ELF Communications System Ecological Monitoring Program: Litter Decomposition and Microflora Studies – Final Report

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The U.S. Navy has completed a program monitoring flora, fauna, and ecological relationships for possible effects from electromagnetic fields produced by its Extremely Low Frequency (ELF) Communications System. This report documents studies of litter decomposition and soil microflora conducted near its transmitting antenna in Michigan.

From 1982 through 1993 researchers from the Michigan Technological University (MTU) monitored overall litter decomposition, as well as microflora (bacteria and fungi) important both as processors of organic material and causative agents of tree disease. Studies were performed in areas near (treatment) and far (control) from the ELF antenna. Study parameters included total number of streptomycete individuals and species; mass loss of maple, oak, and pine leaf litter; and frequency of red pine mortality from *Armillaria* root disease.

The MTU research team used several statistical models; however, nested analysis of covariance was the most frequently used test. Based on the results of their study, MTU investigators conclude that the EM fields produced by the Naval Radio Transmitting Facility-Republic, Michigan did not affect soil bacteria populations or the spread of the root disease. Loss of foliar mass suggests a statistically significant, but modest, increase in the rate of litter decomposition, possibly associated with electromagnetic exposure.

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FOREWORD

This report by researchers from Michigan Technological University (MTU) summarizes the results and conclusions of their study of soil microflora and associated processes. In this effort, MTU monitored microflora exposed to electromagnetic fields produced by the U.S. Navy's ELF Communications System in Michigan. The Space and Naval Warfare Systems Command (SPAWAR) funded this study through contracts N00039-81-C-0357, N00039-84-C-0070, N00039-88-C-0065, and N00039-93-C-0001 to IIT Research Institute (IITRI). IITRI, a not-for-profit organization, provided engineering support to MTU and managed their study through subcontract agreements.

MTU initiated their studies in late 1982. Their early efforts focused on selecting study sites, validating assumptions made in proposals, and characterizing critical study aspects. As these tasks were accomplished in 1984 and 1985, MTU then emphasized accumulating a data base for statistical analysis. The MTU research team and IITRI evaluated each study variable for continued funding before contract renewals in 1984, 1988, and 1993. As a result, several originally proposed study elements were either expanded or discontinued in subsequent periods of performance.

Since its inception, scientific peers have reviewed the technical quality of this study on an annual basis. In similar fashion, a draft of this report has been reviewed by peers with experience in soil ecology, statistics, and electromagnetics. MTU authors have considered, and addressed, peer critiques prior to submitting a revised manuscript to IITRI. Except for added prefatory and title pages, MTU's manuscript is here issued by IITRI on behalf of SPAWAR without further changes or editing by IITRI or SPAWAR.

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Respectfully submitted,
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ELF COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING PROGRAM:

LITTER DECOMPOSITION AND MICROFLORA

The Michigan Study Site

FINAL REPORT

SUBCONTRACT NUMBER: E06549-84-C-002

MICHIGAN TECHNOLOGICAL UNIVERSITY

HOUGHTON, MICHIGAN

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ABSTRACT

Nine single-year decomposition experiments have been completed with red pine, northern red oak, and red maple foliar litter in hardwood stands (control and overhead antenna sites) and red pine plantations (control, overhead antenna, and grounded antenna sites). The sample units consisted of bagged bulk leaf samples of each species, for determination of dry matter mass loss expressed as the proportion of original dry matter mass remaining (X_m) with elapsed time through the growing season following sample placement in the field. Supplemental studies with individual leaves were discontinued in 1991. Nutrient analyses of retrieved samples were discontinued in 1989, in favor of funding additional statistical modeling of dry matter mass loss. Our initial intentions to model nutrient flux were dropped, partly due to variability and chaotic relationships in the nutrient data. Nevertheless, we have monitored the initial nutrient status of the annual "parent" litter collections from which field samples were arbitrarily drawn.

Precision in the data sets was greater for the hardwood stands than for the plantations. The hardwood stands provided more stable environments than did the rapidly developing pine plantations. This was an important consideration with our objective of detecting possible effects of increasing ELF electromagnetic (EM) field exposures. Pine and oak provided more precise data than did maple, primarily because maple litter fragmented to a greater extent than

did pine or oak litter. Very small changes in decomposition progress are nonetheless statistically detectable for all three species in both the hardwood stands and the plantations.

Two types of ANACOV model were used to evaluate the relationship between sites over time. The traditional Effects Model ANACOV examined datasets for differences among years, sites, and months, with blocking by plot nested within site, and for site-year interaction. The mathematically equivalent Means Model ANACOV identifies differences between site-year combinations termed "siteyears" (*e.g.*, control-1985, antenna-1985, ground-1985, control-1986, *etc.*), and between months. Multiple comparisons were used to identify significant differences among siteyears, and thereby trends across years.

Our principal objectives have been 1) to use ANACOV to explain differences among years and sites, and site-year interactions, using covariates unrelated to ELF field exposures, and 2) to evaluate the temporal patterns of remaining differences relative to periods of ELF antenna operation. We have utilized only ecologically appropriate seasonal weather covariates that could not reasonably have been affected by ELF fields. We have settled on a set of weather covariates that permits expression of the effects of seasonal energy inputs with respect to concurrent precipitation inputs. One additional covariate corrects for the differences among years in monthly sample collection dates.

Analyses of the siteyear patterns in the hardwood stands (for all three litter species) suggest that ELF EM fields may slightly accelerate the rate of litter decomposition. Throughout the nine years of study, annual litter decomposition patterns have tended to be similar for both study hardwood stands. Nevertheless, ANACOV indicates that decomposition progressed more quickly at the control site than at the overhead antenna site through 1987, but more quickly at the overhead antenna site than at the control site from 1988 through 1993. This tendency was not statistically significant for all years, and was most pronounced for oak litter. While the patterns of X_m differences between years in each hardwood stand do not support the finding of an ELF EM field effect, we know that our covariates are more effective in explaining variation within years than among years. For example, our covariates can not account for differences in substrate quality (*e.g.*, initial nutrient content) between years. It seems clear that only statistically powerful studies controlling both EM field, weather, and substrate variables could determine whether or not the apparent effect is real. The apparent magnitude of the effect is a shift of approximately 5-8 percent in X_m at the overhead antenna site. Although an effect of this magnitude would be biologically significant in terms of nutrient cycling, such an effect caused by the ELF Communications System would likely become muted to the point of inconsequence at a short distance from the antenna, since 76 Hz field intensities decline steeply with distance from the antenna. Also, a 5-8 percent shift is modest relative to the observed year-to-year variability (as high as 14 percent for oak in the overhead antenna hardwood stand).

Emphasis in the Red Pine Mycorrhizoplane Streptomycete studies focused on the enumeration and characterization of streptomycetes associated with the predominant mycorrhizal morphology type observed on red pine seedlings in the three plantations. Seven years (1985-1991) of mycorrhizoplane streptomycete population data were collected in all three study plantations. Estimates of both total streptomycete levels and streptomycete morphotype numbers were made. Each morphotype was characterized for ability to degrade complex organic compounds.

In contrast to the litter decomposition work element, there was no indication of any ELF EM field effect through 1991 on mycorrhizoplane streptomycete populations. ANACOV (using annual running totals of degree days and precipitation variables as covariates) explained all differences among sites and months, as well as the year-site interaction, for streptomycete morphotype numbers. Morphotype numbers decreased following plantation establishment in 1984. We suspect that the observed decrease in morphotype numbers with plantation age is associated with the establishment of red pine monocultures on sites which formerly supported more diverse hardwood forests. A similar ANACOV explained the differences among sites and the year-site interaction for total streptomycete levels. Levels did not follow a recognizable pattern from 1984 through 1991. Seasonally, levels were lower in October than during May through September.

Obtaining sufficient statistical power to detect subtle ELF EM field effects has been a major difficulty in estimating total streptomycete population levels. A change of 26 to 50 percent between two "siteyears" would be detected only 50 percent of the time. Large detectable differences for morphotype numbers (20-37 percent for siteyears) are a smaller problem, because the numbers detected are very low. Nevertheless, with 2 to 4 morphotypes detected per sample, shifts of this magnitude would likely require declines in abundance (or loss) of several of the approximately 20 streptomycete morphotypes observed over the past six years.

The Armillaria root disease epidemics in all three plantations have been documented since their onset in 1986. Armillaria root disease is easily diagnosed, permitting accurate mapping for statistical modeling. Sampling is accomplished by taking a census of each plantation periodically. Pathogenic *Armillaria* genets (individuals) have killed from 8 to 43 percent of the red pine plantation populations to which they have had access. Documented Lake States epidemics of Armillaria root disease in red pine have peaked after 10 years of activity. Nevertheless, relatively little root disease mortality developed in 1992 and 1993. The combination of markedly cool wet weather and increased seedling size may have had the combined effect of reducing seedling vulnerability.

ANOVA was used to compare the monomolecular rates of disease progress in the three plantations. Preliminary models were based on rate coefficients calculated for all of the 12 quarter-plots comprising each plantation. Preliminary ANOVA results indicated that rates of disease progress were highest in the overhead antenna plantation and lowest in the grounded antenna plantation. These results were unrealistic, because the grounded antenna plantation is only partially occupied by *Armillaria* genets (individuals). It is most appropriate to base rates of disease progress on land area units colonized by individual *Armillaria* genets, rather than on land area units only partially colonized by *Armillaria* genets.

Once the spatial distributions of all genets were finally mapped, the rates of disease progress for all *Armillaria* genets which have killed at least 10 seedlings were compared among plantations by ANOVA, and with each other by the Tukey-Kramer method for unplanned comparisons. Although no significant differences in disease progress rates were found among plantations, many significant differences were detected among genets. Rates of disease progress ranged similarly in all three plantations, and were only correlated with seedling size at the control site.

Our results suggest 1) significant and similar variation in virulence among the pathogenic *Armillaria* genets occurring in the three study plantations, and 2) no detectable effect of ELF EM field exposures on rate of Armillaria root disease progress.

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EXECUTIVE SUMMARY

Maple, oak, and pine leaf litter decomposition was studied from December 1984 through November 1993. Pine seedling mycorrhiza-associated streptomycete bacteria populations were studied during the 1985 through 1991 field seasons. The ongoing Armillaria root disease epidemics in the three study pine plantations have been studied since their onset in 1986.

Litter Decomposition: We have studied litter decomposition in red pine plantations at our grounded antenna, overhead antenna and control sites, as well as in neighboring hardwood stands at our overhead antenna and control sites. Hardwood stands and plantations present very different study environments. Oak, maple, and pine foliar litter substrates differ in composition, favoring different components of the decomposer community. Maple litter decays fastest (with the greatest amount of fragmentation), providing the most variable data; pine litter decays slowly with the least amount of fragmentation, providing the least variable data; and oak litter is intermediate. Very small changes in decompositon progress were statistically detectable for all three species in both stand types.

The experimental design employed is to compare decomposition progress on the three sites over a period including both pre- and post-treatment years. Because climatic conditions vary among sites

and years, the decomposition data were adjusted for temperature and precipitation variation using covariate analysis (ANACOV). We are using a set of seasonal covariates which permits expression of the seasonal effects of energy inputs with respect to concurrent precipitation inputs. One additional covariate corrects for the differences among years in monthly sample collection dates.

The site-year interaction measures whether the relationship between sites changes with time. Because of the pre- and post-treatment design, insignificant site-year interactions imply no ELF effect. Further, significant site-year interactions imply an ELF effect only if they mimic the temporal pattern of site exposure to ELF EM fields. Many differences in decomposition progress among sites and years, and site-year interactions, remain unexplained by ANACOV. These differences have been evaluated in light of what we know about ELF EM field exposures at the study sites.

Analysis of site-year patterns in the hardwood stands suggested that ELF EM fields may slightly accelerate litter decomposition. The pattern of differences between the overhead antenna and control hardwood stands appears to have reversed beginning in 1988. The difference between stands is not statistically significant for all years, and was most pronounced for oak litter. Although the patterns of X_m differences among years in each hardwood stand do not likewise indicate an ELF EM field effect, we know that our covariates are more effective in explaining variation within years than among years. For example our covariates can not account for differences in substrate quality between years. It seems clear that only statistically powerful experiments controlling EM field, weather and substrate variables could determine whether or not the apparent effect is real. The apparent magnitude of the effect is a shift of approximately 5-8 percent in X_m at the overhead antenna site. Although an effect of this magnitude would be biologically significant in terms of nutrient cycling, such an effect caused by the ELF antenna would be spatially muted to the point of inconsequence as 76 Hz field intensities decline steeply with distance from the antenna. Also, a 5-8 percent shift is modest relative to observed annual fluctuations (as high as 14 percent for oak in the overhead antenna site hardwood stand).

Mycorrhizoplane Streptomycetes: There is no indication of an ELF EM field effect through 1991 on red pine mycorrhiza-associated streptomycete populations. ANACOV using weather-related covariates explained all differences among sites and months, as well as the site-year interaction, for numbers of streptomycete morphotypes. Morphotype numbers have decreased in the plantations since plantation establishment in 1984. We suspect that this decrease is associated with the establishment of red pine monocultures on sites which formerly supported more diverse mixed hardwood/conifer forests. ANACOV also explained differences among sites and the site-year interaction for total streptomycete numbers. Levels have not followed a recognizable pattern over the years.

Obtaining sufficient statistical power to detect effects of ELF EM fields has been difficult. A change in streptomycete levels of 26 to 50 percent between two site-year treatment combinations ("siteyears") would be detected only 50 percent of the time. Large detectable differences for morphotype numbers (20 to 37 percent for site-year combinations) are less of a problem, because the numbers detected are low. Nevertheless, ranging from 2 to 4 morphotypes per sample, shifts of this magnitude would likely involve declines in abundance (or outright loss) of several of the approximately 20 streptomycete morphotypes observed over the past six years.

Armillaria Root Disease Epidemiology: *Armillaria* genets have killed 8-43 percent of the accessible red pine plantation populations. Disease progress rates for pathogenic *Armillaria* genets in the three plantations were compared by ANOVA. Disease progress rates were not significantly different between plantations, primarily because disease progress rates differed greatly and ranged similarly for the genets in each plantation. Rates of disease progress were inversely correlated with seedling size at the control plantation (but not at the other two plantations). Our results suggest 1) significant and similar variation in aggressiveness among the pathogenic *Armillaria* genets occurring in the three study plantations, and 2) no detectable effect of ELF EM fields on rate of Armillaria root disease progress.

INTRODUCTION

Background

In 1982, Michigan Technological University initiated research at the Michigan antenna site intended to determine whether ELF EM fields cause fundamental changes in forest health. The MTU research program included two separate yet integrated projects, the Herbaceous Plant Cover and Tree Studies project and the Litter Decomposition and Microflora project. Work elements of the Litter Decomposition and Microflora project have examined 1) litter decomposition as dry matter mass loss in both hardwood stands and red pine plantations, 2) mycorrhizoplane streptomycete population dynamics on red pine plantation seedlings, and 3) Armillaria root disease epidemiology in the red pine plantations. These work elements have shared the same field sites with the Upland Flora Studies project. In fact, the Armillaria root disease work element was adopted in 1992 from the Upland Flora Studies project with the discontinuation of the mycorrhizoplane streptomycete study. These three work elements have complemented and extended the program of the Upland Flora Studies project. The information obtained is being used for comparison of pre-operational and operational status of the study variables on both treatment and control sites, to evaluate possible ELF EM field effects on the local forest ecosystem.

We believe that the research programs representing all three work elements are biologically and statistically defensible. However, only the litter decomposition study has provided preliminary evidence of possible ELF EM field effects, whereas the mycorrhizoplane streptomycete and the Armillaria root disease epidemiology studies have not. This Final Report examines the historical course of each research program, and the degree of success achieved by research in each of the three work elements.

Objectives

The overall objectives of these work elements are to determine the impacts of ELF EM fields on:

1) rates of litter decomposition for three important local tree species (red maple, northern red oak, and red pine),

2) overall levels and taxonomic richness of mycorrhizoplane streptomycete populations, and

3) rates of Armillaria root disease progress in red pine plantations.

We have attempted to determine whether ELF EM fields impact these functions/segments of upland forest communities by testing four general hypotheses (Table 1) through relatively long-term studies.

Table 1. Critical null hypotheses tested to fulfill objectives of the ELF environmental monitoring program Litter Decomposition and Microflora project.

I. There is no difference in the level of foliar litter decomposition between the sites that cannot be explained by factors unaffected by ELF electromagnetic field exposure.

II. There is no difference in the level or the seasonal pattern of mycorrhizoplane streptomycete populations on the plantation red pine seedlings that cannot be explained using factors unaffected by ELF antenna operation.

III. There is no difference in the representation of different identifiable strains of mycorrhizoplane streptomycetes on the plantation red pine seedlings that cannot be explained using factors unaffected by ELF antenna operation.

IV. There is no difference in the rate of Armillaria root disease progress in the study red pine plantations that cannot be explained using factors unaffected by ELF antenna operation.

PROJECT DESIGN

Overview of Experimental Design

Emphasis was placed on development of a statistically rigorous experimental design capable of separating potentially subtle ELF EM field effects from the natural variability associated with edaphic, vegetational, climatic and temporal factors. Consequently, in order to most effectively test our hypotheses, we integrated our studies with those of the Upland Flora Studies project. This permitted us to take full advantage of both that project's basic field design and the extensive data collected by that project on the tree, stand and site factors which influence or regulate the processes and populations we measured (Table 2). The measurements made and the associated analyses are discussed more thoroughly in the following sections. The experimental designs, which integrate direct measures with site variables, are a common thread through the work elements of both projects due to shared components of the field design.

Because of the similarity in analyses, an understanding of this experimental design is essential. However, the rationale and progress for measurements in each work element of this study are necessarily unique, and are presented separately in the following sections.

Table 2. Measurements needed to test the critical hypotheses (Table 1) of the ELF environmental monitoring program Litter Decomposition and Microflora project, the objective each group of measurements relates to, and the work elements which address the necessary measurements and analyses.

Hypothesis Number	Related Objective	Measurements	Work Elements
I	1	**Monthly determinations of dry matter loss, from bulk leaf litter samples of oak, maple, and pine**[2]**;** climatic variables	1,(1)[1]
II	2	**Monthly estimates of total streptomycete levels associated with Type 3 red pine seedling mycorrhizae;** climatic variables	2,(1)
III	2	**Monthly estimates of numbers of streptomycete morphotypes associated with Type 3 red pine seedling mycorrhizae;** climatic variables, sample processing delay	2,(1),(4)
IV	3	**Periodic mapping and identification of** ***Armillaria*** **cultures isolated from red pine seedling mortality and basidioma;** climatic variables, seedling size, hardwood stump population characteristics	3,(1),(2)

[1] Numbers in parentheses refer to work elements in the Upland Flora Studies project: (1) Ambient (weather) monitoring; (2) Tree productivity; (4) Mycorrhizae characterization & root growth.

[2] Bold print designates the response variable; other variables listed are covariates.

Experimental Design and Electromagnetic Exposure

The EM fields associated with the ELF system are different at the overhead antenna and grounded antenna locations. Therefore, the general approach of the study required plots to be located along a portion of the overhead antenna, at a grounded antenna terminal, and at a control location some distance from the antenna. IITRI has measured 76 Hz EM field intensities at the study sites since 1986 when antenna testing began; background 60 Hz field intensities have been measured at all sites since 1985. Three types of EM field have been measured: magnetic (Mg), longitudinal (mV/m), and transverse (V/m). Appendix B, which is discussed more completely below, documents the ELF field measurements for the sites and provides maps representing the experimental plot spatial layout (e.g. - see pages B-23 and B-24).

The most general experimental design for the Upland Flora Studies project is a split-plot in space and time. Each site (control, overhead antenna, and grounded antenna) was subdivided into two stand types: pole-sized hardwood stands and red pine plantations. Each site has also been subjected to a unique spatio-temporal set of ELF EM field exposures. Each stand type at each field site was divided into three contiguous plots to control variation. The time factor is the number of years in which an experiment is conducted for pre-operational and operational comparisons, or the number of sampling periods in one season for year-to-year comparisons. It is necessary to account for time when successive measurements are made on the same whole units over a long period of time without re-randomization. A combined analysis involving a split-plot in space and time is made to determine both the average treatment response (site difference) over all years, and the consistency of such responses from year to year.

Each site follows this design with one exception. No pole-sized hardwood stand plots were established at the grounded antenna site, because the necessary buffer strips would have placed the hardwood stand type too far from the grounded antenna for meaningful exposure. Thus one treatment factor (hardwood stands) is eliminated at the grounded antenna site. Depending on the variable of interest, the stand type treatment factor may or may not be pertinent. Where analyses are conducted separately on the two stand types, the stand type treatment factor is irrelevant and is not included in the analysis. This is the case for all studies of the Litter Decomposition and Microflora project. All other factors remain unchanged.

ANALYTIC METHODS

In this section, we describe the evolution of our analytical approach away from exponential regression techniques to ANACOV, and our selection of covariates. Our emphasis on site-year interaction and the means model form of ANACOV to test for ELF EM field effects is explained. Finally, we explain our use of detection limits rather than statistical power for quantitative assessment of achieved precision levels.

Exponential Decay Regressions

Exponential regression is often used to model litter decomposition (Wieder and Lang 1982). The functional form of the model is:

$$r = e^{-kt},$$

where r is the proportion of initial mass remaining, t is elapsed time, and k is the rate constant. The value of k can be used to compare decomposition rates for different substrates, locations, time periods, *etc*. This functional representation implies a decay process for which periodic mass loss starts at its highest level and monotonically decreases with elapsed time (Minderman 1968).

However, this representation of the process displayed a lack of fit for at least two of the three species studied. Appendix A from our

1988 Annual Report (pages 319-324) presents scatter plots used to evaluate the exponential decay model. The scatter plots occur in pairs, one pair for each species. This analysis of residuals used all bulk sample data across years (1985-1988) and plots. The first scatter plot of each pair presents the predicted and observed values on the ordinate with elapsed time in the field on the abscissa; the second plot presents the observed residual on the ordinate with elapsed time in the field again represented on the abscissa. The residual plot for maple shows a more or less uniform distribution of errors across time. However, the residual plots for both oak and pine show a highly skewed error distribution, with nearly all residuals positive in the first half of the field season, and negative residuals in the second half of the field season. This pattern is characteristic of a statistical model whose functional form is not correctly specified. Because of the lack of flexibility in the model's functional form, the estimated model did a poor job of predicting actual mass loss for any portion of the first year of oak and pine litter decomposition.

The specification problem could be resolved using an exponential regression approach analogous to covariance analysis in linear models. For example, measures of site moisture or temperature could be incorporated. Unfortunately, this extension would result in k values which are not comparable to those in the literature for simple exponential regressions. Moreover, k values derived using different combinations of covariates, or derived using the same covariates in a different mathematical form, would also not be comparable. Because k and temperature- and moisture-related variables are all highly related, the estimates of k would have a different interpretation in each exponential decay model form.

In addition, analysis of an exponential regression using covariates is more obscure than the linear model approach, and probably no more powerful. For example, consider inclusion of a measure of precipitation (represented as p) into the model. Without p, the simple representation of the model is:

$$r = e^{-kt},$$

where k is the only parameter to be estimated. Several alternatives could be considered as reasonable ways to incorporate p into the model. Some examples are:

$$r = e^{-(k1)t-(k2)p} = e^{-(k1)t}\ e^{-(k2)p},$$

or

$$r = e^{-kpt},$$

or

$$r = e^{-(k1)t} + e^{-(k2)p},$$

where k, k1, and k2 are parameters to be estimated. Clearly, a wide variety of functional forms can be considered when covariates are included in the inherently nonlinear exponential model. Exponential models would become extremely complex with the inclusion of categorical variables and interaction terms. Although traditional covariance analysis involves a more restrictive set of options, the hypothesis testing procedures for linear models are well documented and available in statistical packages. This is not, in general, true of nonlinear model formulations.

Of course, these complexities do not exclude the approach from use in the broader sense of scientific investigation of phenomena. Instead, they show the tremendous flexibility and usefulness of the nonlinear representation of the process. However, for the mission-oriented objective of this research (*i.e.*, the detection of ELF EM field effects on the decomposition process), the nonlinear approach with covariates is overly complex. Taken to an extreme, concern could be raised that the analysis might even hide an effect of the ELF exposure.

For all of the reasons presented above, we rejected the exponential regression approach to analysis of litter decomposition progress. Nevertheless, we also presented results of single exponential regression analyses for each year (1985-1988), site, stand type, and species in the 1988 Annual Report (pages 27-38).

Analysis of Covariance

Analysis of variance (ANOVA) and analysis of covariance (ANACOV) were used to determine treatment effects on decomposition progress, streptomycete population levels and morphotype numbers, and rates of Armillaria root disease progress. Litter decomposition treatments include year, individual plantation or hardwood stand, and monthly sampling date. For streptomycete population dynamics, treatments included year, plantation, and monthly sampling date. For rate of root disease progress, the only treatment was the individual plantation. The statistical design employed for all three work elements reported here is a factorial design with covariates. The factors included in the design vary somewhat by experiment. They include site, year, month, and blocking for the litter decomposition and streptomycete studies. Site is the only factor included in the final design for root disease study; time is accounted for in the rate constant. In the litter decomposition studies, separate analyses were conducted for the hardwood and pine plantation stand types, to satisfy the assumptions required by the ANOVA and ANACOV models.

