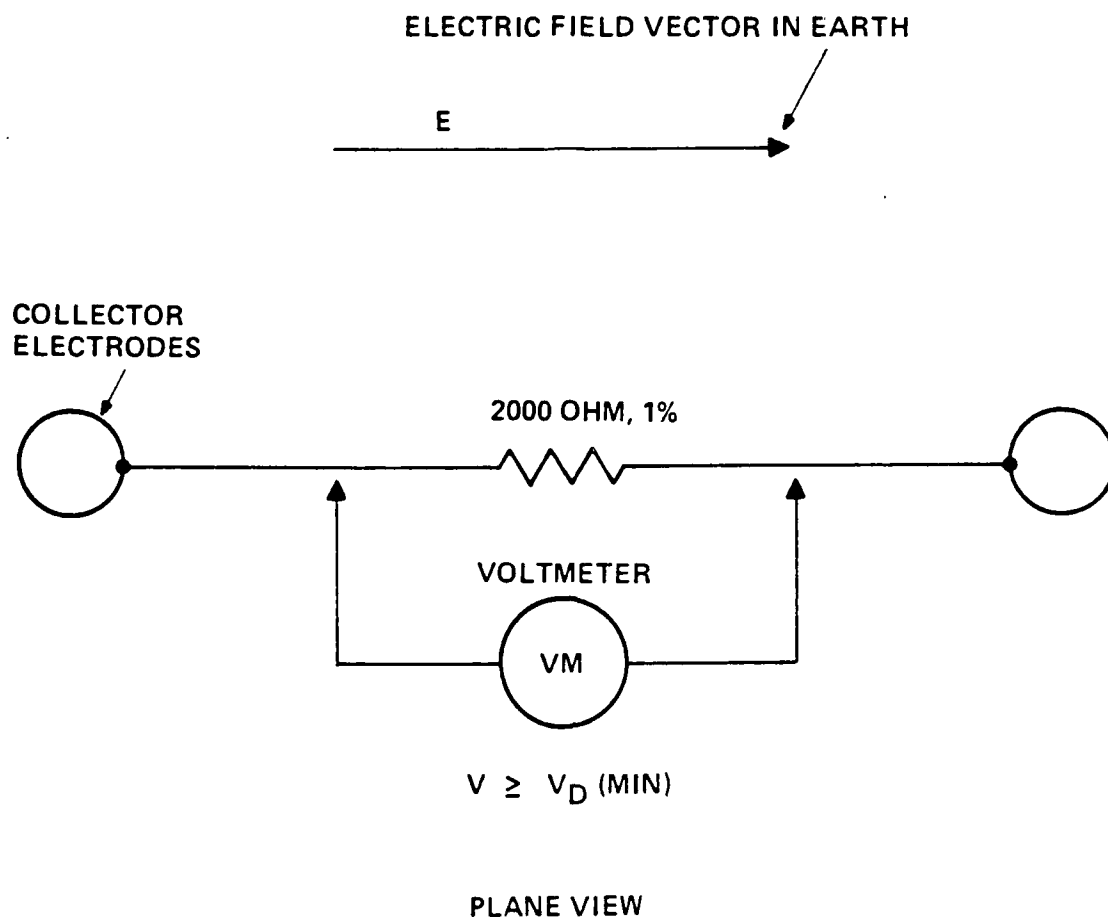
- (3) Locate collector electrodes in line with the maximum electric field in the earth, and spaced far enough apart to generate a voltage across a 2000 ohm resistor that is greater than or equal to V_{DR} (min) (see Figure L-1).
- (4) Measure and record electrode spacing and the open circuit (no load) electrode voltage, V_{OC} .
- (5) Connect the test cell and monitoring box to the electrodes (see Figure L-2). While monitoring the voltage across the test cell only, V_{CL} , adjust the variable resistor so that the cell voltage 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 with the test cell and monitoring box connected and adjusted as per Step 5, V_{DR} .

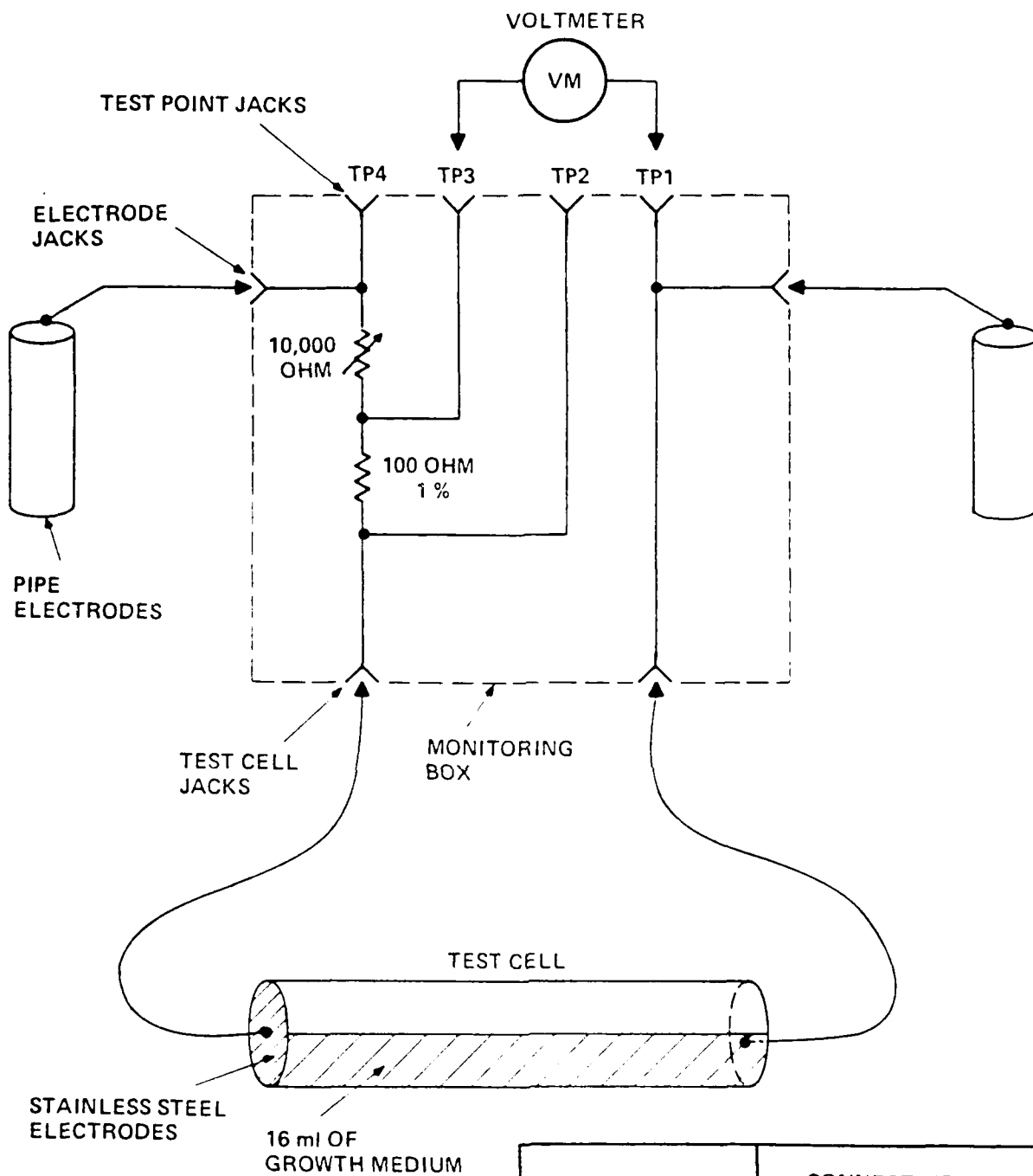
MATCHED CURRENT DENSITY PROTOCOL

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



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FIGURE L-1. DETERMINATION OF DRIVE VOLTAGE.



TO MEASURE	CONNECT METER ACROSS
V_{CL}	TP1 - TP2
V_R	TP2 - TP3
V_{DR}	TP1 - TP4

FIGURE L-2. TEST CELL HOOKUP FOR MATCHED E-FIELD PROTOCOL.

- (4) Connect current-limiting test chamber (see Figure L-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 L-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.