The experiments conducted in the Litter Decomposition and Microflora project were not split-plot experiments across time, the design frequently used in the Upland Flora Studies project. A split-plot design across time requires repeated measurements on the same experimental unit. In contrast, the experimental units in the litter decomposition and streptomycete work elements are destructively sampled to obtain the required measurements; the experimental units in the root disease work element are 18 naturally occurring pathogenic *Armillaria* genets present in the three study plantations (3, 6, and 9 genets in the grounded antenna, overhead antenna, and control plantations).

Blocking is employed to control variability. In the litter decomposition models, for example, the three plots comprising each plantation and hardwood stand served as blocks, from which experimental units were sampled. This blocking produced an unbalanced incomplete block design, because not all ELF treatments could be represented in each block. The incomplete block design is dictated by the spatial separation of the ELF treatments.

Our experimental design directly controls experimental error to increase precision. Indirect or statistical control can also reduce variability and remove potential sources of bias through the use of ANACOV. This involves the use of variables (covariates) which are related to the dependent variable of interest (variate). ANACOV removes the effects of an environmental source of variation that would either inflate the experimental error or inappropriately increase the variability explained by the treatments. Identification of covariates which are both biologically meaningful and independent of treatment effects has been one of our greatest concerns. Variables must be unaffected (both directly and indirectly) by ELF EM fields in order to be legitimately used as covariates to explain (with respect to ELF EM fields) any non-ELF-induced differences in response variables among years or sites. Testing the weather- and site-related covariates for ELF-independence has been a responsibility of the Upland Flora Studies project. We have utilized only ecologically appropriate seasonal weather covariates that could not reasonably have been affected by ELF electromagnetic fields.

Different sets of covariates were used to model the various dependent variables (Table 2). For the litter decomposition studies, preliminary analyses considered measures of actual evapotranspiration (AET; Meentemeyer and Berg 1986, Thornthwaite and Mather 1957), annual running totals of air- and soil-temperature degree days and precipitation amounts and events, initial percent lignin, percent N and P at retrieval, and exposures to 60 Hz and 76 Hz EM fields (1990 Annual Report, pages 193-224). Final litter decomposition models include a set of seasonal cumulative (rather than annual cumulative) weather-related covariates which reflect the seasonal interaction between energy and moisture inputs to the decomposition process. We also developed a useful procedural covariate based on the deviation (in days) between a standard set of retrieval dates and each actual retrieval date. These covariates are both biologically meaningful and statistically significant without violating the assumptions of ANACOV. They also do the best job of explaining treatment differences detected by ANOVA. Final streptomycete ANACOV models include covariates computed as annual running totals of air- or soil-temperature degree days, total precipitation, and/or numbers of precipitation events. Covariates have not been incorporated into the Armillaria root disease progress analysis. With only 18 genets and 3 sites, we considered it imprudent to reduce the degrees of freedom for error by including covariates in the model.

The adjusted treatment means presented for each litter decomposition ANACOV model represent the arc sin square root transformation of X_m, the proportion of initial dry matter mass remaining. For mycorrhizosphere streptomycete levels and morphotype numbers, the adjusted treatment means presented for each model represent $\log_{10}$-transformed raw data. The adjusted treatment means represent the transformed data after the treatment means have been adjusted for the effect of the covariate(s). Throughout the ANACOV discussion, differences detected between means are after the effect of the covariate(s) have been considered. Thus, for example, when it is stated that decomposition failed to progress during a given month, the interpretation is that the covariate(s) adequately explained any change that occurred during that month.

Testing for ELF EM Field Effects

With permission from IITRI, Appendix B presents excerpts from IITRI Technical Report D06209-1 (Haradem et al., 1994), for the sole purpose of providing reviewers of this report with background into the nature and characteristics of the ELF EM field exposures encountered during the course of the studies reported here. In partial summary, transverse and longitudinal electric fields are affected by vegetation and soil factors, though magnetic fields are not. All ELF EM field intensities vary spatially at each treatment site during antenna operation. Also, the operating time (percent of total), intensity (amperes), and number of on/off cycles per unit time characterizing ELF EM field treatments have varied greatly through multiple phases of antenna testing prior to full operation. The antenna of interest here (the southern east-west antenna) was activated for very short duration low intensity intermittent testing during the 1986 growing season, and didn't achieve fully operational status until late in 1989. Also, this antenna was not operated from April through July 1991, and again from December 1991 through March 1992. With such variable treatment characteristics, it is difficult to objectively divide the study period (1985-1993) into treatment level categories (*e.g.*, pre- and post-operational). For example, periods of maximum frequency of on/off cycles correspond with both low percent operating time and low to medium field intensity. In addition, we do not know which measures of EM field properties most likely affect the litter decomposition process (*e.g.*, cumulative exposure time *vs*. frequency of on/off cycling; at all intensity levels *vs*. only during "windows" of specific intensity levels). For these reasons, we decided to evaluate the site-year interaction in our ANACOV models for evidence of temporal change in the relationship between treatment and control sites corresponding to periods of change in ELF EM field treatments.

Effects *vs.* Means Models for ANOVA and ANACOV

We initially used what is referred to as the "effects" model for ANOVA and ANACOV analysis. In this form, treatments of a factorial experiment are treated as main effects, while the "lack of additivity" is combined into an interaction term. As mentioned above, the main focus of analysis for possible ELF effects was to try to explain three terms in the linear model:

1. Because of the pre- and post-exposure design of the study, explaining year-to-year differences may suggest that no ELF effect occurs.

2. Because of the inclusion of treatment (exposed to ELF fields) and control sites, explaining site-to-site differences may suggest that no ELF effect occurs.

3. If no year-by-site interaction occurs, then we can conclude that no ELF effect occurs.

In the litter decomposition study, ANACOV models nearly always indicated significant site-year interactions. Furthermore, these interactions were highly significant. The interpretation of a significant site-year interaction is that the year must be known to predict the site effect, and conversely the site must be known to predict the year effect. In this case, explaining the main effect of year or site does not necessarily indicate that no ELF EM field effect is occurring. Furthermore, it can be hard to interpret the interaction term to understand if the effect follows the same pattern as the ELF EM field exposure, or if it is only random variation due to microclimatic factors not represented in the analysis.

An alternative ANACOV model, referred to by Milliken and Johnson (1984) as the means model, has been formulated to address this problem. In this representation, each combination of the factor levels is included as a separate treatment. Thus, the two treatments and the interaction term are combined into one treatment, which we call Siteyear. Individual treatment levels include, for example, Control-1985, Control-1986, ..., and Control-1993. This approach is mathematically equivalent to the effects model, but it allows more detailed analysis of the treatment combinations. The means model was demonstrated in the 1990 Annual Report (pages 33-36), using the bulk pine experiment. The means model allowed us to analyze the information at a much more disaggregated level than does the effects model.

Detection Limits and Statistical Power

As sample size increases and/or sample variance decreases, detection of a statistically significant difference between treatments becomes increasingly likely. Yet the biological effect of the given treatments on the dependent variable remains unchanged, and is either consequential (biologically significant) or not, regardless of the statistical significance achieved. According to Mize and Schultz (1985),

"Means can be consequentially and (or) statistically different. A consequential difference is a difference that is large enough to be important. A statistical difference is a difference that is larger than expected, given the variability of the characteristic that was studied. Sometimes, consequential differences are not statistically different. Also, statistical differences are sometimes not consequential. The researcher should be primarily interested in discussing the statistical significance of consequential differences."

Our experimental design with respect to litter decomposition was powerful enough to detect some statistical differences which, because of their small size, appear to be inconsequential. We view this situation to be highly preferable to the reverse situation.

Because of the variability inherent in ecosystem studies, coupled with the expected subtle nature of any perturbations due to ELF EM field exposure, a quantitative assessment of the level of precision achieved by each study is central to likelihood of perturbation detection. Two different measures were considered to make this evaluation: statistical power and detection limits.

Power is defined as the likelihood that a particular statistical test will lead to rejection of the null hypothesis if the null hypothesis is false. Exact calculation of power requires 1) knowledge of the α level (Type I error), 2) knowledge of the parameters of the distribution of the variable of interest under the null hypothesis, 3) specification of a given alternative parameter value, and 4) knowledge of the probability of detecting a change of the chosen magnitude (also called β or Type II error level). In a t-test, for example, to determine power one must know the α level (commonly 0.05), the value of the test statistic under the null hypothesis (zero, if the test is to determine whether two means are different), the degree of difference in the means which is considered biologically important (*e.g.*, 10 percent difference), and the proportion of the time this change would be detected (*e.g.*, a 90 percent chance that a 10 percent change would be detected). The last two values are difficult for scientists to agree upon in ecological studies, because it is often a matter of judgment. Quantitative knowledge of ecological relationships is often poor, and certain knowledge may be lacking (*e.g.*, whether a ten percent difference in a parameter is important where a five percent difference is not). While it is possible to construct curves showing power for a number of alternative hypotheses, one is still left with the question of how much of a difference is important.

An alternative procedure is the *a posteriori* calculation of the detection limit (*i.e.*, the percent difference between two means which results in a specified chance of correctly rejecting the null hypothesis for a given alpha level). This is really just another way of wording a power statement. Use of the detection limit allows reviewers to evaluate the test in light of their own views of what percent difference is important. A detection limit is not exact, since it is an *a posteriori* test, depending on the data used in the test procedure and the procedure itself. The detection limits presented in this report were calculated from the results of ANACOV models and the least square means option (available in the SAS Proc GLM software) for detecting significant differences after adjustment for covariates.

In summary, calculation of statistical power has the advantage of being exact (if variability is known *a priori*), but the disadvantage for ecological studies of requiring specification of the degree of change and probability of detection considered important. Also, we lack *a priori* measures of variability (MSE). The calculation of detection limits has the advantage of not requiring specification of an alternative (power is fixed at 50 percent), but the disadvantage of being an *a posteriori* calculation, and therefore not exact. We feel that the detection limit provides the same information as statistical power, and that the detection limit is more suitable for ecological studies since specification of an exact alternative hypothesis is not required.

Calculation of Detection Limits

The following example uses the mycorrhizoplane streptomycete levels ANACOV for all 7 study years (1985 - 1991). Two points need to be made before the examples are presented:

1) In ANACOV, the variance and standard error for each effect level (*e.g.*, year) is different. This happens because the mean of each covariate value representing each effect level is not the grand mean for that covariate. The closer the covariate values representing each effect level are to their grand mean, the lower the variability (standard error) will be for the corresponding LSMEAN.

2) Our analytical approach is based on the ability to determine whether or not two sample means are statistically different. The process for determining if two sample-based means are different is outlined below.

General Approach: Because the standard error of the LSMEAN varies, it seemed reasonable to evaluate the power of two LSMEANs for each effect (*e.g.*, year), the one with the lowest variability and the one with the highest variability. In addition, we chose to make each of these two comparisons with another hypothetical, equally-variable LSMEAN. This approach should provide a reasonable range of detection limit estimates for the effect considered.

The Least Variable LSMEAN: Considering the Year effect in the streptomycete levels ANACOV, 1989 had an LSMEAN of 5.4516 and a standard error of 0.03224. The size of the test is 5 percent ($\alpha = 0.05$), and the power of the test is 50 percent ($\beta = 0.50$):

$$Z = (LSMEAN1 - LSMEAN2) / (SE_{LSMEAN1}^{2} + SE_{LSMEAN2}^{2})^{0.5}$$

Because $\alpha = 0.05$, the Z value is 1.96. Therefore,

$$1.96 = (LSMEAN1 - LSMEAN2) / (0.03224^{2} + 0.03224^{2})^{0.5}, \text{ and}$$

$$\begin{aligned} LSMEAN1 - LSMEAN2 &= 1.96 * (0.03224^{2} + 0.03224^{2})^{0.5} \\ &= 1.96 * 0.04559 \\ &= 0.08936 \end{aligned}$$

Therefore, for another LSMEAN to be different from 1989 (assuming it has the same variance, and using Tukey's HSD multiple range test), it would need to have a value outside the range: 5.4516 ± 0.08936. It follows that LSMEANs outside the range

$$5.3622 \leq LSMEAN \leq 5.5410$$

would be significantly different from the 1989 mean. The detection limit statement for this interval would be: If two effects level means (log_{10}-transformed data) differ by 0.08936, then there is a 50 percent chance that this difference will be found if $\alpha = 0.05$.

Since the dependant variable is transformed, the interval above is more biologically meaningful if translated back to the original units. Unfortunately, transformation back to the original units does not preserve the interpretation of the detection limits. This occurs, in part, because the mean of the transformed dependent variable does not, upon reverse transformation, equal the mean of the original dependent variable (*i.e.*, the mean of the dependent variable is not invariate under non-linear transformation). We used the back-transformation process to estimate the detection limits in biologically meaningful units, but must emphasize that this produces a biased approximation of the true detection limits. Furthermore, the direction and magnitude of the bias are unclear.

$$10^{5.3622} \leq (\text{observed value} = 10^{5.4516}) \leq 10^{5.5410}, \text{ or}$$

$$230{,}250 \leq (\text{observed value} = 282{,}879) \leq 348{,}498$$

Note that the interval, when transformed back to the original units, is not symmetric about the 1989 LSMEAN. That is, the lower limit is closer to the mean than the upper limit. The detection limit can also be approximately expressed as a proportion of the back-transformed LSMEAN, as:

$$0.5 * (348{,}498 - 230{,}250) / 282{,}879 = 0.2090$$

The Most Variable LSMEAN: The most variable year in the streptomycete levels ANACOV was 1985, with an LSMEAN of 5.3288 and a standard error of the LSMEAN of 0.05699. (Note: One reason for the larger LSMEAN standard error for 1985 is the smaller initial sample size used in 1985.) The same process followed above is used to establish the "low estimate" of power using these values. It follows that LSMEANs outside the following range would be significantly different from the 1985 mean.

$$5.1708 \leq \text{LSMEAN} \leq 5.4868$$

The <u>detection limit statement</u> for this interval would be: If two effect level means ($\log_{10}$-transformed data) differ by 0.15798, then there is a 50 percent chance that this difference will be found if $\alpha = 0.05$.

Back-transformed to the original streptomycete colony-forming units, the interval above becomes[1]:

$$148{,}184 \leq (\text{observed value} = 213{,}206) \leq 306{,}761$$

As a proportion of the back-transformed LSMEAN, the detection limit is approximately[1]:

$$0.5 * (306{,}761 - 148{,}184) / 213{,}206 = 0.3719$$

In this report, detection limits will be expressed both as 1) the detection limit difference in transformed units (*e.g.*, 0.08936 and

0.15798, for 1989 and 1985, respectively), and 2) a proportion of the back-transformed LSMEAN[1] (*e.g.*, 0.2090 and 0.3719, for 1989 and 1985, respectively).

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[1] See the above discussion concerning bias resulting from this non-linear transformation.

WORK ELEMENTS

The work elements of the Litter Decomposition and Microflora project represent the three diverse study areas included within this project. Data from work elements of the "Trees" project are used to test each hypothesis posed by this project (Table 2). The following sections present a synopsis of the study rationale, historical development, measures, and analytical results for each work element of this project.

ELEMENT 1: LITTER DECOMPOSITION

Introduction

Knowledge of key decomposition processes and their rates is essential to conceptualization of ecosystem dynamics. Organic matter decomposition is primarily accomplished by microorganisms, whose activities are regulated by the environment. Environmental factors which disrupt decomposition processes detract from the orderly flow of nutrients to vegetation. As a new and anthropogenic environmental factor, ELF EM fields merit investigation for possible effects on the litter decomposition subsystem.

Microfloral population shifts have been shown to influence the rate of total litter decomposition (Mitchell and Millar 1978). Conversely, dry matter mass loss is a useful measure of the impact of environmental perturbations on the integrated activities of the litter biota. The methods employed in these studies integrate the activities of all but the largest soil fauna, and ELF EM fields represent one possible cause of environmental perturbation.

Studies of litter decomposition also extend the usefulness of litter production data collected in the course of forest vegetation studies. Knowledge of litter biomass production and nutrient content provide one link between the overstory and forest floor components of the forest ecosystem.

The forest vegetation at all three study sites is classified in the *Acer-Quercus-Vaccinium* habitat type (Coffman *et al*. 1983). The two hardwood species selected for study, northern red oak (*Quercus rubra* L.) and red maple (*Acer rubrum* L.), are common to both of the hardwood stand subunits. Red pine (*Pinus resinosa* Ait.) was selected as the conifer species for study because 1) it exists as scattered mature specimens throughout the area, and 2) the study plantations were established with red pine. These three study species represent a range of decomposition strategies and rates.

Nine years of maple, oak, and pine leaf litter decomposition study have been completed at the grounded antenna, overhead antenna, and control study sites. The sites were selected in late 1983. The three red pine plantations were established with 2-0 bare-root planting stock in June of 1984. The first completely on-site decomposition experiment was placed in the field in December 1984. The last field samples were retrieved in November 1993. The resulting study consisted of nine sequential annual experiments.

The litter decomposition study element involved evaluation of the potential for subtle ELF EM field effects on the activities of communities of interacting microorganisms. This study spanned two pre-operational years, three (possibly four, including 1991) years of intermittent antenna testing, and three fully operational years (excluding 1991).

Methods

Experiments in this project were conducted annually, focusing on decomposition progress during the year (December through November) following autumn litterfall. Litter decomposition was quantified as percent change in dry matter mass with elapsed time. Dry matter mass loss from freshly fallen foliar litter samples has been widely used as a measure of fully integrated litter decomposition (Jensen 1974, Millar 1974, Witkamp and Ausmus 1976, Fogel and Cromack 1978). It has been suggested that we should have expressed X_m on an ash-free basis. However, because we have been working with the early stages of litter decomposition, the difference between modeling dry matter mass *versus* ash-free dry matter mass should be minor. Nevertheless, we have determined ash-free X_m for use as the independent variable in our oak/hardwood stand ANACOV model, and present the results of that analysis in this final report.

Sample Preparation, Placement, and Recovery

A single parent litter collection was made annually, from a single location for each study species, in order to avoid the effects of possible differences in substrate quality associated with geographically different litter sources. Fresh-fallen red pine litter was collected on netting in the LaCroix red pine plantation near Houghton, due to 1) its proximity to MTU, and 2) its remoteness from interfering ELF EM fields. Red maple litter was similarly collected seven miles from Houghton, for the same reasons. Northern red oak litter was collected just northeast of the control plantation. Had sufficient resources been available, it would have been interesting to use litter collected adjacent to the study sites, but this would have tripled the number of samples required in order to include exchanges among the three sites.

Each year, each species' parent litter collection was mixed and allowed to achieve equilibrium moisture content before samples were drawn arbitrarily. Fresh to dry mass ratios and initial nutrient contents were determined for approximately 15 samples taken from each parent litter collection at regular intervals during field sample preparation. Single species samples were used for efficiency, and because decomposition of each species in a mixed species litter sample is apparently not affected by the mixture, even if the component species differ in nutritional quality (Thomas 1968; Blair *et al.* 1990; Klemmedson 1992).

Analyses of litter nutrient content were conducted by the Soils Analysis Laboratory, School of Forestry and Wood Products, MTU. Laboratory protocol included analysis of NBS standard no. 1575 (pine needles) as every 20th sample for N and P, and as every 15th sample for cations. All mass loss data are based on 30°C dry masses. Initial lignin content of the 1984 through 1989 parent litter collections was also determined. Lignin content was estimated using the TAPPI technique (Official Testing Method T 222 om-88, revised 1988) entitled "Acid-insoluble lignin in wood and pulp". A modification to this procedure involved autoclaving the digesting sample for 1 hour rather than boiling it for 4 hours (step 9.4; V.L.C. Chiang, personal communication). Other studies have found lignin content useful for explaining differences in decomposition rate (*e.g.*, Melillo *et al.* 1982). We anticipated that lignin content might be particularly useful in evaluating the maple data, because the influence of lignin on decomposition rate increases as mass loss progresses (Meentemeyer and Berg 1986, Berg *et al.* 1984, Fogel and Cromack, Jr. 1977).

Samples destined for the field are pre-massed and enclosed in nylon mesh envelopes (3 mm aperture) constructed to lie flat on the ground. Bulk pine sample envelopes measured 22 cm x 28 cm, and contained 10 g (air dry) of the parent collection. Bulk maple and oak sample envelopes measured 44 cm x 28 cm, and contained 15 g (air dry) of the parent collection. All samples were placed in the field in December, and subsets were retrieved at approximately monthly intervals from early May to early November. Snow cover at the study sites dictated the earliest and latest possible recovery dates from the plantation subunits. The following experimental design (for bulk litter samples) was used throughout the study. Two clusters of randomized samples were arbitrarily located in each of the three plots comprising each study plantation and hardwood stand. One envelope per species was retrieved each month from each of the 6 clusters per plantation or hardwood stand.

The 1984/85 through 1990/91 experiments also evaluated X_m using individual leaves. Individual leaves offer the opportunity to study decomposition of individual foliage units. Our objective was to determine whether the extra effort required to work with individual leaves would produce more realistic and precise data than those from bulk samples. Individual leaf samples were derived from the same parent litter collections as the bulk samples. Each individual leaf was completely intact initially. Effects of pine fascicle fragmentation on decomposition measurements were especially easy to eliminate by discarding any fascicles which lost fragments during the course of study. An indicator variable for initial leaf density (g cm^{-2}) was calculated for each individual maple and oak leaf.

Prior to the 1986/87 experiment, individual leaf envelopes contained multiple tethered leaves of a single species (4 maple leaves, or 8-10 oak or pine leaves). One envelope per month per species was recovered from a single cluster arbitrarily located in each of the three plots comprising each study plantation or hardwood stand. Beginning with the 1986/87 experiment, having learned about pseudo-replication, we began collecting one envelope (22 cm X 28 cm, containing one pine fascicle and one oak leaf) from each of eight locations per plot each month. As a result, the individual sample leaves of each species were clearly independent of one another, and recovery of samples from 24 locations per plantation or hardwood stand (instead of 3) better represented site variability. Individual leaf studies were discontinued in 1991, because there was no evidence that they provided more realistic or precise data than did the bulked leaf studies.

Analysis of Covariance

Dry matter mass loss data were transformed to the arc sin square root of X_m to homogenize variances (Steel and Torrie 1980). Sufficient samples were recovered monthly to permit analysis of differences among sites, years, and sampling dates by ANACOV. Our principal objectives have been 1) to use ANACOV to explain differences among sites, years, and siteyears, using covariates unrelated to ELF field exposures, and 2) to evaluate the temporal patterns of remaining unexplained differences relative to ELF EM field variables. Potential covariates were categorized as follows.

1) Covariates characterizing annual parent litter collections provide values which apply to all samples from each collection (*e.g.*, initial percent nitrogen content).

2) Covariates characterizing individual leaf samples prior to placement in the field provide each sample with a unique value (*e.g.*, individual oak leaf density).

3) Covariates characterizing retrieved samples provide each sample a unique value (*e.g.*, percent nitrogen content).

4) Covariates which characterize dynamic aspects of the study site environment provide sample cohorts (by plot, year) with common values (*e.g.*, degree days, precipitation amount and frequency).

Category 1 covariates (*i.e.*, initial nutrient and lignin content) can be used to distinguish among years but not sites, because each year's parent litter collections are distributed to all sites. Though Proc GLM permits ANACOV with these covariates, we can not conduct multiple comparisons within these models. Therefore, unless these covariates explain all differences among years, we remain uncertain of what they accomplish. This problem arises because there is only one estimate of each parent litter property for each year. The perfect colinearity between these covariates and one of the degrees of freedom associated with years results in one fewer degrees of freedom associated with the Type III sum of squares for Year, and zero degrees of freedom for the covariate. When SAS detects this, no estimates of adjusted means or standard errors are computed, and no multiple comparisons are made.

Category 2 covariates can be used to distinguish among years, sites and sampling dates, because each sample unit has a characteristic value. Unfortunately, use of these individual leaf covariates is not practical with bulked leaf samples.

Category 3 covariates include the percent N, P, K, Ca, and Mg contents of the retrieved bulk litter samples. Our approach to studying the nutritional aspects of litter decomposition shifted, from the original intent to consider nutrient fluxes as dependent variables (*i.e.*, X_N, X_P, X_K, X_{Mg}, and X_{Ca}) toward use of percent nutrient contents as covariates to help explain patterns of X_m. Shortly thereafter, we moved away from consideration of nutrient content as covariates. We then suspended nutrient analysis of retrieved samples in order to devote available resources to mass loss studies. Discontinuation of nutrient analyses on retrieved samples was also justified by the tenability of nutrient data re: detection of an ELF effect. If decomposition is at all affected by ELF EM fields, it is quite likely that sample nutrient content would also be affected. The use of covariates which may be influenced by the experimental treatment (*i.e.*, ELF EM fields) could mask the presence of treatment effects in the analysis. However, all retrieved bulk litter samples were archived for possible future nutrient analysis. The residual portion of every ground sample, beyond the portion required for nutrient analysis, was also archived for future reference.

Category 4 covariates include measures of air and soil temperature degree days, total precipitation, and precipitation event frequency, and actual evapotranspiration (AET: *e.g.*, Thornthwaite and Mather 1957, Meentemeyer and Berg 1986). AET calculations were based on 25 mm soil moisture retention, to reflect the relatively xeric conditions experienced by litter on the forest floor. Initially, only annually cumulative covariates were calculated.