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

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

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

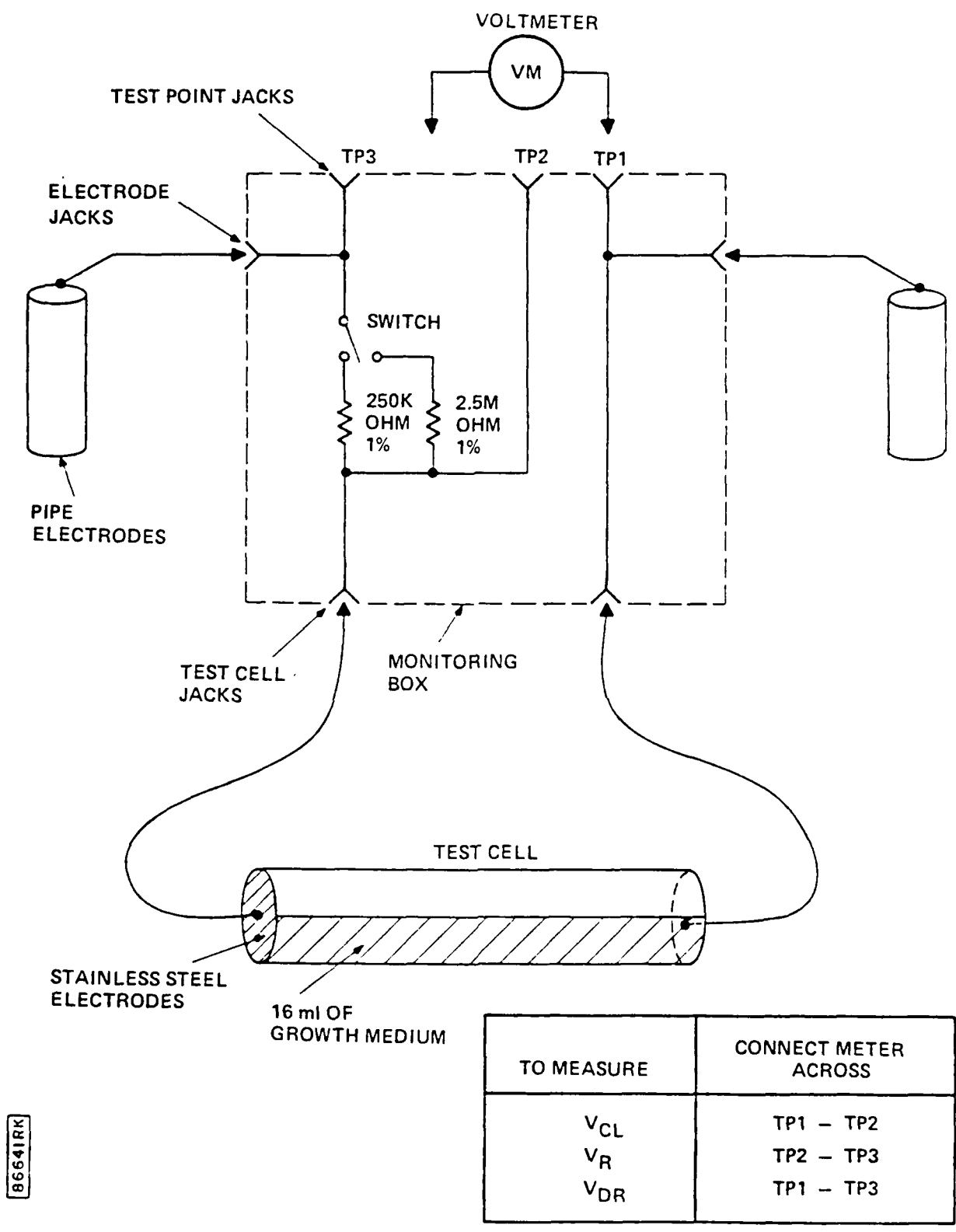


FIGURE L-3. TEST CELL HOOKUP FOR MATCHED CURRENT DENSITY PROTOCOL.