With the exception of AET, each weather covariate was calculated independently of the others. Although AET integrates temperature, precipitation, water-holding capacity, and the effect of lattitude, AET fails to account for inhibiting effects of energy inputs during dry summer periods. During such periods, warm weather dries out the litter, depressing the rate of decomposition progress.

For this reason, we developed covariates based on monthly (and seasonal) inputs of degree days, precipitation amounts and event frequencies (*e.g.*, ATDD-MAY, PRT-MAY, PR.10-MAY, *etc.*, and ATDD-SPRING, PRT-SPRING, PR.10-SPRING, *etc.*). Spring was defined as lasting through early June, summer consisted of early June through early September, and autumn consisted of early September through early November. This type of covariate permits at least some expression, within the ANACOV model, of the differential seasonal effects of temperature with respect to concurrent precipitation. One additional covariate corrects for the differences among years in monthly sample collection dates.

Whenever ANACOV is used, there is concern that the covariate values can be affected by the treatment under investigation (in this case, ELF EM field exposure). Where this type of effect occurs, a portion of the observed response which should be allocated to the treatment may be inappropriately allocated to the covariate. Thus, if a covariate and the treatment are correlated, and if the correlation could have been caused by the treatment, it would be inappropriate to use that covariate. Nevertheless, it is frequently the case that a covariate value could not reasonably be affected by the treatment. This is most clearly true in any case where the covariate is measured before the treatment is applied, but is often clearly true even if the covariate is measured during or after treatment application. We can argue strongly that this is true for our weather covariates. Any effects of the Michigan ELF antenna on biotic communities are expected to be subtle, but there seems no plausible argument for any effect of ELF EM fields on the basic weather pattern at the treatment sites. Thus, we maintain that our precipitation and temperature covariate patterns were not causally affected by ELF.

It is possible for a treatment to display non-causative but statistically significant correlation with covariates. This would result in classic multicolinearity, causing a reduction in statistical power involving both the covariate and the treatment (see Judge *et al.* 1982 for a complete discussion). This does not, however, seem to be a problem for this study, because of the small differences that are detected as statistically significant.

All ANACOVs have been conducted on the mainframe computer, using Proc GLM of the Statistical Analysis System (SAS Institute, Inc. 1985). In all statistical analyses, acceptance or rejection of the null hypothesis is based on $\alpha = 0.05$, regardless of the statistical test employed. Multiple range comparisons among significant differences detected by ANACOV are identified by the Least Square Means pairwise comparison option, within Proc GLM.

The uniformly significant site-year interactions are interesting, because they may indicate an ELF effect on decomposition rate. In order to explain site-year interactions, the Means Model ANACOV was used to identify significantly different "siteyears" (*e.g.*, control-1985, control-1986, *etc.*). The resulting patterns of siteyear differences were used to identify site trends among years.

Description of Progress

Tables 3-5, respectively, present mean X_m summaries (raw data) for the bulk pine, oak and maple foliage samples retrieved in 1993 (by sampling date, site and stand type), along with standard deviations and minimum detectable differences based on 95 percent confidence intervals for sample means. The data show that the following shifts in sample means should be detectable ($\alpha = 0.05$):

Plantations: Pine - 5%; Oak - 5%; Maple - 5%
Hardwood Stands: Pine - 4%; Oak - 3%; Maple - 5%

Figures 1 and 2 present comparisons of monthly dry matter mass loss progress for bulk pine fascicles during the 1992/93 study in the red pine plantation and hardwood stand types, respectively. Means representing the raw (untransformed) data are plotted between bars

Table 3. Mean proportion[a] of initial dry matter mass (30°C basis) remaining at different times in 1993, for bulk **red pine** foliar litter samples disbursed in December, 1992.

Sampling Date	Antenna Unit					
	Plantation			Hardwood Stand		
	Mean	S.D.[b]	%[c]	Mean	S.D.	%
9 May	0.91	0.01	2	0.90	0.03	3
5 June	0.91	0.01	2	0.90	0.01	1
5 July	0.84	0.03	4	0.87	0.01	1
1 August	0.84	0.02	3	0.83	0.01	1
4 September	0.80	0.05	7	0.75	0.03	4
2 October	0.76	0.02	2	0.75	0.02	3
31 October	0.78	0.01	2	0.75	0.02	3

Table 3. (cont)

Sampling Date	Control Unit					
	Plantation			Hardwood Stand		
	Mean	S.D.	%	Mean	S.D.	%
9 May	0.90	0.01	1	0.90	0.01	1
5 June	0.88	0.03	3	0.89	0.02	2
5 July	0.86	0.02	2	0.88	0.01	2
1 August	0.83	0.01	2	0.84	0.02	2
4 September	0.78	0.01	2	0.78	0.01	2
2 October	0.75	0.03	4	0.76	0.03	4
31 October	0.73	0.04	6	0.75	0.01	2

Table 3. (cont)

Sampling Date	Ground Unit		
	Plantation		
	Mean	S.D.	%
9 May	0.91	0.02	2
5 June	0.90	0.02	2
5 July	0.85	0.04	5
1 August	0.84	0.03	3
4 September	0.78	0.03	4
2 October	0.76	0.04	5
31 October	0.76	0.02	2

[a] Proportion ($X_m = M_1/M_0$), where M_0 and M_1 represent the 30°C dry matter masses of samples initially and at time 1, respectively. Dry matter mass at time 0 was estimated from fresh to dry mass (30°C) ratios determined for arbitrary subsamples taken at the time of field sample preparation.

[b] standard deviation

[c] detectable difference: estimated shift in each mean value detectable 95 percent of the time (α = .05), calculated as $t_{0.05,5}$ * S.E./Mean and expressed as a percentage of the mean.

Table 4. Mean proportion[a] of initial dry matter mass (30°C basis) remaining at different times in 1993, for bulk **northern red oak** litter samples disbursed in December, 1992.

Sampling Date	Antenna Unit					
	Plantation			Hardwood Stand		
	Mean	S.D.[b]	%[c]	Mean	S.D.	%
9 May	0.92	0.02	2	0.93	0.02	2
5 June	0.92	0.02	2	0.92	0.02	2
5 July	0.85	0.01	1	0.88	0.02	2
1 August	0.84	0.01	2	0.85	0.01	2
4 September	0.79	0.03	4	0.77	0.02	3
2 October	0.72	0.03	5	0.73	0.02	2
31 October	0.73	0.01	2	0.74	0.02	2

Table 4. (cont)

Sampling Date	Control Unit					
	Plantation			Hardwood Stand		
	Mean	S.D.	%	Mean	S.D.	%
9 May	0.94	0.02	3	0.93	0.02	2
5 June	0.93	0.03	3	0.92	0.02	2
5 July	0.89	0.03	3	0.90	0.01	2
1 August	0.84	0.04	5	0.86	0.02	3
4 September	0.77	0.03	4	0.77	0.02	3
2 October	0.76	0.04	5	0.75	0.02	3
31 October	0.74	0.02	3	0.74	0.02	3

Table 4. (cont)

Sampling Date	Ground Unit		
	Plantation		
	Mean	S.D.	%
9 May	0.94	0.02	2
5 June	0.92	0.01	1
5 July	0.87	0.02	2
1 August	0.83	0.01	2
4 September	0.80	0.04	6
2 October	0.74	0.04	5
31 October	0.76	0.02	3

[a] Proportion ($X_m = M_1/M_0$), where M_0 and M_1 represent the 30°C dry matter masses of samples initially and at time 1, respectively. Dry matter mass at time 0 was estimated from fresh to dry mass (30°C) ratios determined for separate arbitrary subsamples taken at the time of field sample preparation.

[b] standard deviation

[c] detectable difference: estimated shift in each mean value detectable 95 percent of the time (α = .05), calculated as $t_{0.05,5}$ * S.E./Mean, and expressed as a percentage of the mean.

Table 5. Mean proportion[a] of initial dry matter mass (30°C basis) remaining at different times in 1993, for bulk **red maple** litter samples disbursed in December, 1992.

Sampling Date	Antenna Unit					
	Plantation			Hardwood Stand		
	Mean	S.D.[b]	%[c]	Mean	S.D.	%
9 May	0.80	0.01	2	0.81	0.03	4
5 June	0.76	0.02	2	0.78	0.02	2
5 July	0.71	0.02	4	0.74	0.02	3
1 August	0.67	0.03	5	0.69	0.03	5
4 September	0.66	0.03	5	0.67	0.03	5
2 October	0.62	0.01	2	0.62	0.05	8
31 October	0.62	0.03	5	0.64	0.02	4

Table 5. (cont)

Sampling Date	Control Unit					
	Plantation			Hardwood Stand		
	Mean	S.D.	%	Mean	S.D.	%
9 May	0.82	0.03	4	0.82	0.04	5
5 June	0.78	0.03	4	0.78	0.03	4
5 July	0.74	0.04	5	0.76	0.01	2
1 August	0.69	0.03	5	0.73	0.04	5
4 September	0.68	0.03	5	0.67	0.03	5
2 October	0.61	0.03	4	0.65	0.02	3
31 October	0.63	0.05	8	0.68	0.04	6

Table 5. (cont)

Sampling Date	Ground Unit		
	Plantation		
	Mean	S.D.	%
9 May	0.81	0.03	3
5 June	0.78	0.03	4
5 July	0.72	0.04	5
1 August	0.70	0.02	3
4 September	0.65	0.02	4
2 October	0.63	0.02	3
31 October	0.61	0.03	6

[a] Proportion ($X_m=M_1/M_0$), where M_0 and M_1 represent the 30°C dry matter masses of samples initially and at time 1, respectively. Dry matter mass at time 0 was estimated from fresh to dry mass (30°C) ratios determined for separate arbitrary subsamples taken at the time of field sample preparation.

[b] standard deviation

[c] detectable difference: estimated shift in each mean value detectable 95 percent of the time (α = .05), calculated as $t_{0.05,5}$ * S.E./Mean, and expressed as a percentage of the mean.

depicting their associated 95 percent confidence intervals. Figures 3 and 4, and 5 and 6, present analogous comparisons for bulk oak and maple leaf samples, respectively.

Mean dry matter mass loss values for each year, litter species, and month (through 1993), along with their associated coefficients of variation (CV), are presented in Tables 6-10 (for the antenna ground plantation, overhead antenna plantation and hardwood stand, and control plantation and hardwood stand, respectively). As noted above, the experimental design appropriately supports data analysis by ANACOV. ANACOV is based on much larger samples than are the monthly CV values reported in Tables 6-10, and tend to explain much of the variability evident in the CV values. This is partly because n is larger, but also because factors used for statistical blocking and covariance analysis are included in the ANACOV models. The CV values presented in Tables 6-10 are therefore quite conservative compared to ANACOV results.

Pine has generally provided the most precise mass loss data over the years, and maple the least precise. Maple leaves are by far the most fragile of the three test substrate species and pine needle fascicles are the most durable. Over the 1985-1993 study period, annual mean dry matter mass losses for bulk maple, oak and pine litter samples ranged 20-60 percent, 22-39 percent, and 22-30 percent, respectively. Only maple samples consistently lost mass faster in the plantations than in the hardwood stands.

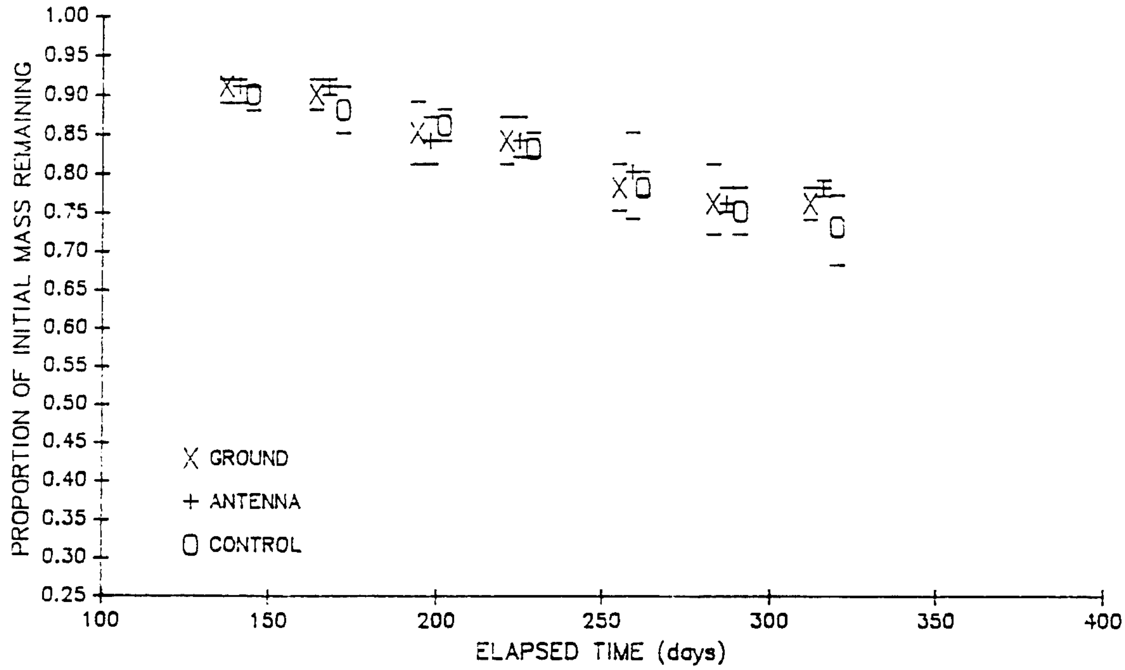

FIGURE 1. Proportion (X) of initial dry matter mass remaining for bulk pine needle samples retrieved from the three plantation subunits during the 1992–1993 experiment.

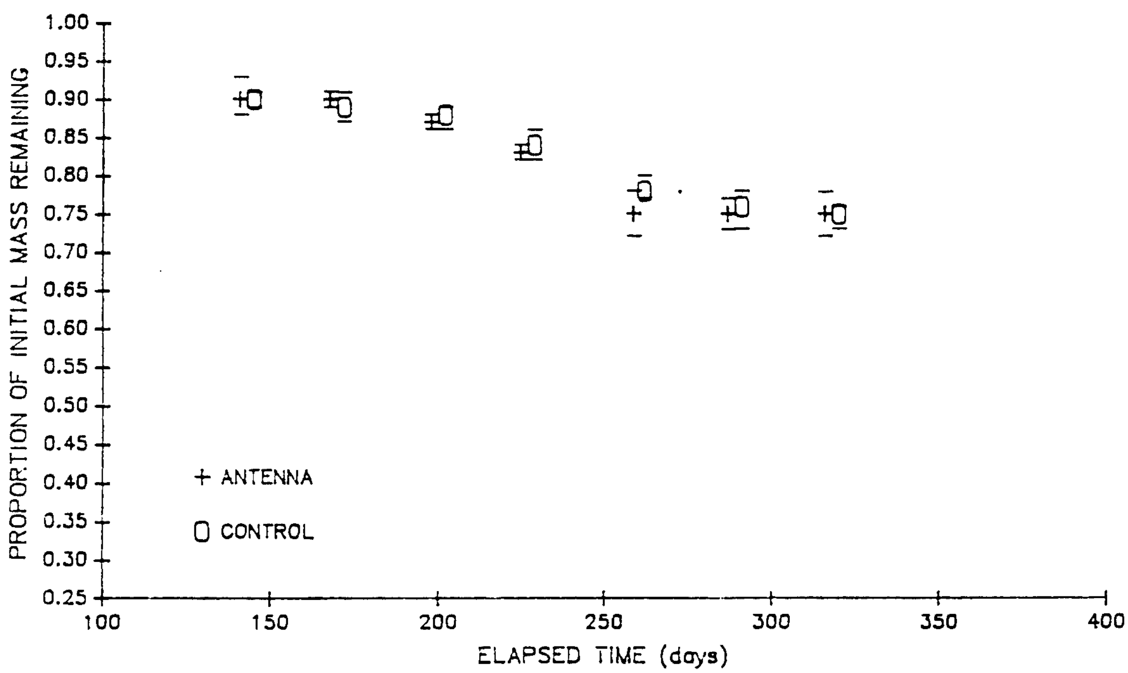

FIGURE 2. Proportion (X) of initial dry matter mass remaining for bulk pine needle samples retrieved from the two hardwood stand subunits during the 1992–1993 experiment.

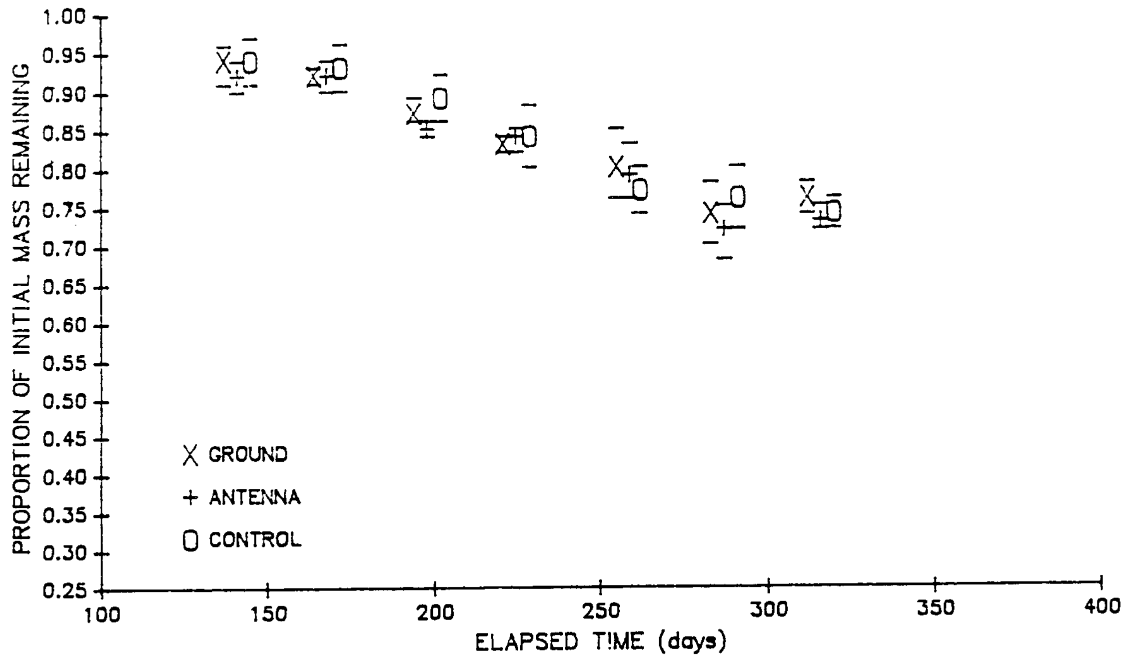

FIGURE 3. Proportion (X) of initial dry matter mass remaining for bulk oak leaf samples retrieved from the three plantation subunits during the 1992–1993 experiment.

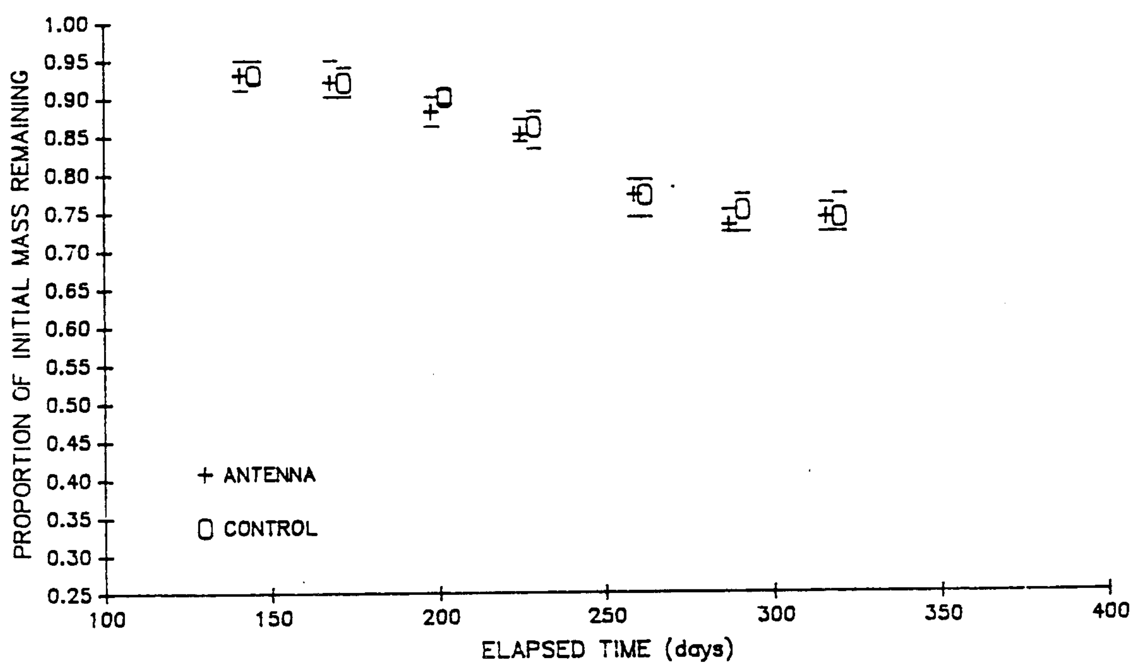

FIGURE 4. Proportion (X) of initial dry matter mass remaining for bulk oak leaf samples retrieved from the two hardwood stand subunits during the 1992–1993 experiment.

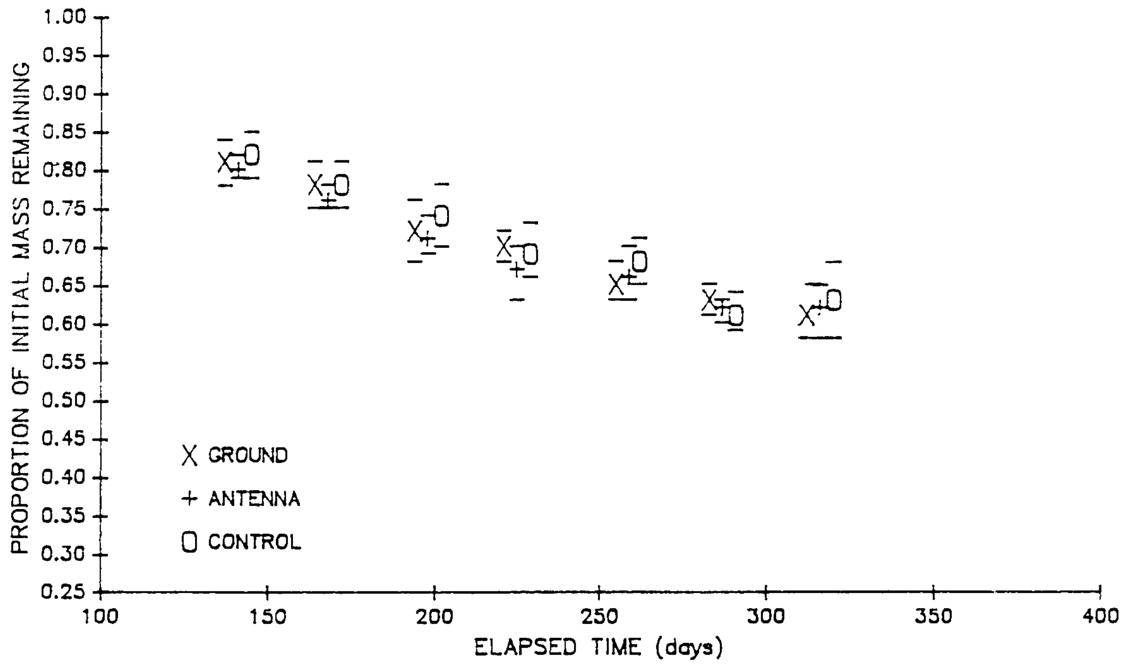

FIGURE 5. Proportion (X) of initial dry matter mass remaining for bulk maple leaf samples retrieved from the three plantation subunits during the 1992–1993 experiment.

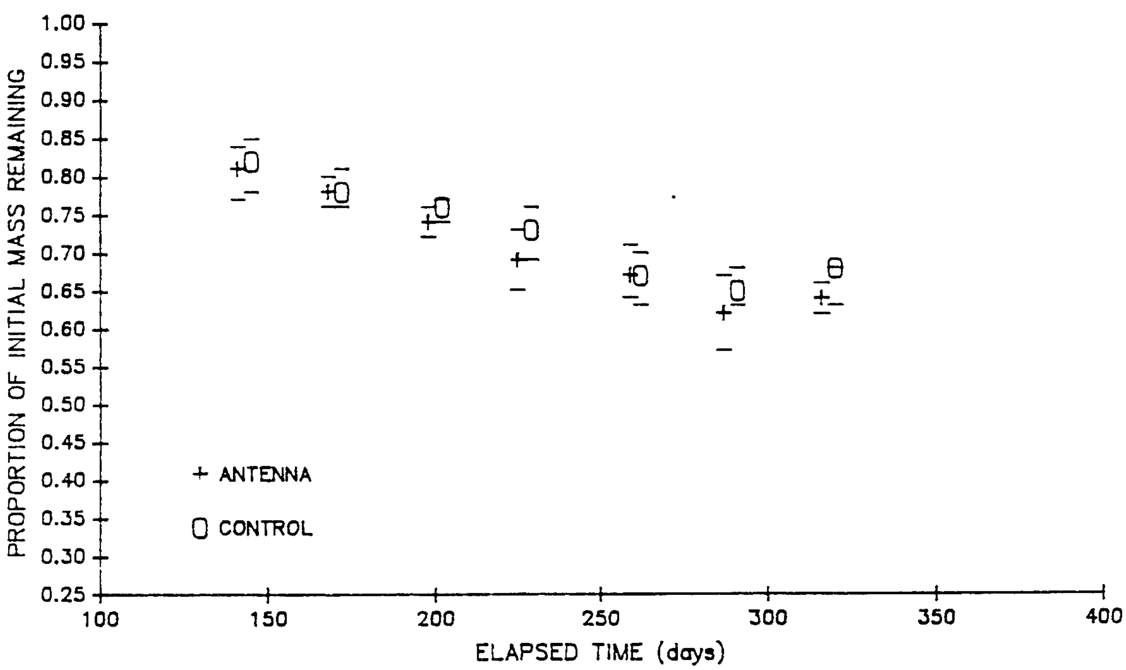

FIGURE 6. Proportion (X) of initial dry matter mass remaining for bulk maple leaf samples retrieved from the two hardwood stand subunits during the 1992–1993 experiment.

Table 6. Monthly mean X_m[a] and percent coefficient of variation (CV) for bulk litter envelopes at the **Antenna Ground Plantation.**

Year	Species		May	Jun	Jul	Aug	Sep	Oct	Nov
1985	Maple	Xm	0.64	0.59	0.55	0.52	0.45	0.40	0.40
		CV	9.3	2.2	3.2	6.1	8.3	9.1	29.2
	Oak	Xm	0.92	0.88	0.85	0.81	0.75	0.69	0.68
		CV	2.1	1.8	1.6	2.5	4.2	4.8	6.3
	Pine	Xm	0.90	0.85	0.83	0.82	0.76	0.71	0.70
		CV	0.8	0.9	1.3	2.6	2.9	1.9	8.2
1986	Maple	Xm	0.80	0.80	0.76	0.70	0.61	0.54	0.47
		CV	3.9	3.9	2.1	5.1	7.3	10.6	23.1
	Oak	Xm	0.93	0.93	0.90	0.86	0.81	0.74	0.67
		CV	1.1	1.8	1.6	2.0	2.3	4.3	8.4
	Pine	Xm	0.91	0.87	0.88	0.84	0.81	0.72	0.71
		CV	1.8	3.6	4.8	3.8	1.4	2.6	1.5
1987	Maple	Xm	0.84	0.78	0.74	0.70	0.62	0.61	0.58
		CV	6.8	8.6	7.1	9.6	9.5	8.1	12.6
	Oak	Xm	0.92	0.94	0.87	0.80	0.79	0.76	0.74
		CV	9.8	1.3	11.9	15.5	2.6	5.0	3.3
	Pine	Xm	0.93	0.92	0.90	0.85	0.78	0.74	0.75
		CV	1.5	2.1	1.5	2.2	1.6	4.6	1.7
1988	Maple	Xm	0.77	0.70	0.68	0.63	0.56	0.51	0.50
		CV	3.0	4.0	3.5	4.0	4.6	5.2	5.4
	Oak	Xm	0.92	0.89	0.88	0.84	0.77	0.72	0.66
		CV	2.0	1.7	3.7	3.0	3.4	3.4	11.7
	Pine	Xm	0.91	0.91	0.89	0.87	0.78	0.75	0.74
		CV	1.5	3.0	0.6	1.5	2.5	1.9	5.2
1989	Maple	Xm	0.89	0.85	0.80	0.77	0.73	0.67	0.71
		CV	1.4	1.5	4.3	2.7	5.3	4.0	3.7
	Oak	Xm	0.91	0.86	0.83	0.77	0.73	0.70	0.67
		CV	4.4	3.1	2.7	4.1	4.6	4.9	6.9
	Pine	Xm	0.90	0.87	0.85	0.81	0.78	0.73	0.75
		CV	2.2	2.3	2.0	3.2	2.8	5.0	2.8
1990	Maple	Xm	0.88	0.84	0.80	0.72	0.71	0.65	0.58
		CV	2.5	4.7	5.8	4.1	8.5	5.2	4.4
	Oak	Xm	0.96	0.93	0.89	0.85	0.82	0.78	0.75
		CV	0.9	0.9	1.4	2.4	2.9	2.0	5.5
	Pine	Xm	0.94	0.92	0.87	0.86	0.83	0.79	0.75
		CV	1.1	1.8	1.6	0.6	2.4	2.4	1.3
1991	Maple	Xm	0.82	0.75	0.71	0.68	0.64	0.62	0.57
		CV	3.5	4.4	4.2	4.2	5.2	6.2	10.3
	Oak	Xm	0.92	0.87	0.82	0.78	0.75	0.68	0.66
		CV	2.1	0.7	2.2	2.1	3.1	6.0	5.2
	Pine	Xm	0.93	0.89	0.86	0.83	0.79	0.77	0.75
		CV	1.3	2.5	1.9	1.0	3.0	2.1	1.7
1992	Maple	Xm	0.88	0.83	0.79	0.74	0.71	0.68	0.63
		CV	3.0	2.8	1.9	2.5	3.3	6.6	4.8
	Oak	Xm	0.91	0.85	0.81	0.77	0.73	0.70	0.67
		CV	1.8	1.5	4.1	3.3	3.4	1.9	2.8
	Pine	Xm	0.90	0.87	0.86	0.83	0.79	0.78	0.75
		CV	0.9	2.6	1.5	3.0	3.4	3.3	1.8
1993	Maple	Xm	0.81	0.78	0.72	0.70	0.65	0.63	0.61
		CV	3.7	3.8	5.6	2.9	3.1	3.2	4.9
	Oak	Xm	0.94	0.92	0.87	0.83	0.80	0.74	0.76
		CV	2.1	1.1	2.3	1.2	5.0	5.4	2.6
	Pine	Xm	0.91	0.90	0.85	0.84	0.78	0.76	0.76
		CV	2.2	2.2	4.7	3.6	3.8	5.3	2.6

[a] X_m is the proportion of dry matter mass remaining at retrieval.

Table 7. Monthly mean X_m* and percent coefficient of variation (CV) for bulk litter envelopes at the **Overhead Antenna Plantation**.

Year	Species		May	Jun	Jul	Aug	Sep	Oct	Nov
1985	Maple	Xm	0.70	0.63	0.59	0.54	0.53	0.45	0.46
		CV	2.9	8.1	7.7	6.9	10.5	5.2	21.1
	Oak	Xm	0.92	0.87	0.86	0.83	0.78	0.70	0.74
		CV	3.1	3.3	2.9	2.8	3.3	6.7	10.6
	Pine	Xm	0.92	0.88	0.86	0.84	0.78	0.72	0.72
		CV	1.1	1.5	1.8	2.5	4.0	1.7	2.3
1986	Maple	Xm	0.82	0.82	0.75	0.68	0.62	0.52	0.48
		CV	3.3	2.1	3.5	2.5	7.8	5.9	6.5
	Oak	Xm	0.93	0.93	0.90	0.87	0.80	0.73	0.69
		CV	2.0	0.7	1.6	1.0	1.5	3.4	9.2
	Pine	Xm	0.92	0.90	0.89	0.86	0.81	0.76	0.74
		CV	1.4	1.8	1.8	1.4	1.9	6.7	2.9
1987	Maple	Xm	0.81	0.75	0.69	0.65	0.61	0.54	0.54
		CV	9.2	7.8	8.6	9.2	7.7	9.9	6.6
	Oak	Xm	0.94	0.86	0.88	0.81	0.76	0.74	0.71
		CV	2.8	9.0	6.5	10.6	2.5	5.3	3.5
	Pine	Xm	0.94	0.94	0.91	0.86	0.80	0.77	0.75
		CV	1.4	2.3	2.8	2.6	2.6	1.5	2.3
1988	Maple	Xm	0.76	0.70	0.68	0.63	0.56	0.51	0.50
		CV	2.8	4.0	3.8	3.7	9.7	5.5	5.6
	Oak	Xm	0.91	0.90	0.87	0.84	0.76	0.74	0.67
		CV	1.6	1.4	1.6	2.8	4.9	4.3	5.6
	Pine	Xm	0.90	0.89	0.88	0.86	0.81	0.79	0.73
		CV	2.0	1.3	1.3	2.1	2.1	3.3	2.5
1989	Maple	Xm	0.92	0.85	0.83	0.77	0.76	0.70	0.68
		CV	3.3	2.8	2.2	2.8	5.3	5.2	11.0
	Oak	Xm	0.92	0.89	0.85	0.80	0.73	0.72	0.69
		CV	4.1	2.7	2.1	8.4	6.2	6.7	7.2
	Pine	Xm	0.91	0.89	0.86	0.84	0.78	0.76	0.76
		CV	1.5	2.5	3.0	2.2	3.0	2.2	3.2
1990	Maple	Xm	0.93	0.83	0.78	0.74	0.70	0.67	0.61
		CV	3.4	5.5	3.4	3.7	5.5	6.1	11.1
	Oak	Xm	0.97	0.94	0.91	0.89	0.85	0.78	0.74
		CV	1.4	1.2	1.3	1.7	2.1	6.2	1.8
	Pine	Xm	0.95	0.93	0.90	0.88	0.84	0.79	0.74
		CV	1.3	2.6	2.5	2.4	3.3	3.7	3.6
1991	Maple	Xm	0.83	0.76	0.73	0.68	0.65	0.63	0.60
		CV	4.0	4.2	5.0	4.7	3.5	3.4	4.4
	Oak	Xm	0.93	0.88	0.83	0.78	0.75	0.70	0.67
		CV	1.6	2.5	3.7	1.9	2.4	5.1	2.1
	Pine	Xm	0.93	0.89	0.86	0.81	0.79	0.75	0.74
		CV	2.5	2.2	2.0	1.5	3.0	2.1	2.5
1992	Maple	Xm	0.88	0.83	0.77	0.74	0.73	0.67	0.68
		CV	1.1	2.7	3.5	3.6	2.7	3.1	6.0
	Oak	Xm	0.86	0.86	0.83	0.81	0.75	0.72	0.69
		CV	4.0	2.4	3.0	6.2	11.9	5.5	5.3
	Pine	Xm	0.90	0.88	0.85	0.84	0.80	0.76	0.73
		CV	1.5	1.4	2.0	3.5	1.8	2.4	4.8
1993	Maple	Xm	0.80	0.76	0.71	0.67	0.66	0.62	0.62
		CV	1.2	2.6	2.8	4.5	4.5	1.6	4.8
	Oak	Xm	0.92	0.92	0.85	0.84	0.79	0.72	0.73
		CV	2.2	2.2	1.2	1.2	3.8	4.2	1.4
	Pine	Xm	0.91	0.91	0.84	0.84	0.80	0.76	0.78
		CV	1.1	1.1	3.6	2.4	6.2	2.6	1.3

* Xm is the proportion of dry matter mass remaining at retrieval.

Table 8. Monthly mean X_m* and percent coefficient of variation (CV) for bulk litter envelopes at the **Overhead Antenna Hardwood Stand.**

Year	Species		May	Jun	Jul	Aug	Sep	Oct	Nov
1985	Maple	Xm	0.71	0.63	0.69	0.64	0.60	0.55	0.54
		CV	3.4	4.8	6.2	2.6	1.2	4.9	6.6
	Oak	Xm	0.92	0.88	0.89	0.88	0.81	0.73	0.78
		CV	1.7	0.9	2.2	3.5	3.2	5.7	12.1
	Pine	Xm	0.89	0.83	0.84	0.84	0.77	0.71	0.71
		CV	0.6	0.7	2.4	5.8	1.6	1.3	3.5
1986	Maple	Xm	0.86	0.85	0.84	0.78	0.76	0.71	0.63
		CV	1.1	2.1	3.8	3.4	4.4	6.2	4.6
	Oak	Xm	0.94	0.95	0.94	0.91	0.87	0.81	0.74
		CV	2.3	0.7	1.1	1.7	2.2	2.6	5.2
	Pine	Xm	0.94	0.91	0.91	0.86	0.79	0.75	0.72
		CV	0.9	1.9	0.9	1.0	2.0	2.4	1.7
1987	Maple	Xm	0.85	0.84	0.83	0.77	0.72	0.66	0.67
		CV	5.3	6.0	5.0	6.7	6.8	7.7	8.1
	Oak	Xm	0.96	0.97	0.92	0.87	0.80	0.75	0.75
		CV	1.3	3.3	2.0	2.0	2.6	3.4	2.5
	Pine	Xm	0.94	0.93	0.89	0.82	0.77	0.74	0.73
		CV	1.3	1.3	1.9	1.2	1.1	1.2	1.5
1988	Maple	Xm	0.75	0.73	0.72	0.67	0.64	0.55	0.56
		CV	2.5	3.3	1.6	5.1	4.7	6.0	4.4
	Oak	Xm	0.93	0.93	0.91	0.90	0.78	0.74	0.68
		CV	1.7	0.8	2.6	2.6	3.3	2.5	5.5
	Pine	Xm	0.92	0.91	0.89	0.88	0.77	0.74	0.73
		CV	0.6	0.6	1.0	1.2	0.8	1.5	1.7
1989	Maple	Xm	0.92	0.87	0.87	0.82	0.77	0.73	0.77
		CV	2.0	1.1	3.3	2.2	5.5	3.3	2.7
	Oak	Xm	0.93	0.89	0.84	0.79	0.73	0.71	0.68
		CV	1.1	3.5	3.3	3.3	2.4	6.3	4.2
	Pine	Xm	0.90	0.89	0.86	0.83	0.78	0.74	0.74
		CV	1.0	2.2	1.7	1.4	0.5	1.2	2.3
1990	Maple	Xm	0.93	0.85	0.82	0.75	0.71	0.63	0.67
		CV	4.2	3.5	2.7	4.0	8.7	5.9	12.6
	Oak	Xm	0.97	0.95	0.91	0.88	0.82	0.75	0.75
		CV	0.9	0.7	1.7	1.9	2.3	1.8	8.6
	Pine	Xm	0.94	0.93	0.88	0.83	0.81	0.74	0.73
		CV	0.8	1.6	2.2	2.3	2.7	1.4	1.8
1991	Maple	Xm	0.82	0.76	0.75	0.72	0.66	0.66	0.65
		CV	3.0	2.5	7.1	6.8	4.5	6.5	7.7
	Oak	Xm	0.93	0.88	0.82	0.77	0.73	0.64	0.61
		CV	1.4	1.7	2.0	1.2	3.0	6.3	2.3
	Pine	Xm	0.93	0.89	0.85	0.79	0.76	0.75	0.73
		CV	1.2	1.9	1.8	2.4	2.7	0.9	1.7
1992	Maple	Xm	0.90	0.85	0.82	0.81	0.79	0.73	0.71
		CV	1.8	2.2	2.7	2.0	1.8	4.2	3.6
	Oak	Xm	0.90	0.87	0.82	0.78	0.75	0.68	0.63
		CV	1.7	2.8	1.6	5.9	5.0	2.6	3.5
	Pine	Xm	0.91	0.89	0.85	0.84	0.80	0.76	0.74
		CV	0.9	1.8	1.6	1.6	2.5	1.0	2.4
1993	Maple	Xm	0.81	0.78	0.74	0.69	0.67	0.62	0.64
		CV	3.7	2.6	2.7	4.3	4.5	8.1	3.1
	Oak	Xm	0.93	0.92	0.88	0.85	0.77	0.73	0.74
		CV	2.2	2.2	2.3	1.2	2.6	2.7	2.7
	Pine	Xm	0.90	0.90	0.87	0.83	0.75	0.75	0.75
		CV	3.3	1.1	1.1	1.2	4.0	2.7	2.7

* X_m is the proportion of dry matter mass remaining at retrieval.

Table 9. Monthly mean X_m* and percent coefficient of variation (CV) for bulk litter envelopes at the **Control Plantation.**

Year	Species		May	Jun	Jul	Aug	Sep	Oct	Nov
1985	Maple	Xm	0.70	0.62	0.57	0.56	0.50	0.53	0.48
		CV	3.7	7.7	6.4	5.4	6.8	15.6	15.0
	Oak	Xm	0.95	0.90	0.85	0.84	0.79	0.75	0.69
		CV	1.5	2.3	2.9	2.1	3.8	10.2	16.8
	Pine	Xm	0.89	0.86	0.83	0.80	0.80	0.73	0.71
		CV	1.6	1.3	1.2	0.7	6.2	4.5	2.9
1986	Maple	Xm	0.82	0.81	0.76	0.69	0.68	0.59	0.57
		CV	2.3	3.1	2.8	3.0	7.2	21.3	11.4
	Oak	Xm	0.94	0.92	0.90	0.87	0.83	0.76	0.68
		CV	1.0	1.1	1.3	2.1	2.9	5.2	11.5
	Pine	Xm	0.90	0.87	0.87	0.84	0.78	0.76	0.70
		CV	1.4	5.5	2.8	2.2	2.8	4.1	4.5
1987	Maple	Xm	0.85	0.79	0.77	0.72	0.65	0.62	0.60
		CV	1.4	2.4	2.2	3.7	4.5	6.2	4.7
	Oak	Xm	0.95	0.92	0.90	0.85	0.78	0.74	0.73
		CV	2.6	1.7	3.4	1.5	3.6	7.9	4.9
	Pine	Xm	0.92	0.91	0.88	0.84	0.77	0.74	0.74
		CV	1.9	1.3	2.6	0.6	1.2	1.5	1.9
1988	Maple	Xm	0.77	0.72	0.68	0.64	0.57	0.54	0.49
		CV	3.7	3.6	3.1	5.4	7.5	3.6	9.9
	Oak	Xm	0.95	0.90	0.89	0.87	0.79	0.75	0.68
		CV	1.0	2.2	3.6	1.8	2.6	3.4	6.1
	Pine	Xm	0.92	0.89	0.88	0.88	0.79	0.76	0.73
		CV	0.5	2.7	1.0	2.3	1.4	1.7	1.3
1989	Maple	Xm	0.91	0.86	0.83	0.81	0.73	0.72	0.72
		CV	2.8	3.5	1.9	3.0	5.5	4.0	4.7
	Oak	Xm	0.92	0.88	0.84	0.81	0.75	0.70	0.68
		CV	1.7	1.3	2.7	2.5	2.9	2.5	5.5
	Pine	Xm	0.91	0.88	0.85	0.81	0.79	0.73	0.76
		CV	2.2	1.8	1.3	3.1	1.7	1.7	5.6
1990	Maple	Xm	0.93	0.82	0.77	0.72	0.69	0.63	0.62
		CV	3.3	2.4	3.3	6.5	6.1	4.5	11.8
	Oak	Xm	0.97	0.94	0.90	0.87	0.82	0.76	0.72
		CV	1.0	1.6	1.9	2.4	1.9	3.0	2.5
	Pine	Xm	0.93	0.93	0.90	0.87	0.83	0.78	0.74
		CV	2.6	1.4	2.0	3.3	2.4	3.9	3.9
1991	Maple	Xm	0.80	0.77	0.73	0.71	0.65	0.64	0.60
		CV	1.4	4.8	3.6	5.3	4.6	8.9	7.5
	Oak	Xm	0.92	0.88	0.83	0.79	0.74	0.67	0.66
		CV	1.4	1.4	4.8	3.0	2.1	4.2	6.5
	Pine	Xm	0.92	0.89	0.86	0.82	0.78	0.75	0.74
		CV	1.6	1.2	1.9	2.6	2.4	1.9	3.7
1992	Maple	Xm	0.87	0.84	0.82	0.78	0.78	0.69	0.70
		CV	3.0	1.2	4.4	5.1	8.9	6.5	10.6
	Oak	Xm	0.89	0.85	0.82	0.77	0.75	0.68	0.62
		CV	1.6	5.8	3.2	3.0	4.6	3.2	5.8
	Pine	Xm	0.91	0.88	0.86	0.83	0.80	0.75	0.75
		CV	0.7	1.8	1.8	1.2	1.3	1.3	3.7
1993	Maple	Xm	0.82	0.78	0.74	0.69	0.68	0.61	0.63
		CV	3.7	3.8	5.4	4.3	4.4	4.9	7.9
	Oak	Xm	0.94	0.93	0.89	0.84	0.77	0.76	0.74
		CV	2.1	3.2	3.4	4.8	3.9	5.3	2.7
	Pine	Xm	0.90	0.88	0.86	0.83	0.78	0.75	0.73
		CV	1.1	3.4	2.3	1.2	1.3	4.0	5.5

* X_m is the proportion of dry matter mass remaining at retrieval.

Table 10. Monthly mean X_m* and percent coefficient of variation (CV) for bulk litter envelopes retrieved from the **Control Hardwood Stand**.

Year	Species		May	Jun	Jul	Aug	Sep	Oct	Nov
1985	Maple	Xm	0.72	0.65	0.64	0.64	0.58	0.54	0.51
		CV	3.0	2.5	2.4	3.2	3.7	5.5	4.7
	Oak	Xm	0.93	0.90	0.87	0.87	0.79	0.70	0.68
		CV	1.1	1.6	1.0	5.4	2.5	4.5	4.1
	Pine	Xm	0.89	0.83	0.83	0.81	0.77	0.71	0.70
		CV	0.9	0.6	1.1	2.4	1.8	1.9	3.4
1986	Maple	Xm	0.84	0.85	0.82	0.77	0.75	0.69	0.63
		CV	2.7	1.1	3.1	3.8	2.2	4.4	4.0
	Oak	Xm	0.94	0.95	0.93	0.91	0.85	0.78	0.72
		CV	0.6	1.1	1.0	1.5	2.4	0.7	1.6
	Pine	Xm	0.93	0.92	0.89	0.85	0.79	0.75	0.72
		CV	0.9	2.0	2.2	1.3	1.8	1.2	1.8
1987	Maple	Xm	0.87	0.83	0.84	0.81	0.75	0.71	0.70
		CV	1.7	2.3	2.4	3.5	5.7	4.8	5.0
	Oak	Xm	0.95	0.93	0.90	0.86	0.80	0.71	0.74
		CV	1.4	1.8	1.9	1.7	3.5	10.0	3.1
	Pine	Xm	0.94	0.92	0.88	0.83	0.77	0.74	0.73
		CV	1.3	1.4	1.2	1.0	2.0	2.4	2.3
1988	Maple	Xm	0.80	0.76	0.75	0.71	0.66	0.64	0.62
		CV	2.4	3.2	4.6	4.0	5.7	4.7	8.4
	Oak	Xm	0.95	0.94	0.94	0.92	0.84	0.77	0.73
		CV	1.1	1.1	1.8	1.8	2.7	4.0	4.1
	Pine	Xm	0.94	0.92	0.92	0.92	0.82	0.78	0.75
		CV	0.8	0.7	1.1	0.8	1.5	1.5	2.8
1989	Maple	Xm	0.92	0.90	0.88	0.87	0.81	0.80	0.80
		CV	3.3	2.7	2.1	2.8	1.9	3.6	3.1
	Oak	Xm	0.92	0.90	0.86	0.82	0.78	0.75	0.73
		CV	1.8	3.0	3.6	3.5	4.2	3.8	4.9
	Pine	Xm	0.92	0.89	0.87	0.83	0.81	0.78	0.77
		CV	2.2	2.6	2.7	2.4	1.6	2.0	1.1
1990	Maple	Xm	0.93	0.87	0.84	0.80	0.76	0.67	0.69
		CV	3.7	5.8	3.7	4.4	5.8	6.4	5.6
	Oak	Xm	0.97	0.96	0.93	0.89	0.83	0.76	0.74
		CV	0.5	0.8	2.2	1.8	1.2	1.2	4.3
	Pine	Xm	0.96	0.96	0.92	0.88	0.84	0.76	0.74
		CV	0.9	0.8	1.8	2.8	5.8	1.4	3.5
1991	Maple	Xm	0.81	0.76	0.76	0.70	0.66	0.62	0.64
		CV	2.5	2.7	5.2	3.1	3.3	4.6	5.1
	Oak	Xm	0.93	0.87	0.82	0.79	0.73	0.68	0.65
		CV	3.0	1.7	1.8	2.3	4.4	4.6	4.6
	Pine	Xm	0.94	0.91	0.87	0.82	0.78	0.75	0.74
		CV	0.9	1.6	1.5	3.2	0.7	2.0	2.1
1992	Maple	Xm	0.88	0.84	0.83	0.81	0.81	0.75	0.75
		CV	2.7	4.6	3.2	4.2	1.6	7.8	5.9
	Oak	Xm	0.89	0.85	0.84	0.76	0.73	0.71	0.63
		CV	1.3	1.2	2.2	3.6	3.8	2.4	8.3
	Pine	Xm	0.90	0.89	0.88	0.82	0.81	0.77	0.75
		CV	1.2	1.4	1.4	5.1	2.0	3.3	2.4
1993	Maple	Xm	0.82	0.78	0.76	0.73	0.67	0.65	0.68
		CV	4.9	3.8	1.3	5.5	4.5	3.1	5.9
	Oak	Xm	0.93	0.92	0.90	0.86	0.77	0.75	0.74
		CV	2.2	2.2	1.1	2.3	2.6	2.7	2.7
	Pine	Xm	0.90	0.89	0.88	0.84	0.78	0.76	0.75
		CV	1.1	2.2	1.1	2.4	1.3	3.9	1.3

* X_m is the proportion of dry matter mass remaining at retrieval.

Precision in the data was slightly higher for the hardwood stands than the plantations. The hardwood stands presented more stable environments for comparison of decomposition mass loss among years than did the rapidly developing pine plantations. This was an important consideration with respect to our objective of detecting possible effects of increasing ELF EM field exposures. Therefore, special interest in testing ELF-related hypotheses was directed toward comparison of the two study hardwood stands.