EXPOSURE SETUP PROTOCOLS FOR SLIME MOLD STUDIES

MATCHED ELECTRIC FIELD PROTOCOL

- (1) Measure maximum electric field in soil with 1 meter probe, E .
- (2) Multiply electric field value by 0.2 to determine the minimum required chamber voltage, V_{CH} (min).

$$V_{CH} \text{ (min)} = E \times 0.2 \text{ (volts)}$$

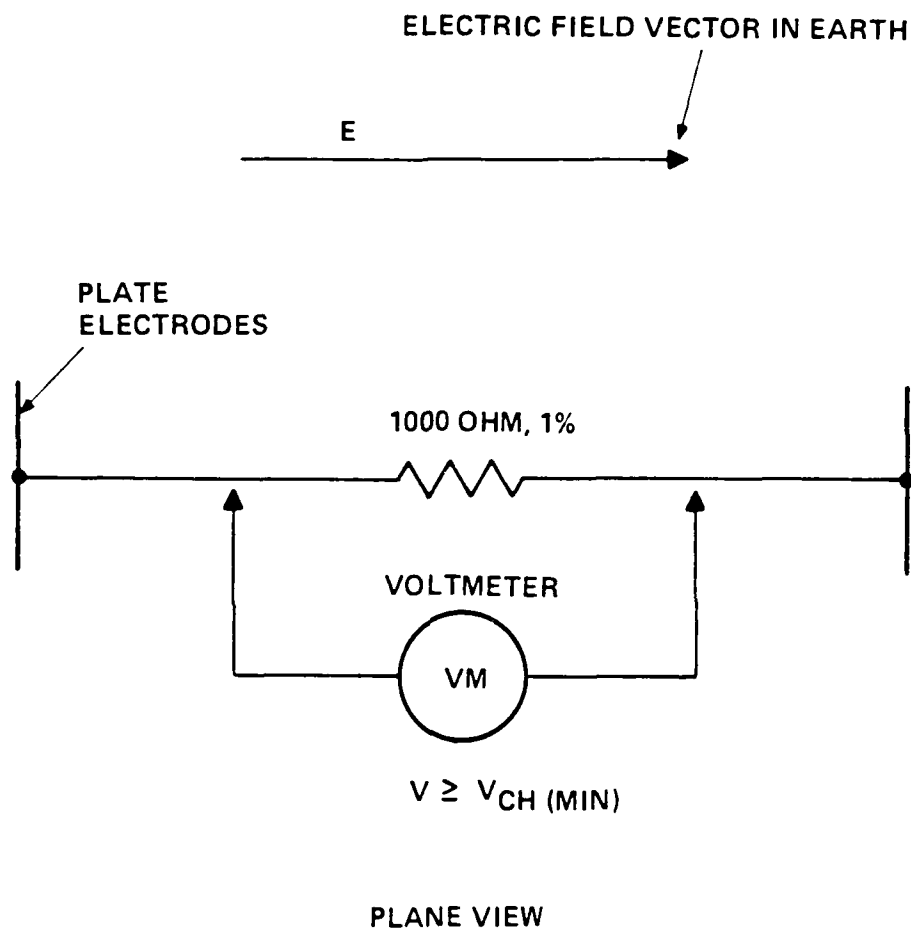
- (3) Locate collector electrodes in line with maximum electric field in the earth and spaced far enough apart to generate a voltage across a 1000 ohm resistor that is greater than or equal to V_{CH} (min) (see Figure L-4).
- (4) Measure and record electrode spacing and open circuit (no load) voltage, V_{OC} .
- (5) Connect test chamber to electrodes. Connect voltmeter to measure voltage across test cell, V_{CL} . Adjust variable resistor (Pot) so that the voltage across the test cell is equal to V_{CL} as determined by the formula:

$$V_{CL} = E \times 0.155 \text{ (volts)}$$

- (6) Measure and record the voltage across the 100 ohm series resistor, V_R (see Figure L-5). This allows calculation of the cell current and current density.
- (7) Measure and record the voltage between the electrodes with the test chamber connected and adjusted as per Step 5, V_{CH} .