The covariates included in our ANACOV models are conceptually and logically straightforward. Total precipitation, the number of precipitation events delivering at least 0.01 or 0.1 inches of rain, and soil temperature degree days (4°C basis, at 5 cm depth) are the weather parameters included. However, to adequately address the impact of these parameters on the biological process of leaf litter decomposition, their representation within the ANACOV models appears somewhat complex.

These weather parameters can have very different implications for decomposition progress depending on their distributions temporally and with respect to each other over the course of each annual experiment. For example, moisture events during the spring, soon after melting of the typically large snowpack and before the landscape has warmed sufficiently to favor rapid decomposition, contribute far less to decomposition than equivalent rainfall events during mid-summer, when the decomposer system is likely to be more limited by moisture availability than by temperature. Because of these relationships, we included each weather parameter as three independent covariates representing spring, summer, and autumn levels. This results in the use of nine variables (three seasons times three weather parameters) in our ANACOV models. Our success with weather-related covariates undoubtedly underestimates their biological importance, because of the complexity of the relationships to be represented.

The only other covariate in our ANACOV models deals with the procedural fact that monthly samples could not always be retrieved from the field on the same dates each year. The covariate value used to correct for differing sample retrieval dates is the number of days, plus or minus, between each monthly target date and the actual retrieval date. Decomposition rates vary greatly through the year; litter mass loss is generally slowest in the early spring and again in late autumn, and fastest during mid- to late summer. Therefore, this covariate is also represented within the ANACOV models with a "seasonal" adjustment. Separate retrieval date deviation covariates are included independently for each month.

Means Model ANACOV results are presented in Tables 11-12, 13-14, and 15-16, for maple, oak, and pine samples (respectively) in the hardwood stands. Corresponding ANACOV results for maple, oak and pine samples in the plantations are presented in Tables 17-18, 19-20, and 21-22. All covariate names are defined in Table 23.

Table 11. **Means Model ANACOV** table for detection of differences in **red maple** litter dry matter mass loss (arcsin square root of X_m, the proportion of initial mass remaining) in the two **hardwood stands**[a].

Source of Variation	df	SS	Type III SS	F	Signif. of F	r^2
Model	39	9.13		129.98	0.0001	0.88
Siteyear	17		2.14	70.03	0.0001	
Month	6		0.07	6.37	0.0001	
ST5DDSPR	1		0.03	20.68	0.0001	
ST5DDSUM	1		0.01	5.97	0.0148	
ST5DDAUT	1		0.02	10.57	0.0012	
PRWSPR	1		0.01	6.00	0.0145	
PRWSUM	1		0.00	0.07	0.7921	
PRWAUT	1		0.00	0.19	0.6615	
PR.01SPR	1		0.00	2.37	0.1240	
PR.01SUM	1		0.00	1.50	0.2204	
PR.01AUT	1		0.00	0.16	0.6927	
DEV*MONTH	7		0.03	2.22	0.0310	
Error	714	1.29				
Corrected Total	753	10.41				

[a] Covariates are defined in Table 23.

Table 12. Adjusted means, standard errors, and significantly different pairs of means, based on the **Means Model** for **maple** litter in the **hardwood stands** (Table 11).

Source of Variation	Adj. Mean[a]	Std Error[b]	Significant Differences[c]	5	6	7	8	9	0	1	2	3	5	6	7	8	9	0	1	2	3
Siteyear																					
A85	0.93	0.018	A85																		
A86	1.05	0.015	A86	*																	
A87	1.08	0.015	A87	*																	
A88	0.94	0.011	A88		*	*															
A89	1.14	0.011	A89	*	*	*	*														
A90	1.09	0.009	A90	*	*		*	*													
A91	1.02	0.009	A91	*		*	*	*	*												
A92	1.12	0.014	A92	*	*	*	*		*	*											
A93	1.04	0.012	A93	*			*	*	*		*										
C85	0.91	0.019	C85		*	*	*	*	*	*	*	*									
C86	1.03	0.015	C86	*			*	*	*		*		*								
C87	1.08	0.019	C87	*			*	*		*			*								
C88	0.99	0.010	C88	*	*	*	*	*	*	*	*	*	*	*	*						
C89	1.17	0.017	C89	*	*	*	*	*	*	*	*	*	*	*	*	*					
C90	1.14	0.010	C90	*	*	*	*		*	*		*	*	*	*	*					
C91	1.04	0.016	C91	*			*	*	*		*		*				*	*			
C92	1.12	0.008	C92	*	*	*	*	*	*	*		*	*	*	*	*	*		*		
C93	1.04	0.012	C93	*				*	*		*		*			*	*	*		*	

Source of Variation	Adj. Mean	Std Error		M	J	J	A	S	O
Month									
May	1.15	0.032	May						
June	1.00	0.033	June	*					
July	1.03	0.021	July	*					
August	1.05	0.017	Aug	*					
September	1.07	0.029	Sept	*					
October	1.04	0.032	Oct						
November	1.04	0.051	Nov						

[a] adjusted mean of transformed data
[b] standard error of the least squares mean, provided by the Least Squares Means option of SAS Proc GLM
[c] $\alpha = 0.05$, Least Squares Means procedure

Table 13. **Means Model ANACOV** table for detection of differences in **red oak** litter dry matter mass loss (arcsin square root of X_m, the proportion of initial mass remaining) in the two **hardwood stands**[a].

Source of Variation	df	SS	Type III SS	F	Signif. of F	r^2
Model	39	12.09		196.57	0.0001	0.91
Siteyear	17		1.16	43.10	0.0001	
Month	6		0.01	1.49	0.1787	
ST5DDSPR	1		0.00	0.77	0.3794	
ST5DDSUM	1		0.01	5.70	0.0172	
ST5DDAUT	1		0.01	5.12	0.0239	
PRWSPR	1		0.03	17.22	0.0001	
PRWSUM	1		0.04	22.92	0.0001	
PRWAUT	1		0.00	0.08	0.7778	
PR.01SPR	1		0.00	1.47	0.2264	
PR.01SUM	1		0.01	3.34	0.0681	
PR.01AUT	1		0.01	7.29	0.0071	
DEV*MONTH	7		0.04	5.80	0.0003	
Error	716	1.13				
Corrected Total	755	13.22				

[a] Covariates are defined in Table 23.

Table 14. Adjusted means, standard errors, and significantly different pairs of means, based on the **Means Model** for **oak** litter in the **hardwood stands** (Table 13).

Source of Variation	Adj. Mean[a]	Std Error[b]	Significant Differences[c]	5	6	7	8	9	0	1	2	3	5	6	7	8	9	0	1	2	3
Siteyear																					
A85	1.24	0.019	A85																		
A86	1.16	0.013	A86	*																	
A87	1.23	0.013	A87		*																
A88	1.14	0.010	A88	*		*															
A89	1.11	0.010	A89	*	*	*	*														
A90	1.21	0.007	A90		*		*	*													
A91	1.11	0.015	A91	*	*	*	*		*												
A92	1.05	0.011	A92	*	*	*	*	*	*	*											
A93	1.18	0.009	A93	*		*	*	*	*	*	*										
C85	1.18	0.016	C85	*		*		*	*	*	*										
C86	1.16	0.012	C86	*		*		*	*	*	*										
C87	1.19	0.014	C87	*		*	*	*		*	*										
C88	1.20	0.010	C88		*		*	*		*	*			*							
C89	1.14	0.011	C89	*		*		*	*		*	*			*	*					
C90	1.25	0.008	C90		*		*	*	*	*	*	*	*	*	*	*	*				
C91	1.15	0.020	C91	*		*			*	*	*							*			
C92	1.08	0.010	C92	*	*	*	*	*	*			*	*	*	*	*	*	*	*		
C93	1.22	0.016	C93		*		*	*		*	*	*	*	*	*		*		*	*	

Month	Adj. Mean	Std Error		M	J	J	A	S	O
May	1.20	0.027	May						
June	1.19	0.027	June						
July	1.18	0.017	July						
August	1.17	0.012	Aug						
September	1.14	0.023	Sept						
October	1.13	0.026	Oct						
November	1.14	0.036	Nov						

[a] adjusted mean of transformed data
[b] standard error of the least squares mean, provided by the Least Squares Means option of SAS Proc GLM
[c] $\alpha = 0.05$, Least Squares Means procedure

Table 15. **Means Model ANACOV** table for detection of differences in **red pine** litter dry matter mass loss (arcsin square root of X_m, the proportion of initial mass remaining) in the two **hardwood stands**[a].

Source of Variation	df	SS	Type III SS	F	Signif. of F	r2
Model	39	7.34		214.74	0.0001	0.92
Siteyear	17		0.43	28.95	0.0001	
Month	6		0.02	4.47	0.0002	
ST5DDSPR	1		0.01	8.71	0.0033	
ST5DDSUM	1		0.04	45.51	0.0001	
ST5DDFAL	1		0.00	1.47	0.2253	
PRWSPR	1		0.01	8.37	0.0039	
PRWSUM	1		0.02	19.46	0.0001	
PRWFAL	1		0.00	4.55	0.0332	
PR.10SPR	1		0.00	4.79	0.0290	
PR.10SUM	1		0.00	0.13	0.7175	
PR.10FAL	1		0.03	33.26	0.0001	
DEV*MONTH	7		0.03	8.71	0.0001	
Error	714	0.63				
Corrected Total	753	7.96				

[a] Covariates are defined in Table 23.

Table 16. Adjusted means, standard errors, and significantly different pairs of means, based on the **Means Model** for **pine** litter in the **hardwood stands** (Table 15).

Source of Variation	Adj. Mean[a]	Std Error[b]	Significant Differences[c]	5	6	7	8	9	0	1	2	3	5	6	7	8	9	0	1	2	3
Siteyear																					
A85	1.11	0.014	A85																		
A86	1.14	0.010	A86																		
A87	1.15	0.010	A87	*																	
A88	1.16	0.007	A88	*																	
A89	1.15	0.008	A89	*																	
A90	1.18	0.005	A90	*	*	*	*	*													
A91	1.16	0.011	A91	*																	
A92	1.14	0.008	A92				*		*	*											
A93	1.15	0.007	A93	*					*												
C85	1.08	0.011	C85	*	*	*	*	*	*	*	*	*									
C86	1.15	0.008	C86	*					*				*								
C87	1.14	0.010	C87	*					*				*								
C88	1.21	0.007	C88	*	*	*	*	*	*	*	*	*	*	*	*						
C89	1.17	0.008	C89	*	*			*			*	*	*	*	*	*					
C90	1.23	0.006	C90	*	*	*	*	*	*	*	*	*	*	*	*	*	*				
C91	1.20	0.014	C91	*	*	*	*	*		*	*	*	*	*	*			*			
C92	1.13	0.007	C92	*			*		*				*			*	*	*	*		
C93	1.15	0.012	C93	*					*				*			*		*	*		

Source of Variation	Adj. Mean[a]	Std Error[b]	Significant Differences[c]	M	J	J	A	S	O
Month									
May	1.17	0.019	May						
June	1.10	0.019	June	*					
July	1.13	0.012	July	*	*				
August	1.15	0.007	Aug		*	*			
September	1.17	0.015	Sept		*				
October	1.17	0.017	Oct		*				
November	1.19	0.023	Nov		*				

[a] adjusted mean of transformed data
[b] standard error of the least squares mean, provided by the Least Squares Means option of SAS Proc GLM
[c] $\alpha = 0.05$, Least Squares Means procedure

Table 17. **Means Model ANACOV** table for detection of differences in **red maple** litter dry matter mass loss (arcsin square root of X_m, the proportion of initial mass remaining) in the three **plantations**[a].

Source of Variation	df	SS	Type III SS	F	Signif. of F	r^2
Model	48	17.25		155.11	0.0001	0.87
Siteyear	26		3.01	49.99	0.0001	
Month	6		0.04	2.63	0.0154	
ST5DDSPR	1		0.00	1.12	0.2909	
ST5DDSUM	1		0.02	6.84	0.0090	
ST5DDAUT	1		0.01	3.04	0.0817	
PRWSPR	1		0.00	0.83	0.3633	
PRWSUM	1		0.00	0.77	0.3793	
PRWAUT	1		0.01	6.31	0.0122	
PR.01SPR	1		0.00	0.04	0.8505	
PR.01SUM	1		0.02	7.66	0.1758	
PR.01AUT	1		0.00	1.83	0.1758	
DEV*MONTH	7		0.01	0.89	0.5171	
Error	1079	2.50				
Corrected Total	1127	19.74				

[a] Covariates are defined in Table 23.

Table 18. Adjusted means, standard errors, and significantly different pairs of means, based on the **Means Model** (Table 17) for **maple** litter in the **plantations**.

Source	Adj. Mean[a]	Std Error[b]	Significant Differences[c]	5	6	7	8	9	0	1	2	3	5	6	7	8	9	0	1	2	3	5	6	7	8	9	0	1	2	3
Siteyear																														
G85	0.79	0.018	G85																											
G86	0.96	0.014	G86	*																										
G87	1.00	0.013	G87	*	*																									
G88	0.91	0.011	G88	*	*	*																								
G89	1.08	0.011	G89	*	*	*	*																							
G90	1.05	0.011	G90	*	*	*	*	*																						
G91	0.98	0.009	G91	*			*	*	*																					
G92	1.05	0.015	G92	*	*	*	*	*		*																				
G93	1.01	0.010	G93	*	*		*	*	*		*																			
A85	0.85	0.018	A85	*	*	*	*	*	*	*	*	*																		
A86	0.95	0.014	A86	*		*	*	*	*		*	*	*																	
A87	0.96	0.014	A87	*		*	*	*	*		*	*	*																	
A88	0.90	0.011	A88	*	*	*		*	*	*	*	*	*	*	*															
A89	1.10	0.011	A89	*	*	*	*		*	*	*	*	*	*	*	*														
A90	1.07	0.009	A90	*	*	*	*			*		*	*	*	*	*	*													
A91	0.99	0.009	A91	*	*		*	*	*		*		*	*		*	*	*												
A92	1.05	0.013	A92	*	*	*	*	*		*		*	*	*	*	*	*		*											
A93	1.00	0.012	A93	*	*		*	*	*		*		*	*		*	*	*		*										
C85	0.85	0.017	C85	*	*	*	*	*	*	*	*	*		*	*		*	*	*	*	*									
C86	0.99	0.013	C86	*	*		*	*	*		*		*	*		*	*	*		*		*								
C87	1.02	0.017	C87	*	*		*			*			*	*	*	*	*	*				*								
C88	0.92	0.010	C88	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*	*	*	*	*						
C89	1.11	0.017	C89	*	*	*		*	*	*	*	*	*	*	*	*		*	*	*	*	*	*	*	*					
C90	1.05	0.009	C90	*	*	*	*			*		*	*	*	*	*	*		*		*	*	*		*	*				
C91	1.01	0.016	C91	*	*		*	*					*	*	*	*	*	*				*			*	*	*			
C92	1.09	0.010	C92	*	*	*	*		*	*	*	*	*	*	*	*			*	*	*	*	*	*	*		*	*		
C93	1.02	0.013	C93	*	*		*	*		*			*	*	*	*	*	*				*			*	*			*	

Source	Adj. Mean[a]	Std Error[b]	Significant Differences[c]	M	J	J	A	S	O
Month									
May	1.05	0.030	May						
June	0.97	0.032	June	*					
July	0.97	0.019	July	*					
August	0.97	0.014	Aug	*					
September	0.99	0.027	Sept						
October	0.99	0.030	Oct						
November	1.00	0.042	Nov						

[a] adjusted mean of transformed data
[b] standard error of the least squares mean, provided by the Least Squares Means option of SAS Proc GLM
[c] $\alpha = 0.05$, Least Squares Means procedure

Table 19. **Means Model ANACOV** table for detection of differences in **red oak** litter dry matter mass loss (arcsin square root of X_m, the proportion of initial mass remaining) in the three **plantations**[a].

Source of Variation	df	SS	Type III SS	F	Signif. of F	r^2
Model	48	14.85		144.23	0.0001	0.87
Siteyear	26		1.16	20.84	0.0001	
Month	6		0.01	0.68	0.6619	
ST5DDSPR	1		0.00	1.16	0.2826	
ST5DDSUM	1		0.02	7.85	0.0052	
ST5DDAUT	1		0.00	1.48	0.2246	
PRWSPR	1		0.00	1.36	0.2444	
PRWSUM	1		0.00	0.06	0.8016	
PRWAUT	1		0.00	0.05	0.8285	
PR.01SPR	1		0.00	1.67	0.1965	
PR.01SUM	1		0.02	9.01	0.0027	
PR.01AUT	1		0.00	0.03	0.8564	
DEV*MONTH	7		0.18	11.86	0.0001	
Error	1080	2.32				
Corrected Total	1128	17.17				

[a] Covariates are defined in Table 23.

Table 20. Adjusted means, standard errors, and significantly different pairs of means, based on the **Means Model** (Table 19) for **oak** litter in the **plantations** .

Source	Adj. Mean[a]	Std Error[b]	Significant Differences[c]	5	6	7	8	9	0	1	2	3	5	6	7	8	9	0	1	2	3	5	6	7	8	9	0	1	2	3
Siteyear																														
G85	1.15	0.018	G85																											
G86	1.12	0.014	G86																											
G87	1.18	0.013	G87		*																									
G88	1.11	0.010	G88			*																								
G89	1.09	0.011	G89	*		*																								
G90	1.18	0.010	G90		*		*	*																						
G91	1.12	0.009	G91	*		*			*																					
G92	1.05	0.014	G92	*	*	*	*	*	*	*																				
G93	1.18	0.010	G93		*		*	*		*	*																			
A85	1.18	0.017	A85	*	*		*	*		*	*																			
A86	1.12	0.014	A86			*			*		*	*	*																	
A87	1.16	0.014	A87				*	*		*	*																			
A88	1.11	0.010	A88	*		*			*		*	*	*		*															
A89	1.12	0.010	A89			*		*	*		*	*	*		*															
A90	1.21	0.008	A90	*	*	*	*	*	*	*	*	*		*	*	*	*													
A91	1.12	0.008	A91	*		*			*		*	*	*		*			*												
A92	1.06	0.012	A92	*	*	*	*	*	*	*		*	*	*	*	*	*	*	*											
A93	1.17	0.012	A93		*		*	*		*	*			*		*	*	*	*	*										
C85	1.18	0.016	C85	*	*		*	*		*	*			*		*	*		*	*										
C86	1.14	0.013	C86			*		*	*		*	*				*		*		*										
C87	1.20	0.016	C87	*	*		*	*		*	*			*	*	*	*		*	*		*								
C88	1.15	0.010	C88				*	*	*	*	*	*				*	*	*		*			*							
C89	1.12	0.016	C89			*		*	*		*	*	*					*		*	*		*							
C90	1.20	0.009	C90	*	*		*	*		*	*			*	*	*	*		*	*	*		*		*	*				
C91	1.13	0.015	C91			*			*		*	*	*					*		*	*	*		*			*			
C92	1.06	0.010	C92	*	*	*	*	*	*	*		*	*	*	*	*	*	*	*		*	*	*	*	*	*	*	*		
C93	1.21	0.013	C93	*	*	*	*	*		*	*	*		*	*	*	*		*	*	*		*		*	*		*	*	

Month	Adj. Mean[a]	Std Error[b]	Significant Differences[c]	M	J	J	A	S	O
May	1.17	0.028	May						
June	1.14	0.031	June						
July	1.14	0.018	July						
August	1.15	0.013	Aug						
September	1.15	0.026	Sept						
October	1.13	0.029	Oct						
November	1.11	0.041	Nov						

[a] adjusted mean of transformed data
[b] standard error of the least squares mean, provided by the Least Squares Means option of SAS Proc GLM
[c] $\alpha = 0.05$, Least Squares Means procedure

Table 21. **Means Model ANACOV** table for detection of differences in **red pine** litter dry matter mass loss (arcsin square root of X_m, the proportion of initial mass remaining) in the three **plantations**[a].

Source of Variation	df	SS	Type III SS	F	Signif. of F	r2
Model	48	9.17		192.12	0.0001	0.89
Siteyear	26		0.44	16.86	0.0001	
Month	6		0.01	1.82	0.0928	
ST5DDSPR	1		0.00	0.23	0.6318	
ST5DDSUM	1		0.01	5.78	0.0164	
ST5DDFAL	1		0.01	5.57	0.0184	
PRWSPR	1		0.00	3.99	0.0460	
PRWSUM	1		0.01	6.34	0.0120	
PRWFAL	1		0.00	0.07	0.7843	
PR.01SPR	1		0.00	0.56	0.4534	
PR.01SUM	1		0.02	17.87	0.0001	
PR.01FAL	1		0.00	0.00	0.9602	
DEV*MONTH	7		0.03	3.67	0.0006	
Error	1084	1.08				
Corrected Total	1132	10.25				

[a] Covariates are defined in Table 23.

Table 22. Adjusted means, standard errors, and significantly different pairs of means, based on the **Means Model** (Table 21) for **pine** litter in the **plantations**.

Source	Adj. Mean[a]	Std Error[b]	Significant Differences[c]	5	6	7	8	9	0	1	2	3	5	6	7	8	9	0	1	2	3	5	6	7	8	9	0	1	2	3
Siteyear																														
G85	1.11	0.012	G85																											
G86	1.13	0.009	G86																											
G87	1.17	0.008	G87	*	*																									
G88	1.15	0.007	G88			*																								
G89	1.13	0.007	G89			*																								
G90	1.19	0.007	G90	*	*		*	*																						
G91	1.16	0.006	G91	*	*			*	*																					
G92	1.14	0.009	G92			*			*																					
G93	1.16	0.007	G93	*	*			*	*																					
A85	1.15	0.011	A85	*					*																					
A86	1.15	0.009	A86	*	*			*	*																					
A87	1.20	0.009	A87	*	*	*	*	*		*	*	*	*	*																
A88	1.14	0.007	A88			*			*	*					*															
A89	1.15	0.007	A89	*	*			*	*						*															
A90	1.21	0.006	A90	*	*	*	*	*	*	*	*	*	*	*		*	*													
A91	1.15	0.006	A91	*				*	*						*			*												
A92	1.13	0.008	A92			*			*	*		*		*	*		*	*												
A93	1.17	0.008	A93	*	*		*	*			*				*	*		*	*	*										
C85	1.12	0.011	C85			*			*	*		*	*	*	*		*	*	*		*									
C86	1.13	0.009	C86			*	*		*	*		*		*	*		*	*	*		*									
C87	1.15	0.011	C87	*		*			*						*			*				*								
C88	1.25	0.007	C88	*				*	*						*			*				*	*							
C89	1.13	0.011	C89			*			*	*		*			*		*	*			*									
C90	1.20	0.006	C90	*	*	*	*	*		*	*	*	*	*		*	*		*	*	*	*	*	*	*	*				
C91	1.16	0.011	C91	*	*			*	*						*			*		*		*	*				*			
C92	1.13	0.007	C92			*			*	*		*		*	*		*	*	*		*						*	*		
C93	1.15	0.009	C93	*		*			*	*					*			*			*	*					*			

Source	Adj. Mean[a]	Std Error[b]	Significant Differences[c]	M	J	J	A	S	O
Month									
May	1.16	0.019	May						
June	1.14	0.021	June						
July	1.15	0.012	July						
August	1.16	0.007	Aug						
September	1.16	0.009	Sept						
October	1.15	0.017	Oct						
November	1.15	0.019	Nov						

[a] adjusted mean of transformed data
[b] standard error of the least squares mean, provided by the Least Squares Means option of SAS Proc GLM
[c] $\alpha = 0.05$, Least Squares Means procedure

Table 23. Definitions for names of covariates used in ANACOV models presented in this report.

ST5DDRT	-the running total of soil temperature degree days (5 cm below ground, 4.4°C basis); available 1985-1993.
ST5DD's	-the set of seasonal covariates ST5DDSPR, ST5DDSUM, and ST5DDFAL (see ATDDs); available 1985-1993.
PR.01RT	-the running total of days with rainfall totaling 0.01 inch or more; available 1985-1993.
PR.01's	-the set of seasonal covariates PR01SPR, PR01SUM, PR01FAL (see ATDDs); available 1985-1993.
PR.10's	-the set of seasonal covariates PR10SPR, PR10SUM, and PR10FAL (see ATDDs); available 1985-1993.
PRWRT	-the running total of precipitation; available 1985-1993.
PRW's	-the set of seasonal total precipitation covariates PRCSPR, PRCSUM, and PRCFAL (see ATDDs); available 1985-1993.
DEV*MONTH	-the statistical interaction (calculated in SAS Proc GLM) between the deviation of each actual sample retrieval date from an arbitrary set of monthly collection dates (measured in days, + or -) and the month to which each deviation applies.

Explanation of all differences in decomposition rates among years is an unrealistic goal, especially for the three plantations, where vegetational changes proceeding at different rates have interacted with yearly weather differences. Also, the annual parent litter collections differ substantially in quality, even though they were made at the same locations each year (Tables 24-29). To the extent that substrate quality affects decomposition rate, and that years rank differently in quality for each litter species, it should be expected that years might rank differently in rate of dry matter mass loss for the three species.