MATCHED CURRENT DENSITY PROTOCOL

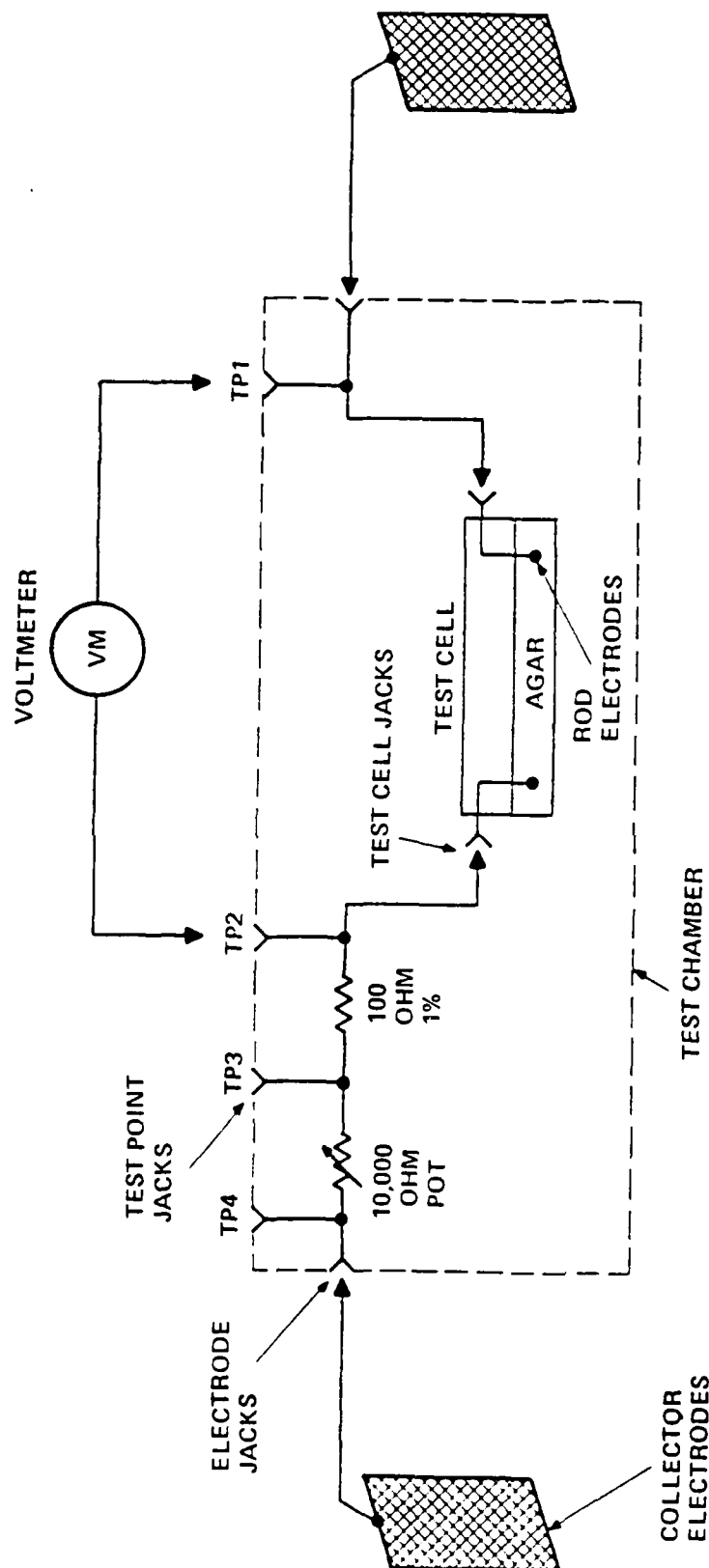
- (1) Measure maximum electric field in soil using 1 meter probe, E .
- (2) Locate collector electrodes in line with maximum electric field with a separation of 1 meter.



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FIGURE L-4. DETERMINATION OF CHAMBER VOLTAGE.

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TEST NUMBER	CONNECT VOLTMMETER ACROSS
4 VOC	COLLECTOR ELECTRODES
5 VCL	TP1 - TP2
6 VR	TP2 - TP3
7 VCH	TP1 - TP4

FIGURE L-5. TEST CHAMBER WIRING FOR MATCHED E-FIELD PROTOCOL.

- (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.
- (4) Connect current-limiting test chamber (see Figure L-6) to electrodes. Place the current limit select switch to the 500 kilohm position (500 K).
- (5) Measure and record the voltages across the test cell, V_{CL} , the resistor, V_R and the test chamber, V_{CH} , using the test point jacks (see Figure L-6 for test point numbering).