Nevertheless, throughout the nine year study, patterns of annual change in X_m have tended to be similar for both study hardwood stands and for all three plantations. However, analyses of the siteyear patterns for all three litter species in the hardwood stands (but not in the plantations) have suggested that ELF EM fields may slightly accelerate litter decomposition. ANACOV indicated a tendency for decomposition to progress more quickly at the control site than at the overhead antenna site through 1987, but more quickly at the antenna site than at the control site from 1988 through 1992 (Figures 7-9). This tendency was not statistically significant for all years, and was most pronounced for oak litter (Figure 8).

However, the adjusted siteyear means calculated by the Means Model ANACOV (Figures 7-9) do not depict uniformly faster decomposition

Table 24. Initial percent **ash** content of the red maple, red oak, and red pine foliar litter parent collections corresponding to samples retrieved during the 1985-1993 field seasons, and results of multiple comparison tests among years based on one-way ANOVA.

					Differences[a]							
Species	Year	Mean (%)	N	Std Error	85	86	87	88	90	91	92	93
Maple	1985	5.37	15	0.155								
	1986	5.56	16	0.150								
	1987	4.79	12	0.173	*	*						
	1988	5.25	14	0.160								
	1989	6.29	15	0.155	*	*	*	*				
	1990	4.12	12	0.173	*	*	*	*	*			
	1991	4.54	12	0.173	*	*		*	*			
	1992	5.25	12	0.173					*	*	*	
	1993	5.92	12	0.173	*		*	*		*	*	*
Oak	1985	4.60	15	0.154								
	1986	3.97	17	0.145	*							
	1987	4.54	12	0.173		*						
	1988	4.18	14	0.160								
	1989	5.04	13	0.166		*	*	*				
	1990	4.25	12	0.173					*			
	1991	4.83	12	0.173		*		*		*		
	1992	4.29	12	0.173					*		*	
	1993	4.62	12	0.173		*						
Pine	1985	1.59	16	0.127								
	1986	1.77	15	0.131								
	1987	1.92	12	0.147								
	1988	1.61	14	0.136								
	1989	2.33	13	0.141	*	*	*	*				
	1990	1.83	12	0.147					*			
	1991	2.03	15	0.131	*			*				
	1992	1.73	11	0.153					*			
	1993	2.08	12	0.147	*			*				

[a] $\alpha = 0.05$, SAS Proc GLM, Least Squares Means procedure

Table 25. Initial percent **nitrogen** content of the red maple, red oak, and red pine foliar litter parent collections corresponding to samples retrieved during the 1985-1993 field seasons, and results of multiple comparison tests among years based on one-way ANOVA.

					Differences[a]							
Species	Year	Mean (%)	N	Std Error	85	86	87	88	90	91	92	93
Maple	1985	0.537	15	0.030								
	1986	1.115	16	0.029	*							
	1987	0.494	12	0.034		*						
	1988	0.495	14	0.031		*						
	1989	0.694	15	0.030	*	*	*	*				
	1990	0.714	12	0.034	*	*	*	*				
	1991	0.733	12	0.034	*	*	*	*				
	1992	0.663	12	0.034	*	*	*	*				
	1993	0.469	12	0.034		*			*	*	*	*
Oak	1985	0.637	15	0.022								
	1986	0.835	17	0.020	*							
	1987	0.428	12	0.024	*	*						
	1988	0.477	14	0.023	*	*						
	1989	0.665	13	0.023		*	*	*				
	1990	0.578	12	0.024		*	*	*	*			
	1991	0.690	12	0.024		*	*	*		*		
	1992	0.631	12	0.024		*	*	*				
	1993	0.627	12	0.024		*	*	*				
Pine	1985	0.429	16	0.014								
	1986	0.309	15	0.014	*							
	1987	0.367	12	0.016	*	*						
	1988	0.316	14	0.015	*		*					
	1989	0.422	13	0.015		*	*	*				
	1990	0.379	12	0.016	*	*		*				
	1991	0.425	15	0.014		*	*	*		*		
	1992	0.449	11	0.017		*	*	*		*		
	1993	0.384	12	0.016	*	*		*				*

[a] $\alpha = 0.05$, SAS Proc GLM, Least Squares Means procedure

Table 26. Initial percent **phosphorus** content of the red maple, red oak, and red pine foliar litter parent collections corresponding to samples retrieved during the 1985-1993 field seasons, and results of multiple comparison tests among years based on one-way ANOVA.

					Differences[a]							
Species	Year	Mean (%)	N	Std Error	85	86	87	88	90	91	92	93
Maple	1985	0.080	15	0.012								
	1986	0.124	16	0.011	*							
	1987	0.051	12	0.013		*						
	1988	0.056	14	0.012		*						
	1989	0.063	15	0.012		*						
	1990	0.133	12	0.013	*		*	*	*			
	1991	0.174	12	0.013	*	*	*	*	*	*		
	1992	0.143	12	0.013	*		*	*	*			
	1993	0.028	12	0.013	*	*			*	*	*	*
Oak	1985	0.071	15	0.005								
	1986	0.083	17	0.005								
	1987	0.107	12	0.006	*	*						
	1988	0.072	14	0.006			*					
	1989	0.080	13	0.006			*					
	1990	0.078	12	0.006			*					
	1991	0.128	12	0.006	*	*	*	*	*	*		
	1992	0.066	12	0.006		*	*				*	
	1993	0.118	12	0.006	*	*		*	*	*		*
Pine	1985	0.037	16	0.011								
	1986	0.048	15	0.011								
	1987	0.039	12	0.013								
	1988	0.052	14	0.012								
	1989	0.045	13	0.012								
	1990	0.074	12	0.013	*							
	1991	0.146	15	0.011	*	*	*	*	*	*		
	1992	0.103	11	0.013	*	*	*	*	*		*	
	1993	0.028	12	0.013						*	*	*

[a] α = 0.05, SAS Proc GLM, Least Squares Means procedure

Table 27. Initial percent **potassium** content of the red maple, red oak, and red pine foliar litter parent collections corresponding to samples retrieved during the 1985-1993 field seasons, and results of multiple comparison tests among years based on one-way ANOVA.

					Differences[a]							
Species	Year	Mean (%)	N	Std Error	85	86	87	88	90	91	92	93
Maple	1985	0.449	15	0.013								
	1986	0.212	16	0.012	*							
	1987	0.146	12	0.014	*	*						
	1988	0.373	14	0.013	*	*	*					
	1989	0.090	15	0.013	*	*	*	*				
	1990	0.446	12	0.014		*	*	*	*			
	1991	0.276	12	0.014	*	*	*	*	*	*		
	1992	0.210	12	0.014	*		*	*	*	*	*	
	1993	0.160	12	0.014	*	*		*	*	*	*	*
Oak	1985	0.119	15	0.009								
	1986	0.144	17	0.008	*							
	1987	0.259	12	0.010	*	*						
	1988	0.198	14	0.009	*	*	*					
	1989	0.127	13	0.009			*	*				
	1990	0.234	12	0.010	*	*		*	*			
	1991	0.266	12	0.010	*	*		*	*	*		
	1992	0.142	12	0.010			*	*		*	*	
	1993	0.288	12	0.010	*	*	*	*	*	*		*
Pine	1985	0.083	16	0.012								
	1986	0.059	15	0.012								
	1987	0.046	12	0.014	*							
	1988	0.034	14	0.013	*							
	1989	0.088	13	0.013			*	*				
	1990	0.174	12	0.014	*	*	*	*	*			
	1991	0.114	15	0.012		*	*	*		*		
	1992	0.116	11	0.015		*	*	*		*		
	1993	0.075	12	0.014				*		*	*	*

[a] $\alpha = 0.05$, SAS Proc GLM, Least Squares Means procedure

Table 28. Initial percent **calcium** content of the red maple, red oak, and red pine foliar litter parent collections corresponding to samples retrieved during the 1985-1993 field seasons, and results of multiple comparison tests among years based on one-way ANOVA.

					Differences[a]							
Species	Year	Mean (%)	N	Std Error	85	86	87	88	90	91	92	93
Maple	1985	0.925	15	0.024								
	1986	1.041	16	0.023	*							
	1987	0.905	12	0.027		*						
	1988	0.965	14	0.025		*						
	1989	1.073	15	0.024	*		*	*				
	1990	0.924	12	0.027		*			*			
	1991	0.964	12	0.027		*			*			
	1992	1.013	12	0.027	*		*			*		
	1993	1.300	12	0.027	*	*	*	*	*	*	*	*
Oak	1985	1.036	15	0.022								
	1986	0.984	17	0.021								
	1987	1.015	12	0.025								
	1988	0.954	14	0.023	*							
	1989	1.050	13	0.024		*		*				
	1990	1.002	12	0.025								
	1991	1.081	12	0.025		*		*		*		
	1992	1.117	12	0.025	*	*	*	*		*		
	1993	1.270	12	0.025	*	*	*	*	*	*	*	*
Pine	1985	0.412	16	0.025								
	1986	0.350	15	0.025								
	1987	0.373	12	0.027								
	1988	0.484	14	0.025	*	*	*					
	1989	0.486	13	0.026	*	*	*					
	1990	0.470	12	0.027		*	*					
	1991	0.474	15	0.025		*	*					
	1992	0.410	11	0.029								
	1993	0.449	12	0.027		*						

[a] $\alpha = 0.05$, SAS Proc GLM, Least Squares Means procedure

Table 29. Initial percent **magnesium** content of the red maple, red oak, and red pine foliar litter parent collections corresponding to samples retrieved during the 1985-1993 field seasons, and results of multiple comparison tests among years based on one-way ANOVA.

					Differences[a]							
Species	Year	Mean (%)	N	Std Error	85	86	87	88	90	91	92	93
Maple	1985	0.137	15	0.003								
	1986	0.130	16	0.003								
	1987	0.115	12	0.004	*	*						
	1988	0.135	14	0.003			*					
	1989	0.100	15	0.003	*	*	*	*				
	1990	0.131	12	0.004			*		*			
	1991	0.108	12	0.004	*	*		*		*		
	1992	0.123	12	0.004	*			*	*		*	
	1993	0.134	12	0.004			*		*		*	*
Oak	1985	0.125	15	0.002								
	1986	0.117	17	0.002	*							
	1987	0.161	12	0.003	*	*						
	1988	0.120	14	0.002			*					
	1989	0.131	13	0.002		*	*	*				
	1990	0.129	12	0.003		*	*	*				
	1991	0.134	12	0.003	*	*	*	*				
	1992	0.125	12	0.003		*	*				*	
	1993	0.139	12	0.003	*	*	*	*	*	*		*
Pine	1985	0.081	16	0.002								
	1986	0.083	15	0.002								
	1987	0.076	12	0.003								
	1988	0.082	14	0.002								
	1989	0.087	13	0.002			*					
	1990	0.091	12	0.003	*	*	*	*				
	1991	0.096	15	0.002	*	*	*	*	*			
	1992	0.083	11	0.003						*	*	
	1993	0.087	12	0.003			*				*	

[a] $\alpha = 0.05$, SAS Proc GLM, Least Squares Means procedure

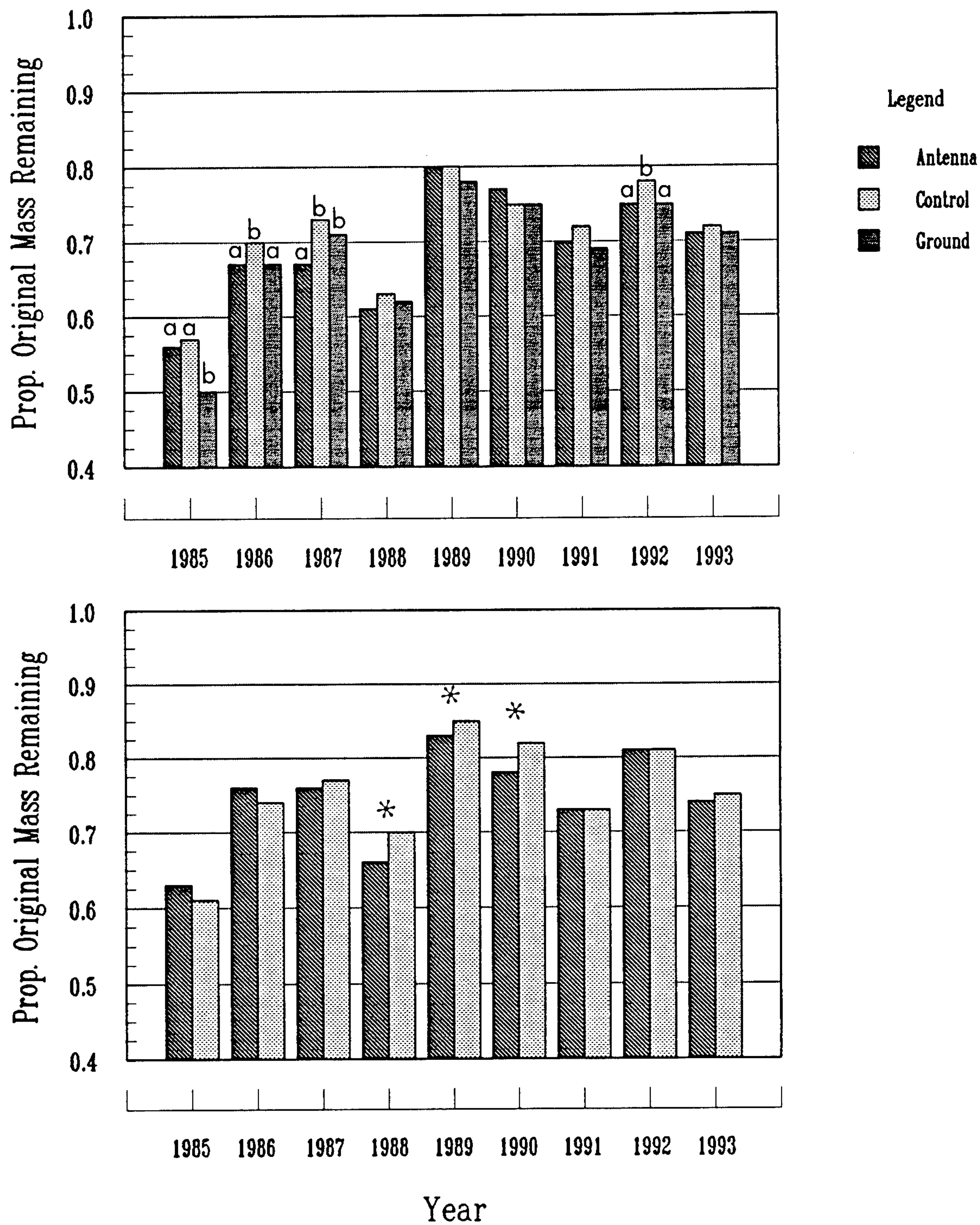

Figure 7. Site comparisons, from Means Model ANACOVs for **maple** litter in the **plantations** (top) and **hardwood stands** (bottom). Data are back-transformed from LSMeans ($\sin^{-1}$ square-root of X_m). Within years, different letters (plantations) or asterisks (hardwood stands) indicate significant differences (α=0.05).

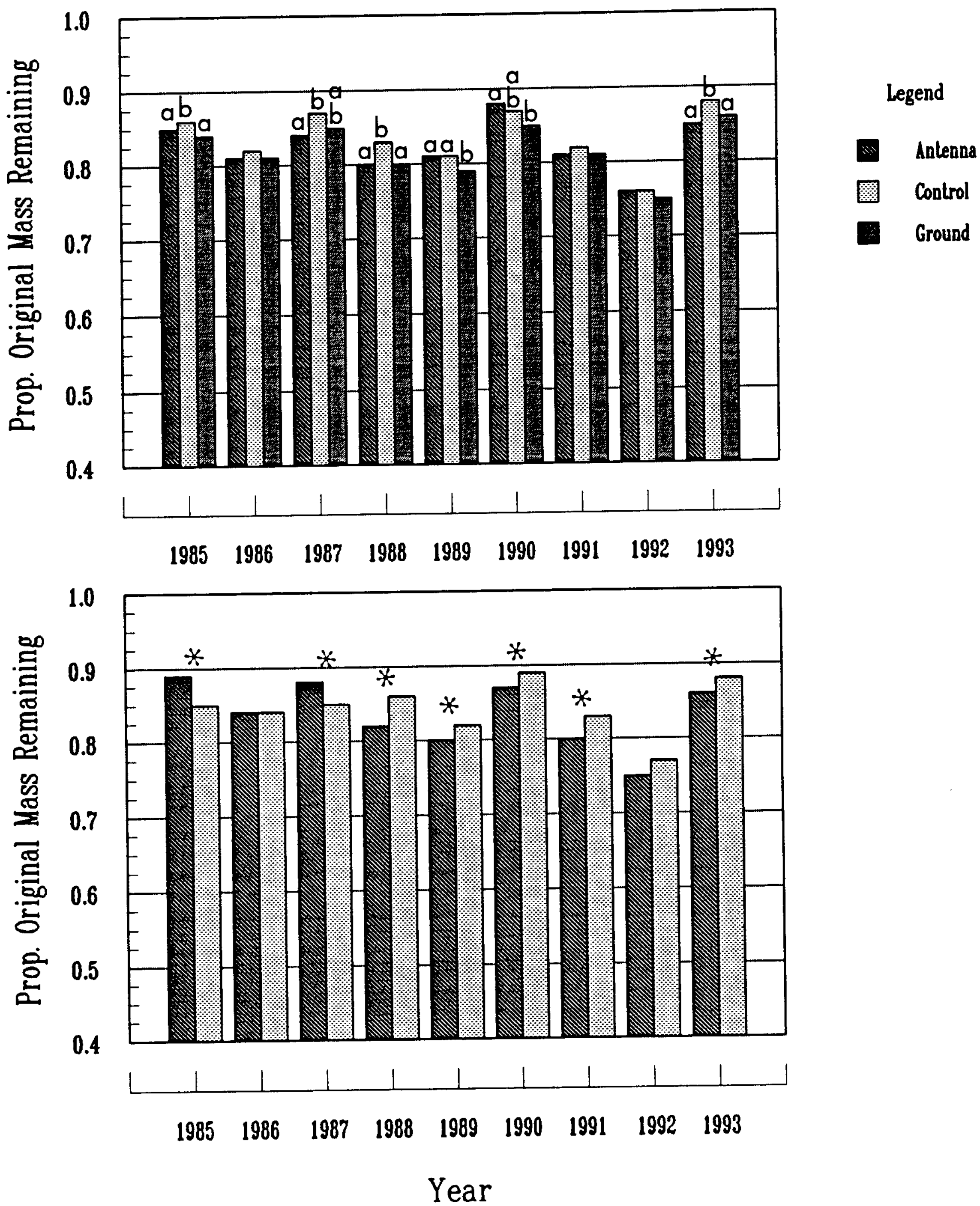

Figure 8. Site comparisons, from Means Model ANACOVs for **oak** litter in the **plantations** (top) and **hardwood stands** (bottom). Data were back-transformed from LSMeans ($\sin^{-1}$ square-root of X_m). Within years, different letters (plantations) or asterisks (hardwood stands) indicate significant differences (α=0.05).

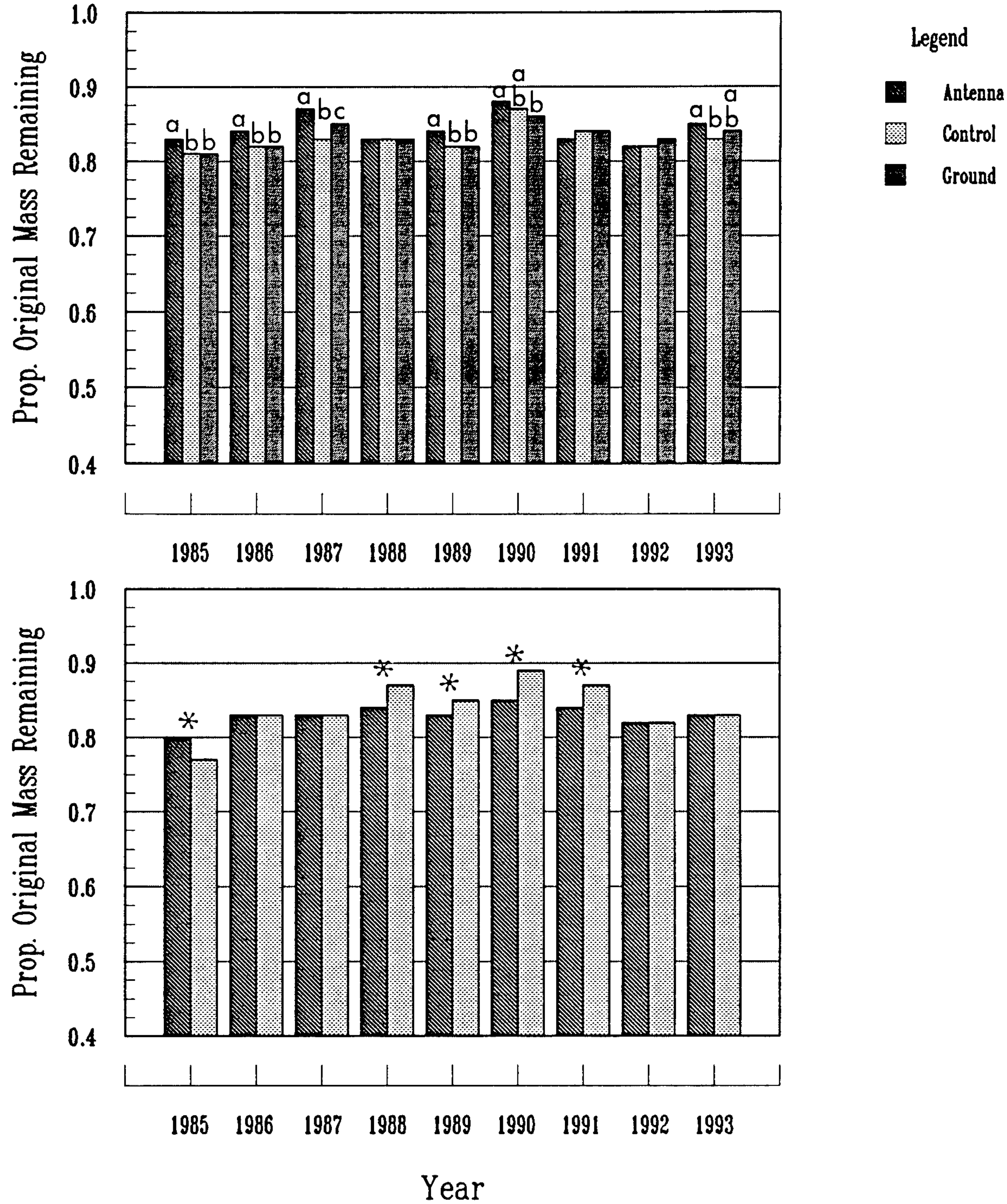

Figure 9. Site comparisons, from Means Model ANACOVs for **pine** litter in the **plantations** (top) and **hardwood stands** (bottom). Data were back-transformed from LSMeans ($\sin^{-1}$ square-root of X_m). Within years, different letters (plantations) or asterisks (hardwood stands indicate significant differences (α=0.05).

in the antenna hardwood stand for 1988-1993 compared to 1985-1987. Also, the same analyses do not depict a constant decomposition rate from 1985-1993 at the control hardwood stand. In other words, the patterns of decomposition rate corrected for our weather-related covariates across the nine study years do not strengthen the argument made above for existence of an ELF effect. We suggest that this apparent contradiction results because our covariates do a much better job of modeling decomposition progress within years than between years. This argument is supported by the fact that our ANACOV models all explain monthly decomposition progress much better than they explain differences among years (Tables 11-22). Also, the differences among annual parent litter collections in substrate quality (Tables 24-29) undoubtedly detract from the strength of our ANACOV models to explain differences among years in decompositon rates.

Detection limits achieved by ANACOV models containing only the seasonal weather-related covariates and the retrieval date correction factor covariate are presented in Table 30. Mean X_m detection limits for years, sites, and siteyears were comparable for the hardwoods and plantations. Litter species ranked maple > oak > pine, in order of decreasing detection limits (increasing statistical power). Detection limits for years were < 8, 4, and 3 percent for maple, oak, and pine, respectively. Detection limits for site differences were < 2 percent. Detection limits for siteyears were < 10, 5, and 3 percent for maple, oak, and pine,

Table 30. **Detection limits** for X_m[a] derived from ANACOV LSMEANs for bulk maple, oak, and pine foliage samples from 1985-1993.

Litter Species	Stand Type	ANACOV Model Type	Effect	Detection Limit Range: δ-ASSRX$_m$[b]	Detection Limit Range: %LSMEANX$_m$[c]
Maple	Hardwoods[d]	Effects	Year	0.021 - 0.044	2 - 7
			Site	0.009	1
			Month	0.038 - 0.121	5 -14
		Means	Siteyear	0.023 - 0.050	2 - 8
	Plantation[d]	Effects	Year	0.018 - 0.044	2 - 8
			Site	0.008 - 0.010	1
			Month	0.037 - 0.117	5 -15
		Means	Siteyear	0.024 - 0.051	3 -10
Oak	Hardwoods[e]	Effects	Year	0.014 - 0.043	1 - 4
			Site	0.007 - 0.008	1
			Month	0.027 - 0.086	2 - 8
		Means	Siteyear	0.019 - 0.052	1 - 5
	Plantation[d]	Effects	Year	0.018 - 0.043	1 - 4
			Site	0.008 - 0.010	1
			Month	0.036 - 0.114	3 -11
		Means	Siteyear	0.023 - 0.039	2 - 5
Pine	Hardwoods[e]	Effects	Year	0.011 - 0.029	1 - 3
			Site	0.006	1
			Month	0.020 - 0.064	2 - 5
		Means	Siteyear	0.014 - 0.034	1 - 3
	Plantation[d]	Effects	Year	0.012 - 0.029	1 - 3
			Site	0.005 - 0.007	1
			Month	0.025 - 0.077	2 - 7
		Means	Siteyear	0.016 - 0.033	1 - 3

[a] X_m is the proportion of dry matter mass remaining at sample retrieval.
[b] δ-ASSRX$_m$ is the detectable change in the LSMEAN, expressed in arcsin square-root transformed X_m units.
[c] % LSMEANX$_m$ is the approximate detectable percentage change in the LSMEAN (calculated in original units of X_m).
[d] Weather covariates used were seasonally accumulated 1) soil temperature degree days, 2) total precipitation, and 3) numbers of days with precipitation > 0.10 in.
[e] Weather covariates used were seasonally accumulated 1) soil temperature degree days, 2) total precipitation, and 3) numbers of days with precipitation > 0.01 in.

respectively. Overall, these low detection limits challenged our ability to explain differences among years, sites, and siteyears.

Summary of Results and Conclusions

Our ANACOV results are summarized in Table 31. The models referenced include data from the 1984/85 through 1992/93 experiments, and include only the set of seasonal weather-related variables and the sample retrieval date correction term as covariates.

Our experimental design is clearly powerful enough to detect subtle differences in decomposition of foliar litter measured as X_m with elapsed time during the first year following litterfall, especially in the more stable hardwood stand environment (Table 30).

Differences in initial substrate quality among annual parent litter collections result in poorer ability to explain X_m differences among years than within years. However, the altered pattern of differences in X_m progress between the treatment and control hardwood stands beginning in 1988 strongly suggests that ELF EM fields may slightly enhance the rate of decomposition progress. The effect is most consistently apparent with oak leaves, and least apparent for maple leaves. We suggest that the effect on maple litter decomposition is less clear because maple leaves are so much more fragile than oak leaves or pine needle fascicles. Statistical

Table 31. Summary of statistical analyses and results for measured variables.

Variable	Model	Test Procedure[a]	Covariates[b]	Treatments	Findings Through 1993[c]
X_m (proportion of initial dry matter mass remaining)					
	Maple, Hardwood Stands	ANACOV	DEV*MONTH, ST5DDs, PRCs, PR01s	Year, Site Siteyear Month	Possible ELF Effect
	Maple, Plantations	ANACOV	DEV*MONTH, ST5DDs, PRCs, PR01s	Year, Site Siteyear Month	No Detectable Effect
	Oak, Hardwood Stands	ANACOV	DEV*MONTH, ST5DDs, PRCs, PR10s	Year, Site Siteyear Month	Possible ELF Effect
	Oak, Plantations	ANACOV	DEV*MONTH, ST5DDs, PRCs, PR01s	Year, Site Siteyear Month	No Detectable Effect
	Pine, Hardwood Stands	ANACOV	DEV*MONTH, ST5DDs, PRCs, PR10s	Year, Site Siteyear Month	Possible ELF Effect
	Pine, Plantations	ANACOV	DEV*MONTH ST5DDs, PRCs, PR01s	Year, Site Siteyear Month	No Detectable Effect

[a] ANACOV = Analysis of Covariance (Proc GLM, SAS)
[b] Covariate names are defined in Table 23. The suffix "s" in a covariate name specifies the set of 3 seasonal covariates (*e.g.*, ST5DDs = ST5DDSPR, ST5DDSUM, and ST5DDFAL).
[c] All statistical tests are at $\alpha = 0.05$.

error associated with litter fragment loss may obscure other effects as subtle as the apparent ELF EM field effect.

The actual magnitude of the rate change for oak foliage appears to be approximately 5-8 percent in X_m at the overhead antenna site, from several percent slower than the control site to several percent faster than the control site. Although an effect of this magnitude would be biologically significant in terms of nutrient cycling, the ecological implications of such an effect are not alarming. Any ramifications of the apparent effect are severely limited by the very steep decline in 76 Hz field intensities with increasing distance from the ELF antenna. Also, a 5-8 percent shift is modest relative to year-to-year variability, which has been observed as high as 14 percent for oak in the hardwood stands.

Responding to one of IITRI's peer reviewers, we re-analyzed the oak data set for the overhead antenna and control site hardwood stands, using ash-free mass $X_{m,a-f}$ as the dependent variable. This analysis (data not shown) identified the same trend of differences detected by analysis of X_m, with the single exception that the 1993 difference was not statistically significant ($p = 0.0967$). We conclude that this supplemental analysis supports our conclusions.

ELF EM field covariates have not been included in our ANACOV models for several reasons. First, we do not know which of the three 76Hz fields produced are most likely to affect decomposition processes (*i.e.*, the magnetic field, the air electric field, and/or the earth electric field). Secondly, we do not know whether an ELF EM field effect is more likely to be related to field intensity, exposure duration, or frequency of on-off switching. Finally, we do not know whether to expect linear dose-response relationship(s) or "window" effect(s) with any of these factors. It seems clear that only statistically powerful and highly controlled studies can determine whether or not the apparent effect is real.

Element 2: RED PINE SEEDLING RHIZOPLANE STREPTOMYCETES

Introduction

Streptomycetes have been implicated in the calcium and phosphorus nutrition of ectomycorrhizae and can influence mycorrhizosphere microbial populations through production and excretion of compounds such as antibiotics, vitamins, amino acids, and hormones (Marx 1982, Keast and Tonkin 1983, Strzelczyk and Pokojska-Burdziej 1984, Strzelczyk *et al.* 1987, Richter *et al.* 1989). Streptomycetes have also been found to degrade calcium oxalate, cellulose, and lignin/lignocellulose, in both coniferous and deciduous ecosystems (Graustein *et al.* 1977, Crawford 1978, Knutson *et al.* 1980, Antai and Crawford 1981, McCarthy and Broda 1984). As part of the indigenous soil and root-related microflora, streptomycete populations are not considered to change greatly in stable ecosystems (Orchard 1984). For these reasons, streptomycete populations associated with the mycorrhizae of the planted red pine seedlings were selected for inclusion in these long-term studies.

The value of the red pine mycorrhizae studies in the Herbaceous Plant Cover and Tree Studies project was extended by quantitative study of the associated streptomycete populations. For instance, we found that *in vitro* growth rates of several common mycorrhizal fungus species are differentially affected by certain streptomycete morphotypes isolated from the mycorrhizoplane of ELF plantation red pine seedlings (Richter *et al.* 1989, Paetchow 1990). Some of these same morphotypes also inhibit the growth of *Armillaria* spp. (Becker *et al.* 1990), one of which causes the only fatal disease found among the plantation red pine seedlings (Moore 1989, Bruhn *et al.* 1994 & 1989, Smith *et al.* 1994, 1992 & 1990).

Field work for these studies was completed in 1991. We found no indication of ELF EM field effects on mycorrhizoplane streptomycete populations through 1991. Unfortunately, occasional problems with obtaining appropriate samples and with fungal contamination of samples have resulted in incomplete streptomycete data sets (for which the planned sample size was already modest). In contrast, the litter decompositon and root disease mortality data sets are both much larger and more complete (*i.e.*, with few missing values).

Methods

The mycorrhizal condition of red pine seedlings in the ELF plantations was monitored on a monthly basis (May through October) by the Herbaceous Plant Cover and Tree Studies project. "Type 3" mycorrhizae (generally caused by *Laccaria* and/or *Thelephora* spp.) predominated in all three ELF plantations throughout the study period, probably because these fungi occur naturally both in the study area and in the nursery from which the seedlings were originally obtained. Five seedlings were excavated each month on each of the three plots comprising each plantation. After washing the seedling root systems free of soil, ectomycorrhizal fine roots were detached and ectomycorrhizae were categorized and counted (Richter *et al*. 1993, Wu *et al*. 1993). At this point, samples of the Type 3 red pine mycorrhizal fine roots collected from each sampled seedling were provided to this study, for analysis of streptomycete population dynamics.

In 1985, one composite fine root sample was derived for analysis from the seedlings sampled in each plot. Beginning in 1986, two independent composite fine root samples were derived from the five seedlings sampled in each plot, one from two of the seedlings and the second from the remaining three seedlings. Ideally, each plantation should therefore be represented by six composite root samples per month (late May to late October). These samples were stored at 4°C and processed within 12 hours of receipt by the Environmental Microbiology lab in the Department of Biological Sciences. For example, in 1990 and 1991 an average of 8.5 days (ranging from 7 to 10 days) was required for processing of field samples, from the time seedlings were excavated in the field to the delivery of washed root samples for streptomycete analysis.

Total numbers of streptomycete colonies and numbers of morphotypes per sample were determined as follows. Using flame-sterilized forceps, 0.1 g (wet weight) of washed roots was placed in 9.9 ml of sterile buffer (0.01 M phosphate buffer, pH 7.2) and homogenized in a flame-sterilized 30 ml blender. This mixture was then transferred to a sterile, screw-cap test tube. Subsequent serial dilutions were made using the same type of sterile buffer. Two larger portions of the washed roots (about 0.5 g each) were transferred to separate pre-weighed aluminum pans and weighed; these portions were then placed in a drying oven (60°C) for determination of dry weights.

The serially diluted root samples were spread-plated onto starch casein agar (SCA) in 100 x 15 mm petri dishes. Cycloheximide (50 mg/l) and nystatin (50 mg/l) were added to the SCA to prevent fungal growth (Andrews and Kennerly 1979, Goodfellow and Dawson 1978). Three dilutions (in duplicate) were spread-plated per sample. All plates were incubated at 20°C. Total numbers of streptomycete colonies were determined after 14 days incubation.

After enumeration, all colonies were characterized to determine the number of morphotypes per sample. All colonies with the same characteristics (*i.e.*, presence/absence of diffusable pigment, presence/absence of aerial mycelium, color of aerial mycelium and any diffusable pigment, and reverse colony color) were considered to represent one morphological type or strain (Keast *et al.* 1984). Throughout the study, several colonies of each morphotype were maintained in pure culture for further study. To evaluate each morphotype's potential contribution to mycorrhiza development and root growth, and to confirm previous results with each morphotype, isolates of each morphotype were tested to evaluate degradation of calcium oxalate (Jayasuriya 1955, Knutson *et al.* 1980), cellulose (Smith 1977), and lignocellulose (Sutherland 1985).

Both the numbers and identity (with respect to recurrence) of distinct streptomycete morphotypes were compared from samples for 1984 through 1991. This allowed us to determine if some of the same types were still present after the red pine seedlings had been in the field for seven years and to determine whether the same types are present in all three ELF study site plantations.

Data for streptomycete levels and morphotype numbers were transformed to $\log_{10}$ for statistical analysis (Orchard 1984). All statistical analyses were conducted on the mainframe computer using Proc GLM of the Statistical Analysis System (SAS 1985). Effects model ANACOVs were used to compare years (1985 through 1991), sampling dates (month), plantations, and year-by-site interactions. Wherever covariance analysis detected significant differences ($\alpha = 0.05$), pairwise comparisons (SAS, Proc GLM, Least Squares Means option) of means were examined. The covariates used are weather-related variables, due both to their effectiveness and to their intrinsic independence of ELF EM field influence. Table 23 presents the abbreviated names and definitions of all covariates used in any of the ANACOV models included in this report. The power of our experimental design was calculated as detection limits, the percentage difference between two sample means that would be detected 50 percent of the time with $\alpha = 0.05$.

Description of Progress

Levels of Mycorrhizoplane Streptomycetes

The mean levels of mycorrhizoplane streptomycetes, with their associated CV values for each sampling date, are presented in Tables 32 through 34, for the three study plantations. The relatively large CV values (and missing data) for 1989 through 1991 are associated with insufficient or inadequate samples (less than six samples provided per site or insufficient sample mass provided) and/or with fungal or bacterial contamination of several of the samples.

The results of Effects Model ANACOV for the 1985 through 1991 streptomycete levels data are presented in Tables 35 and 36. For streptomycete levels, ANACOV utilizing ST5DDRT, PRWRT, and PR.01RT explained all differences between sites ($p = 0.4832$) as well as the year-by-site interaction ($p = 0.0950$). However, this ANACOV did not explain the lower levels consistently detected in October, and it failed to explain about half of the comparisons among years. No pattern in streptomycete levels related to ELF EM field exposure was discerned among the unexplained year-to-year comparisons. Although levels in 1991 were significantly lower than in previous years ($p = 0.0001$), the antenna was not operating from April through July of 1991. Detection limits for streptomycete levels are presented in Table 37. Shifts in streptomycete levels of

Table 32. Levels of streptomycetes (x 10^5) and numbers of streptomycete types, with corresponding percent CV[a], isolated from washed type 3 red pine mycorrhizal fine roots at the **Antenna Ground Plantation.**

Year			May	Jun	Jul	Aug	Sep	Oct
1985	Levels	Avg	9.04	3.91	4.14	4.59	3.56	9.25
		CV	77.0	89.9	71.2	37.3	93.1	13.7
	Types	Avg	7	6	5	5	6	4
		CV	13.7	0.0	20.4	10.9	18.7	43.5
1986	Levels	Avg	3.84	4.56	2.18	2.86	2.87	1.19
		CV	27.2	35.1	24.6	37.5	45.0	26.0
	Types	Avg	7	6	4	4	4	3
		CV	30.5	21.9	12.3	22.0	22.0	22.4
1987	Levels	Avg	3.81	3.57	5.15	4.24	5.99	1.52
		CV	38.4	54.6	28.8	28.4	31.9	28.4
	Types	Avg	4	3	3	3	3	3
		CV	22.3	14.9	23.5	23.5	14.9	30.6
1988	Levels	Avg	3.17	4.49	5.01	4.74	6.00	2.15
		CV	28.1	13.7	12.5	21.0	9.0	33.5
	Types	Avg	4	4	3	3	4	3
		CV	29.9	22.0	41.4	41.0	18.1	30.6
1989	Levels	Avg	2.29	3.42	3.96	2.24	2.53	1.67
		CV	-	25.3	14.6	45.8	39.9	35.1
	Types	Avg	3	3	3	3	2	2
		CV	-	25.3	0.0	33.2	23.3	71.1
1990	Levels	Avg	2.88	-	3.98	4.33	3.60	-
		CV	56.6	-	-	32.9	29.5	-
	Types	Avg	3	-	3	3	3	2
		CV	45.7	-	-	25.9	25.9	0.0
1991	Levels	Avg	1.39	3.32	5.11	0.98	0.14	0.50
		CV	48.1	35.9	32.1	80.5	-	62.0
	Types	Avg	3	2	3	2	2	2
		CV	47.3	25.3	29.2	22.8	-	0.0

[a] Coefficient of Variation, calculated as (standard deviation/ mean)*100.

Table 33. Levels of streptomycetes (x 10^5) and numbers of streptomycete types, with corresponding percent CV[a], isolated from washed type 3 red pine mycorrhizal fine roots at the **Overhead Antenna Plantation.**

Year			Month May	Jun	Jul	Aug	Sep	Oct
1985	Levels	Avg	4.50	5.14	4.54	2.73	4.53	1.47
		CV	34.9	54.6	7.3	42.4	51.9	49.1
	Types	Avg	6	6	5	6	5	4
		CV	32.9	33.1	10.9	9.5	45.2	35.4
1986	Levels	Avg	4.73	3.91	3.35	2.79	2.60	1.14
		CV	44.5	32.8	40.9	36.8	33.4	18.9
	Types	Avg	7	6	5	4	3	3
		CV	13.3	24.7	15.9	15.0	36.9	26.5
1987	Levels	Avg	3.58	5.06	4.60	4.55	6.75	1.78
		CV	42.9	27.6	44.8	45.0	24.4	15.8
	Types	Avg	3	5	3	4	4	3
		CV	30.9	11.4	14.9	29.9	29.9	29.6
1988	Levels	Avg	3.62	3.35	4.07	4.76	5.97	1.83
		CV	27.2	29.0	13.2	14.8	12.1	51.3
	Types	Avg	3	3	3	3	5	3
		CV	24.3	34.6	45.4	41.4	14.8	19.8
1989	Levels	Avg	2.69	2.19	1.61	2.10	2.78	1.91
		CV	26.9	21.3	8.1	66.8	34.6	43.5
	Types	Avg	5	4	4	3	3	3
		CV	31.0	39.6	33.5	16.6	30.0	82.5
1990	Levels	Avg	2.84	2.16	4.54	3.77	3.64	-
		CV	61.3	46.2	58.0	24.7	35.2	-
	Types	Avg	4	3	2	4	4	3
		CV	37.2	22.1	25.3	34.2	30.6	23.6
1991	Levels	Avg	1.34	2.10	3.25	1.75	4.25	0.60
		CV	45.1	51.5	50.7	48.0	11.7	-
	Types	Avg	4	3	3	2	4	2
		CV	22.0	36.4	21.5	19.3	41.9	-

[a] Coefficient of Variation, calculated as (standard deviation/ mean)*100.

Table 34. Levels of streptomycetes (x 10^5) and numbers of streptomycete types, with corresponding percent CV[a], isolated from washed type 3 red pine mycorrhizal fine roots at the **Control Plantation.**

Year			May	Jun	Jul	Aug	Sep	Oct
1985	Levels	Avg	4.54	9.09	1.65	-	1.34	1.04
		CV	62.1	23.7	52.0	-	52.2	44.5
	Types	Avg	7	5	4	-	5	4
		CV	9.0	22.1	13.8	-	22.1	24.9
1986	Levels	Avg	4.20	4.14	3.49	2.18	2.22	1.09
		CV	42.0	56.2	52.5	25.5	60.1	23.5
	Types	Avg	7	5	4	3	4	3
		CV	29.0	19.9	18.1	14.9	27.9	26.5
1987	Levels	Avg	3.97	5.66	4.14	6.27	6.53	1.56
		CV	35.0	32.6	39.7	24.9	21.5	60.1
	Types	Avg	4	4	3	3	3	3
		CV	22.0	22.3	23.7	23.7	30.6	22.4
1988	Levels	Avg	3.35	3.81	4.81	5.31	6.03	1.74
		CV	32.5	33.0	19.3	15.8	19.3	42.3
	Types	Avg	3	2	3	3	4	3
		CV	19.8	22.6	41.4	30.9	37.4	19.8
1989	Levels	Avg	3.07	2.62	3.13	2.13	3.19	1.39
		CV	30.2	56.2	33.6	34.0	35.1	22.0
	Types	Avg	4	3	4	4	4	3
		CV	30.6	16.6	23.7	30.6	27.3	46.0
1990	Levels	Avg	3.96	3.57	2.75	3.95	3.85	-
		CV	44.5	32.8	16.6	11.3	51.3	-
	Types	Avg	3	2	2	4	4	2
		CV	25.9	0.0	23.3	19.9	35.1	33.4
1991	Levels	Avg	1.20	3.48	2.78	1.79	0.70	0.58
		CV	28.3	40.8	45.1	56.4	3.5	42.6
	Types	Avg	3	3	2	2	2	2
		CV	30.6	36.4	33.4	22.8	25.3	0.0

[a] Coefficient of Variation, calculated as (standard deviation/ mean)*100.

Table 35. Covariance analysis table for detection of differences in **streptomycete levels** associated with type 3 red pine mycorrhizae (log_{10}-transformed data), among the three plantations, by year and by month (May-October), using ST5DDRT, PRWRT, and PR.01RT as covariates[a].

Source of Variation	df	SS	Type III SS	F	Signif. of F	r^2
Model	31	23.39		11.58	0.0001	0.43
Year	6		6.99	20.98	0.0001	
Plantation	2		0.08	0.73	0.4832	
Year*Plantation	12		1.05	1.57	0.0950	
Plot(Plantation)	3		0.22	1.32	0.2675	
Month	5		5.16	18.58	0.0001	
ST5DDRT	1		0.03	0.48	0.4894	
PRWRT	1		0.51	9.17	0.0026	
PR.01RT	1		0.10	1.78	0.1824	
Error	553	30.72				
Corrected Total	584	54.11				

[a] ST5DDRT is the running total number of soil temperature degree days (5 cm depth, 4.4°C basis); PRWRT is the running total of rainfall for the year; PR.01RT is the running total of the number of days with precipitation events delivering at least 0.01 inch of rain.

Table 36. Adjusted means, standard errors, and significantly different pairs of means, based on the **streptomycete levels** model described in Table 35.

Source of Variation	Adjusted Mean[a]	Standard Error[b]	Significant Differences[c]						
Year				5	6	7	8	9	0
1985	5.33	0.057	1985						
1986	5.44	0.042	1986						
1987	5.57	0.054	1987	*					
1988	5.56	0.034	1988	*	*				
1989	5.45	0.032	1989				*		
1990	5.44	0.039	1990				*		
1991	5.12	0.038	1991	*	*	*	*	*	*
Month				M	J	J	A	S	
May	5.59	0.174	May						
June	5.62	0.110	June						
July	5.54	0.041	July						
August	5.40	0.053	Aug						
September	5.40	0.122	Sept						
October	4.95	0.177	Oct		*	*	*	*	
Plantation				G	A				
Ground	5.41	0.020	Ground						
Antenna	5.44	0.019	Antenna						
Control	5.40	0.020	Control						

[a] adjusted mean of transformed data
[b] standard error of the least squares mean, provided by the Least Squares Means option of SAS Proc GLM
[c] $\alpha = 0.05$, Least Squares Means procedure

Table 37. **Detection limits** for streptomycete levels and streptomycete morphotype numbers derived from Effects Model ANACOV LSMEANs for 1985 through 1991.

Variable	ANACOV Model Type	Effect	Detection Limit Range $\log_{10}X$[a]	%LSMEANX[b]
Levels[c]	Effects	Year	0.089 - 0.158	21 - 37
		Site	0.052 - 0.056	12 - 13
		Month	0.113 - 0.491	26 -139
Morphotype Numbers[d]	Effects	Year	0.060 - 0.110	14 - 26
		Site	0.036 - 0.039	8 - 9
		Month	0.085 - 0.350	20 - 90

[a] $\log_{10}X$ is the detectable change in the LSMEAN, expressed in $\log_{10}$-transformed units.

[b] %LSMEANX is the approximate detectable percentage change in the LSMEAN (calculated in original units).

[c] Weather covariates used were cumulative soil temperature degree days (4°C, 5 cm depth), total precipitation, and cumulative numbers of days with at least 0.01 in. precipitation.

[d] Weather covariates used were cumulative soil temperature degree days (4°C, 5 cm depth) and cumulative numbers of days with at least 0.01 in. precipitation.

21-37 percent among years, or of 12-13 percent among plantations, should be detectable 50 percent of the time.

Numbers of Mycorrhizoplane Streptomycete Morphotypes

The mean numbers of mycorrhizoplane streptomycete morphotypes recovered and their associated CV values are also presented, for each sampling date at the three study plantations, in Tables 32 - 34. Again, the relatively large CV values and missing data for 1989 through 1991 are associated with insufficient or inadequate samples and/or with fungal or bacterial contamination of several of the samples. Considering the small numbers of morphotypes characteristically recovered from any given sample, a reduction in this variable of 1.0 morphotype per sample might well be detected. Nevertheless, because most morphotypes are not routinely recovered from every sample, it might be necessary for several of the less abundant morphotypes to decline in abundance in order to effect a reduction of 1.0 in morphotype numbers recovered.

For morphotype numbers, ANACOV utilizing ST5DDRT and PR.01RT (Tables 38 and 39) explained all differences between sites ($p = 0.7474$) as well as year-by-site interaction ($p = 0.4996$). Differences between sampling dates were also explained. Morphotype numbers have declined noticeably since 1985 in all 3 plantations, possibly due to vegetation conversion from mixed hardwoods to red pine monoculture. This initial decline and then

Table 38. Covariance analysis table for detection of differences in **numbers of streptomycete morphotypes** associated with type 3 red pine mycorrhizae (log^{10}-transformed data), among the three plantations, by year and month (May-October), using ST5DDRT, and PR01RT as covariates[a].

Source of Variation	df	SS	Type III SS	F	Signif. of F	r^2
Model	30	6.25		6.83	0.0001	0.27
Year	6		3.74	20.48	0.0001	
Plantation	2		0.02	0.29	0.7474	
Year*Plantation	12		0.35	0.95	0.4996	
Plot(Plantation)	3		0.05	0.52	0.6670	
Month	5		0.25	1.66	0.1432	
ST5DDRT	1		0.02	0.50	0.4797	
PR01RT	1		0.18	5.83	0.0160	
Error	567	17.27				
Corrected Total	597	23.52				

[a] ST5DDRT is the running total number of soil temperature degree days (5 cm depth, 4.4°C basis); PR.01RT is the running total of the number of days with precipitation events delivering at least 0.01 inch of rain.

Table 39. Adjusted means, standard errors, detectable differences, and significantly different pairs of means, based on the **streptomycete morphotypes** model described in Table 38.