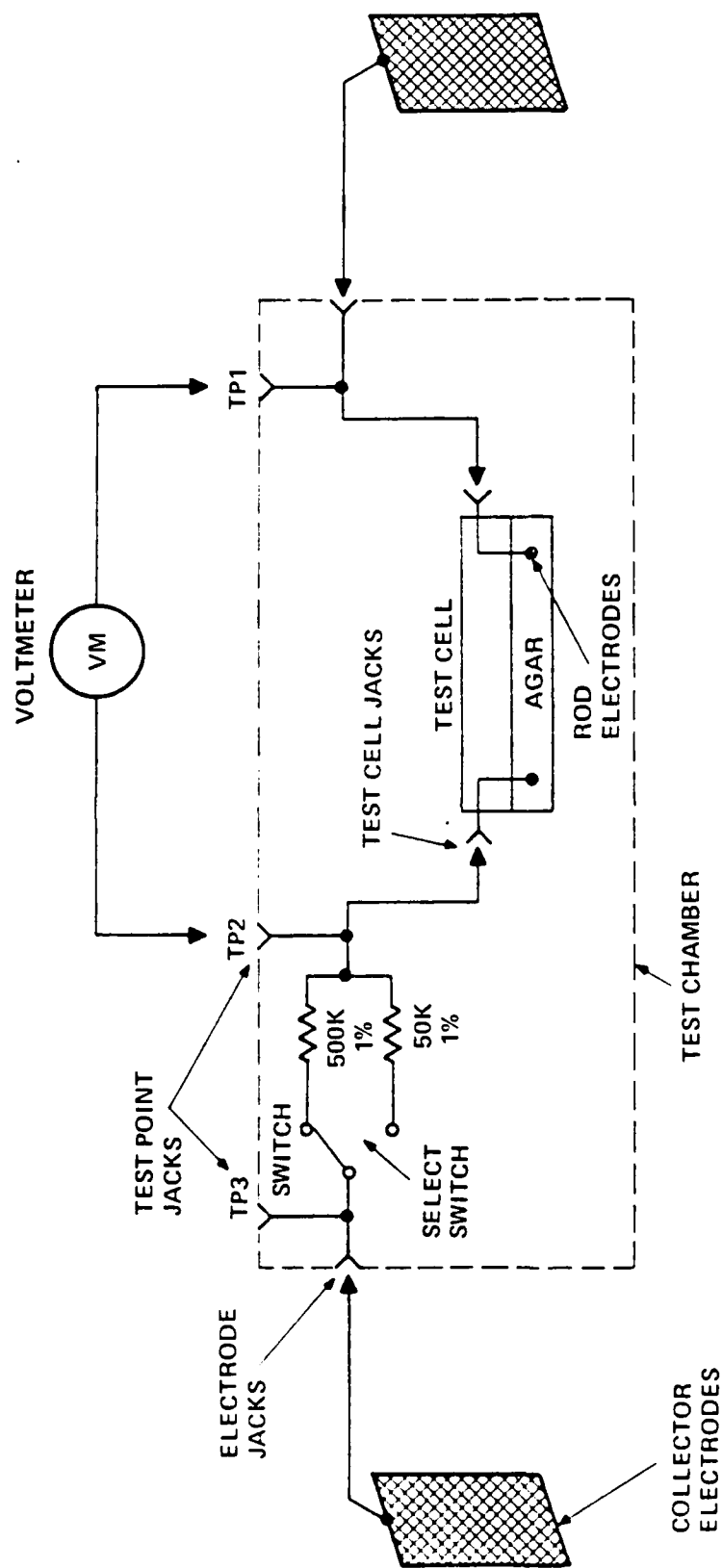
The voltages across the resistor and across the test chamber should be close in value to V_{OC} from Step 3.

$$V_R \approx V_{CH} \approx V_{OC}$$

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

$$V_{CL} \approx 1.6 \times 10^{-3} \times V_{OC} \text{ (volts).}$$

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TO MEASURE VOLTAGE ACROSS	CONNECT VOLT METER BETWEEN
V_{CL} TEST CELL	TP1 - TP2
V_R RESISTOR	TP2 - TP3
V_{CH} TEST CHAMBER	TP1 - TP3

FIGURE L-6. TEST CHAMBER WIRING FOR MATCHED CURRENT DENSITY PROTOCOL.

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APPENDIX M

SUMMARY OF WISCONSIN AND MICHIGAN
TRANSMITTING FACILITY OPERATION

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SUMMARY OF WISCONSIN AND MICHIGAN TRANSMITTING FACILITY OPERATION

The operations of the Wisconsin and Michigan Transmitting Facilities (WTF and MTF) during 1984-1986 and 1986 respectively has 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, and antenna current. 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 antenna element, east-west antenna element, and both antenna elements. The north-south antenna element data represent those times when the north-south antenna element was operating while the east-west antenna element was off; the east-west antenna element data represent those times when the east-west antenna element was operating while the north-south antenna element was off; and the "both antenna elements" data represent only those times when the north-south antenna element and the east-west antenna element were operating simultaneously.

Tables M-1, M-2, and M-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 and 1986 are presented in Tables M-4 through M-9. 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 have also been updated from those presented in the 1984 report, and now represent any change in the transmitter facility operating condition. This would include an initial power up or final power down and changes in the

TABLE M-1. 1984 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	
76	0.94	107.19	--	1.98	7.24	13.85	--	22.10	8.07	1.69	30.17	1.48	194.71
Mode: <u>Modulated Signal</u> ^a													
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

^aFrequencies listed refer to the center frequency of modulation.

^bDenotes small periods of time at other frequencies or undesignated operation.

TABLE M-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: <u>Modulated Signal</u> ^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: <u>Unmodulated Signal</u>													
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

^aFrequencies listed refer to the center frequency of modulation.

^bDenotes small periods of time at other frequencies or undesignated operation.

TABLE M-3. 1984 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												
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

^aFrequencies listed refer to the center frequency of modulation.

^bDenotes small periods of time at other frequencies or undesignated operation.

TABLE M-4. 1985 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: <u>Modulated Signal</u> ^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: <u>Unmodulated Signal</u>													
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 small periods of time at other frequencies or undesignated operation.

TABLE M-5. 1985 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	--	--	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

of frequencies listed refer to the center frequency of modulation.

^bdenotes small periods of time at other frequencies or undesignated operation.

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

Frequency, MHz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: <u>Modulated Signal</u> ^a													
44	1.97	1.97	1.97	1.97	0.46	0.05	29.73	--	--	--	--	--	32.44
7	1.97	1.97	1.97	1.97	45.98	261.68	118.66	74.91	161.36	451.69	657.61	730.96	2526.18
75.41	1.97	1.97	1.97	1.97	0.05	73.94	--	--	0.43	--	--	--	75.41
Sub Totals	1.97	1.97	1.97	1.97	46.44	261.78	222.33	74.91	161.79	451.69	657.61	730.96	2634.03
Mode: <u>Unmodulated Signal</u>													
132.07	1.97	1.97	1.97	1.97	10.35	10.70	--	1.63	4.82	3.40	0.61	--	132.07
12.50	1.97	1.97	1.97	1.97	--	0.98	--	--	--	1.72	--	--	12.50
144.57	1.97	1.97	1.97	1.97	10.35	11.68	--	1.63	4.82	5.12	0.61	--	144.57
80.67	1.97	1.97	1.97	1.97	0.01	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	730.96	2859.27
Number of Transmissions	1	6	55	69	15	48	20	54	38	38	38	38	424

^a Frequencies listed in parentheses are the center frequency of modulation.
Frequencies and hours of operation at other frequencies or undesignated operation.

TABLE M-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												
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	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

TABLE M-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													
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	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

TABLE M-9. 1986 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													
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	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

antenna current, phase (when both antennas are powered), frequency, and modulation scheme.

The MTF operating schedule has been broken down into three antenna conditions: north-south (NS) antenna element only, north east-west (NEW) antenna element only, and south east-west (SEW) antenna element only. These were the only operating modes for the MTF in 1986.

Tables M-10, M-11, and M-12 show the number of hours of operation per month in 1986 for the north-south, north east-west, and south east-west antenna elements, respectively. The columns on 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 "changes in operational mode" of the antenna element on a monthly and annual basis.

TABLE M-10. 1986 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												
76	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
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 (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)	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
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	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.07</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.07</u>
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
Changes in Operational Mode	0	0	0	0	0	0	290	46	62	120	0	0	518

TABLE M-11. 1986 MIF OPERATIONS SUMMARY: NORTH 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													
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 7.4 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 16 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
76 120 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
Subtotal	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	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
Changes in Operational Mode	0	0	0	0	0	55	20	4	52	166	0	0	297

TABLE M-12. 1986 MTF OPERATIONS SUMMARY: SOUTH 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												
76	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
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 (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)	<u>0.00</u>	<u>0.00</u>	<u>3.87</u>	<u>18.64</u>	<u>6.15</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>28.66</u>
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	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.03</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.03</u>
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
Changes in Operational Mode	0	0	54	78	10	12	0	4	60	156	0	0	374

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