Source of Variation	Adjusted Mean[a]	Standard Error[b]	Significant Differences[c]						
Year				5	6	7	8	9	0
1985	0.79	0.040	1985						
1986	0.56	0.029	1986	*					
1987	0.57	0.036	1987	*					
1988	0.46	0.025	1988	*	*	*			
1989	0.51	0.022	1989	*					
1990	0.46	0.027	1990	*	*	*			
1991	0.42	0.024	1991	*	*	*		*	
Month				M	J	J	A	S	
May	0.54	0.126	May						
June	0.53	0.081	June						
July	0.50	0.031	July						
August	0.53	0.037	Aug						
September	0.59	0.085	Sept						
October	0.54	0.122	Oct						
Plantation				G	A				
Ground	0.52	0.014	Ground						
Antenna	0.55	0.013	Antenna						
Control	0.54	0.013	Control						

[a] adjusted mean of transformed data

[b] standard error of the least squares mean, provided by the Least Squares Means option of SAS Proc GLM

[c] estimated shift in the sample mean which would be detected 95 percent of the time ($\alpha = 0.05$), calculated as ($t_{0.05,n-1}$ * S.E. / Mean), and expressed as a percentage of the sample mean

[d] $\alpha = 0.05$, Least Squares Means procedure

stabilization may reflect the establishment and persistence of those streptomycete types most capable of growth and survival with the red pine mycorrhizae at these sites. Detection limits for streptomycete morphotype numbers are presented in Table 37. Shifts in streptomycete morphotype numbers of 14-26 percent among years, or of 8-9 percent among plantations, should be detectable 50 percent of the time. Shifts of this magnitude would likely require declines in abundance (or outright loss) of several of the approximately 20 streptomycete morphotypes observed over the past six years.

Morphotype Distribution and Characterization

Patterns of streptomycete morphotype recovery from type 3 washed mycorrhizal fine roots during the 1991 sampling season are listed in Table 40. In general, the same morphotypes and same general incidence patterns were found during the 1991 sampling season as in 1986 through 1990. With one exception, morphotype B was detected at each plantation on each sampling date. It was often found in multiple samples per plantation per sampling date, but not as often as the predominant type. Morphotypes D, J, S, and T were also commonly detected, similar to 1987 through 1990. Morphotype F occurrence was similar to 1989 and 1990 (*i.e.*, much less frequent than prior to 1989). Incidences of morphotypes A, K, and W were slightly increased over those found in 1990; both the 1990 and 1991 patterns of occurrence of these morphotypes were more similar to

Table 40. Streptomycete morphotypes associated with washed mycorrhizal type 3 fine roots.

Sampling Date (1991)	Study Site[a]	N[b]	Streptomycete Morphotype																			
			A	B	C	D	E	F	G	H	J	K	N	O	P	Q	R	S	T	U	V	W
22 May	C	6	Xc	Xc		X	X				X						Xc					X
	A	6	Xd	Xc		Xd			X			Xc					Xc	X	X			Xc
	G	5	Xd	X	X						X	X					Xc		X			Xc
18 June	C	3	Xd	Xc		Xd											X		X	Xc		Xc
	A	6	Xc	Xc	X	Xc				X	Xc	Xc					X	Xd	X			Xc
	G	6		X		X						Xc					Xc		X	X		
16 July	C	4	X	Xc		Xc					Xc							X				
	A	5	Xc	Xc		Xc					Xd						Xc					X
	G	6	X	X		Xc					X				Xc							Xc
13 August	C	4	Xc	X		X					X								Xc			Xc
	A	6	Xd	Xc		X						X										Xc
	G	4	X	X		X																Xc
9 September	C	3		X				X								X	X				X	Xc
	A	3	X	Xc		X					X				X	X	X	Xc			X	
	G	1	X										X									
14 October	C	2		X		X					X											
	A	1		X														X				
	G	3		X				X			X			X								Xc

[a] C = Control Plantation; A = Antenna Plantation; G = Ground Plantation
[b] N = number of replicate samples/plantation
[c] Morphotype detected in two or more replicate samples/plantation
[d] Predominant morphotype in two or more replicate samples/plantation

those found prior to 1989. Frequencies of isolation of morphotypes E, H, and N were even lower in 1991 than in 1990; however, these levels were still more similar to those found prior to 1989. Morphotype R increased in incidence in many of the 1991 root samples, to approximately the same incidence levels reported in 1989. As noted earlier, detection of morphotypes was made difficult during 1991 due to the increased overgrowth of sample plates by saprophytic fungi and non-streptomycete bacteria. This was particularly the case with the ground plantation samples, for which the incidence of "contamination" increased over the years; however, samples from all sites had occasions of non-streptomycete overgrowth, particularly with the October root samples.

For the control plantation, the incidence pattern found in 1991 was very similar to that found in 1989 and 1990, as well as in many of the previous years' samples. The key exception was that the type S levels were slightly lower in 1991 than those found previously. In general, the overall 1991 antenna plantation morphotype incidence patterns were very similar to the 1990 patterns, particularly for the more common morphotypes B, D, J, T, and W. Morphotype A incidence increased to that found before 1988. Morphotype H was again detected only from the antenna plantation, but only once during the season. There were again relatively few ground plantation sample morphotype data for the 1991 season, primarily due to contamination problems (as noted above). In spite of this, morphotypes A, B, and W were commonly detected. Overall, morphotypes B, J, K, N, P, R, and T were found in about the same levels as in previous sampling seasons at the ground plantation, and morphotypes A and D were present in levels about the same as 1989 and earlier. In contrast to previous years, no morphotype S was detected in any of the ground plantation samples during 1991.

Representatives of each streptomycete type detected during the 1991 sampling season were tested for ability to degrade calcium oxalate, cellulose and lignocellulose. The same results were found as in all past seasons in terms of which morphotypes could degrade one or more of these compounds, again indicating little change detectable in either morphotypes or their activities in the past four sampling seasons.

Summary of Results

ANACOV has been successfully used to explain all differences in both streptomycete levels and morphotype numbers among study plantations. Year-by-site interaction was also explained, as were differences among monthly samples for morphotype numbers. Morphotype numbers have declined since 1985 in all 3 plantations. This initial decline and then stabilization may reflect the establishment and persistence of those streptomycete types most capable of growth and survival with the red pine mycorrhizae at these sites. For two reasons, the significantly lower 1991 streptomycete levels do not appear to have been caused by ELF EM exposure. First, the antenna was not operating from April through July of 1991. Second, ANACOV did not detect a significant year-by-site interaction.

Detection limits calculated for both streptomycete levels and morphotype numbers indicate that we have a 50 percent chance or better (with $\alpha = 0.05$) of detecting shifts in either of these variables of 37 percent among years, and 13 percent among plantations. Shifts of this magnitude would likely require declines in abundance (or outright loss) of several of the approximately 20 streptomycete morphotypes observed over the past six years.

Element 3. Armillaria Root Disease Epidemiology

Introduction

Armillaria is a genus of "white-rot" wood decay fungi (*i.e.*, decomposing both the lignin and cellulose of wood). *Armillaria* species colonize and decay wood in soil contact, including moribund portions of living root systems. *Armillaria* species are unusual among microorganisms in developing very large, essentially continuous, long-lived, spatially distinct, and genetically stable genets (*i.e.*, individuals) (Smith *et al.* 1994, 1992). Genets are initiated by the mating of two sexually compatible spores (Smith *et al.* 1990). A portion of the energy derived from subsequent wood decay is expended to fuel the growth of branching cord-like rhizomorphs through the soil. The mitotic cell lineage thus established spreads through and among foodbases in the forest floor. Armillaria root disease results when susceptible host plants (*e.g.*, red pine plantation seedlings) become infected by rhizomorphs or by root growth into contact with foodbases colonized by virulent *Armillaria* species.

The ongoing Armillaria root disease epidemics in the three ELF study red pine plantations have been documented since the onset of mortality in 1986 (Bruhn *et al.* 1994, 1989; Moore 1989). Armillaria root disease has been of interest to the Ecological Monitoring Program because:

1) as the only lethal disease of red pine in the study plantations, Armillaria root disease mortality was unevenly represented among the three ELF study red pine plantations and demonstrated a non-random spatial distribution within plantations.

2) There was good reason to expect that mortality caused by this disease would continue, because: a) adequate foodbases remained on the sites, b) clones of the virulent *A. ostoyae* were identified, and c) documented epidemics in the Lake States have peaked after 10 years of activity.

3) There is a strong association between Armillaria root disease severity and host (*i.e.*, red pine) health. Various stresses (possibly including ELF EM fields) predispose host plants to successful infection by *Armillaria* spp.

4) Because Armillaria root disease is readily diagnosed, disease progress can be accurately mapped and statistically modeled.

The Armillaria root disease work element involves evaluation of potentially subtle ELF EM field effects on the activities of communities of *Armillaria* genets. While we do not have the means to test for an effect of ELF EM fields on genet establishment, we can test for an effect of ELF EM fields on the rates of disease progress associated with existing genets.

Specific funding was not initially available for Armillaria root disease study because the pathogen (*A. ostoyae* (Romagnesi) Herink) had not been proven to be present at the study sites at the outset of the Ecological Monitoring Program. Indeed, the study sites were not selected and the host populations (the plantation red pine seedlings) were not created until after the Ecological Monitoring Program was funded.

Methods

The spatial densities of target host plants varied greatly across the three plantations, largely due to initial planting failures. Considered together with the uneven distributions of root disease mortality across the plantations, it was clear that comparison of mortality "counts" among plantation subdivisions would be an inappropriate test of ELF EM field effects on Armillaria root disease progress. The appropriate measure of disease progress is the decimal proportion (y_t) of the initial host population which had been killed by Armillaria root disease by any specified point in time. The entire seedling populations in the study plantations were therefore mapped and tagged to enable determination of initial host populations for prescribed land areas. For calculation of y_t, the initial host seedling population was defined as the number of living seedlings at the beginning of the 1986 field season minus those which were destructively sampled during the study period (1986-1993) for any purpose. This provided an initial living population which was not diminished except by Armillaria root disease mortality. The year 1986 was selected because 1) the first root disease mortality in the study plantations occurred in 1986, and 2) at two years of age in 1986, the plantations were beyond the point of experiencing mortality due to planting stress.

The spatial relationships of *Armillaria* genets in the plantations were initially unknown (Bruhn *et al.* 1989, Moore 1989). The pathogen was isolated into pure culture from nearly all seedlings killed by Armillaria root disease. Isolates were also obtained each autumn from *Armillaria* mushrooms developing on the mapped stump population in each plantation. Mapped isolates were confronted with each other on 3% malt extract agar medium in Petri dish culture to assess vegetative compatibility. Compatible isolates have been shown to belong to the same genet (Smith *et al.* 1994, 1992, 1990).

Historical (1986-1993) maps of *Armillaria* genets in the plantations were constructed based on the mapped and dated recoveries of isolates confirming their spatiotemporal positions. We then attributed spatial boundaries to each genet according to a rule set (Table 41), and determined the included host populations. This permitted statistical analysis of the rate of disease progress on an individual genet basis, rather than on an arbitrary land area basis. Analyses based on the areas occupied by genets are attractive, because 1) they take into account the genetic identity

Table 41. Rule set for mapping *Armillaria* genets.

1. A genet boundary consists of the smallest possible number of straight line segments (each < 20 m long) which connect or enclose the largest possible number of points where the genet has been isolated. Each line segment must begin and end at a point where the genet has been isolated.

2. Genet maps may consist of any combination of points, lines, and/or polygons.

3. Sets of map points separated from the rest of their genet by more than 20 m are designated sub-genets of that genet.

of each pathogenic genet, and 2) they restrict calculations of disease progress to the portion of the host population accessible by each pathogen genet. Unlike other studies at these sites, the Armillaria root disease studies are based on repeated census of each plantation. Sampling adequacy is therefore not an issue.

A variety of mathematical models have been used to describe and compare disease progress among plant disease epidemics (Campbell and Madden 1990, Madden and Campbell 1990). Disease progress rates were calculated for each genet which killed at least 10 seedlings. Our analysis considered the monomolecular, Gompertz, and logistic models. The linearized forms of these models are:

monomolecular: $\ln(K/(K-y_t)) = -\ln(B)+rt$

Gompertz: $-\ln(-\ln(y_t/K) = -\ln(B)+rt$

logistic: $\ln(y_t/(K-y_t)) = \ln(y_0/(K-y_0))+rt$

In the above equations, y_t is the level of disease at time t, K is the maximum level of disease attainable (y_{max}, presently presumed K=1.00), B is a constant of integration, y_0 is the initial level of disease (y_0 = 0.00), e is the base of natural logarithms, r is a rate parameter with units of time^{-1}, and exp represents e raised to some specified power.

Disease progress rate constants were estimated using each of the models above, for each of the 18 major pathogenic *Armillaria* genets encountered: 3, 6, and 9 genets in the ground antenna, overhead antenna, and control plantations, respectively. For each model, the transformed y_t was regressed versus air temperature degree days accumulated since plantation establishment in the spring of 1984 (CUATDD). CUATDD was used as a surrogate for elapsed time because of the temperature dependency of biological activity and the long winters in the study area. The most appropriate disease progress model for each genet was identified by comparing the values of R^2, the mean square error, and the standard error of the rate estimate, and by comparing plots of the standardized residuals versus predicted values (Campbell and Madden 1990). The data from all 18 genets were best fit by the monomolecular model.

The monomolecular rate parameter estimates were compared directly, by ANOVA (Madden 1986). Because the rate parameter or regression coefficient is an estimate of the slope of the linearized disease progress model, the Tukey-Kramer method was used to perform an unplanned test of all 18 regression coefficients (Sokal and Rohlf 1981, Rohlf and Sokal 1981). All regressions and ANOVAs were conducted on the mainframe computer using Proc GLM of the Statistical Analysis System (SAS Institute, Inc. 1985). For ANOVA, acceptance or rejection of the null hypothesis was based on α = 0.05. For the Tukey-Kramer unplanned comparison test, an experiment-wise α=.01 was used.

Correlation analysis was used to explore the relationship among genets between monomolecular disease progress rate and seedling height at the end of 1992. Seedling height at the end of 1992 was selected for its value as an indicator of host (target) size and condition throughout the study.

Description of Progress and Summary of Results

The *Armillaria* genets responsible for root disease mortality in the study plantations belong to *A. ostoyae*. Genets of *A. gallica* Marxmuller & Romagnesi were also found widespread, but are not pathogenic toward red pine. It is clear from their size that establishment of at least the largest genets of both species predates the study plantations by centuries (Smith *et al.* 1994, 1992). The plantation sites supported predominantly pine forests for at least several centuries ending with logging and fire in the early 20th century. The *A. ostoyae* genets studied here have apparently led a relatively non-pathogenic necrotrophic existence through more than a half century of hardwood stand development prior to our establishment of research pine plantations.

Our maps of *Armillaria* genets indicated that genets of the same *Armillaria* species overlap little, whereas genets of different *Armillaria* species overlap freely (Smith *et al*. 1994, 1992, 1990). This suggestion of niche partitioning was not very surprizing, because a characteristic difference between *A. ostoyae* and *A. gallica* is their relative preference for conifers *vs*. hardwoods, respectively. Nevertheless, it was therefore possible to compare disease progress rates of *A. ostoyae* genets occurring in the three plantations. This satisfied our concerns for both probable differences in virulence among pathogen genets and incomplete occupation of the plantations by *A. ostoyae*.

Annual disease progress (percent mortality) since plantation establishment is presented in Table 42. Monomolecular rate parameter values for disease progress caused by each of the 18 study genets are presented in Table 43, along with results of the Tukey-Kramer unplanned comparison tests. It is readily apparent that disease progress rates vary greatly among *A. ostoyae* genets, and that each plantation is occupied by genets demonstrating statistically similar ranges of rates. However, only three genets large enough to warrant disease progress analysis occur in the ground antenna plantation, and all three together occupy only slightly more than one-quarter of the plantation area. No significant differences among plantations were detected by ANOVA ($p = 0.5448$; Table 44). The variability in rate values within each plantation, coupled with the modest number of genets available for analysis result in little power to detect differences among the plantations (Table 45).

The ranges of disease progress rates demonstrated by the *Armillaria* genets at each site suggest genetic differences in virulence. However, possibilities remain that these rate differences might have been caused at least partly by differences between the territories occupied by different *A. ostoyae* genets. Such differences might involve 1) red pine seedling size and/or health, 2) the distribution of woody foodbases, and/or 3) some degree of competitive exclusion from foodbase resources associated with *A. gallica* and *A. ostoyae* niche overlap.

Average seedling heights at the end of the 1992 field season within the area occupied by each selected *A. ostoyae* genet are presented in Table 43. A significant negative correlation ($r = -0.6976$, $p = 0.0367$; Table 46) existed between disease progress rate and final seedling height for the 9 genets at the control plantation. A negative correlation might be interpreted to reflect reduced

Table 42. Cumulative disease progress (percent seedling mortality) caused by selected *A. ostoyae* genets occurring in the 3 study plantations.

		Year							
Plantation	Genet	1986	1987	1988	1989	1990	1991	1992	1993
Ground	1	1.9	5.8	12.6	18.4	24.3	25.2	25.2	26.2
	2	1.6	6.4	14.1	19.0	21.8	22.6	22.6	22.6
	3	0.0	1.4	1.4	4.3	6.4	6.4	7.9	7.9
Antenna	1	0.7	7.1	21.6	31.4	37.5	38.5	39.5	39.9
	2	0.0	1.3	8.7	20.8	24.8	26.2	27.5	27.5
	3	0.0	2.0	8.2	18.4	22.4	22.4	28.6	28.6
	4	3.4	5.1	13.6	18.6	22.0	23.7	23.7	25.4
	5	2.9	5.8	15.1	18.0	19.8	19.8	19.8	19.8
	6	3.1	6.2	10.3	11.3	12.4	12.4	13.4	13.4
Control	1	2.7	21.6	29.7	40.5	40.5	40.5	43.2	43.2
	2	1.2	10.8	24.1	31.3	33.7	33.7	33.7	34.9
	3	0.5	6.7	16.4	21.5	26.7	27.2	30.8	31.3
	4	2.2	8.7	15.2	19.6	21.7	21.7	23.9	23.9
	5	0.4	6.1	9.6	14.6	18.6	18.6	19.3	19.3
	6	1.3	9.4	15.4	16.8	17.4	17.4	19.5	19.5
	7	1.1	5.7	8.5	13.3	15.9	16.5	16.9	16.9
	8	0.0	2.4	6.3	9.6	10.8	11.4	12.6	12.6
	9	0.1	2.1	5.3	7.6	9.4	10.0	10.9	11.1

Table 43. Monomolecular rates (r_M) of disease (mortality) progress[2] for individual *A. ostoyae* genets, with associated r^2 and standard errors of the estimates (s_r), and average height (cm) of surviving seedlings[3].

Site	Genet	r_M	r^2	s_r	Height
1	1	0.2531 abcd	0.94	0.026304	269
1	2	0.2092 abcdefg	0.89	0.030399	264
1	3	0.0749 -------h	0.94	0.007692	276
2	1	0.4384 a	0.92	0.052906	297
2	2	0.3020 abc	0.92	0.036647	281
2	3	0.2990 abc	0.96	0.024942	280
2	4	0.2227 abcd	0.95	0.021865	304
2	5	0.1609 -bcdefgh	0.83	0.030195	308
2	6	0.0859 -----fgh	0.87	0.013274	272
3	1	0.3655 abcde	0.85	0.062427	300
3	2	0.3115 abcde	0.85	0.052783	298
3	3	0.2873 ab	0.97	0.021662	310
3	4	0.1866 -bcdefg	0.92	0.023175	320
3	5	0.1642 --cdefg	0.92	0.019874	312
3	6	0.1338 --cdefgh	0.82	0.025961	305
3	7	0.1320 ---defgh	0.93	0.014873	331
3	8	0.1061 ----efgh	0.94	0.010676	334
3	9	0.0890 ------gh	0.97	0.006413	315

1 Values are for disease progress through 1993.

2 The monomolecular model has the following linearized form: $\ln[1/(1-y_i)] = -\ln(B)+rt$, where y_i is the proportion of the initial host population killed, the initial amount of disease (y_0) is 0.0, r is the rate of disease increase, and t is a function of elapsed time (air temperature degree days, in our case). Values of r_M were compared using the Tukey-Kramer method with $\alpha=.01$, k=108, v=18 (Sokal and Rohlf 1981, Rohlf and Sokal 1981). Values of r_M with a letter in common are not significantly different.

3 Total height was measured following growth cessation in 1992.

Table 44. ANOVA table for detection of differences among the 3 study plantations in the monomolecular rates of disease (mortality) increase for selected *A. ostoyae* genets.

Source of Variation	df	SS	F	Signif. of F	r^2	CV
Model	2	0.01454	0.63	0.5448	0.08	50
Error	15	0.17242				
Corrected Total	17	0.18697				

Table 45. Adjusted means, standard errors, and detection limits, based on the model analyzed in Table 43.

Plantation	Least Squares Mean[a]	Standard Error	Detection Limit[b]
Antenna Ground	0.1791	0.0619	95.8
Overhead Antenna	0.2515	0.0438	48.2
Control	0.1973	0.0357	50.2

[a] mean of r_M values
[b] percentage change in the variable for which there is a 50 percent chance of detection at $p = 0.05$.

seedling vulnerability to lethal infection with increasing seedling size. For healthy plants, we expect that root infection and colonization attempts would be met with increasing levels of active resistance in increasingly large plants. Alternatively, larger plants are also larger targets, and may demonstrate increased vulnerability if they are stressed for any reason (*e.g.*, by deformed or damaged root systems, drought, etc.), and especially if local *A. ostoyae* inoculum is abundant. However, disease progress rate and final seedling height were not significantly correlated at either the ground or overhead antenna plantations. This result could represent a balance between relationships which would cause correlations of oppposite sign.

Nevertheless, our results suggest 1) significant and similar variation in virulence among the *A. ostoyae* genets occurring in the three study plantations, and 2) no detectable effect of ELF EM field exposures on rate of Armillaria root disease progress.

Table 46. Pearson correlation coefficients for the relationship between monomolecular rate of mortality increase (r_M) and seedling height at the end of 1992, for the selected *A. ostoyae* genets in the three study plantations.

Plantation	Number of Genets	r_M	P
Ground Antenna	3	-0.7861	0.4242
Overhead Antenna	6	0.1466	0.7817
Control	9	-0.6976	0.0367
Combined	18	-0.2059	0.4125

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GLOSSARY

Actinomycete	A large group of true bacteria, characterized by a mycelial vegetative structure.
AET	Actual evapotranspiration: a measure of the cumulative and concurrent availability of energy and moisture.
Basal Area	The cross-sectional area of a tree at DBH, or of a stump.
Biomass	The amount of living matter in a unit area.
DBH	Diameter at breast height. Average stem diameter, outside bark, measured 4.5 feet above the ground.
Ectomycorrhizae	The type of mycorrhizae in which the fungus component grows only intercellularly within its host root, and produces an external mantle.
Foodbase	Any piece of woody debris suitable for colonization by *Armillaria* species.
Genet	A genetically unique individual organism; a mitotic cell lineage established by a sexual mating event.
Habitat Type	Land areas potentially capable of producing similar plant communities at maturity.
Litter	Dead, largely unincorporated leaves and other plant parts on the forest floor.

Mycorrhizae	A mutually beneficial association between plant roots and certain highly specialized parasitic fungi.
Mycorrhizoplane	The actual surface of mycorrhizal plant roots, together with any closely adhering particles of soil or debris.
Mycorrhizosphere	The narrow zone of surrounding soil subject to the influence of living mycorrhizal roots.
NESS	National Earth Satellite Service.
NOAA	National Oceanographic and Atmospheric Administration.
Rhizomorph	The exploratory, infective cord-like organs produced by *Armillaria* species, composed of differentiated hyphal aggregates, for growth through the soil and colonization of new foodbases.
Streptomycete	Members of the genus *Streptomyces*, a group of actinomycetes which reproduce by forming spores.

APPENDIX A

Bulk litterbag incubation locations at the three study sites, 1987 through 1993.

(Mapping was first undertaken in 1987.)

Year	Site	Standtype	X	Y
1988	Ground	Plantation	8.9	78.0
1988	Ground	Plantation	16.1	74.5
1988	Ground	Plantation	35.5	35.0
1988	Ground	Plantation	42.6	16.6
1988	Ground	Plantation	55.1	43.5
1988	Ground	Plantation	58.5	74.6
1988	Antenna	Plantation	23.0	18.4
1988	Antenna	Plantation	33.9	18.5
1988	Antenna	Plantation	63.3	3.4
1988	Antenna	Plantation	71.7	29.3
1988	Antenna	Plantation	95.3	40.4
1988	Antenna	Plantation	99.1	4.3
1988	Control	Plantation	11.2	25.3
1988	Control	Plantation	33.0	30.4
1988	Control	Plantation	45.9	11.9
1988	Control	Plantation	67.7	33.8
1988	Control	Plantation	85.8	38.5
1988	Control	Plantation	91.4	19.4
1988	Antenna	Hardwoods	-13.6	5.7
1988	Antenna	Hardwoods	-21.8	22.5
1988	Antenna	Hardwoods	-55.9	10.1
1988	Antenna	Hardwoods	-68.0	25.9
1988	Antenna	Hardwoods	-77.3	23.4
1988	Antenna	Hardwoods	-97.5	15.7
1988	Control	Hardwoods	-14.5	11.6
1988	Control	Hardwoods	-31.8	15.4
1988	Control	Hardwoods	-49.2	26.6
1988	Control	Hardwoods	-57.3	8.6
1988	Control	Hardwoods	-79.1	11.2
1988	Control	Hardwoods	-100.0	22.0

Year	Site	Standtype	X	Y
1989	Ground	Plantation	19.0	64.1
1989	Ground	Plantation	23.1	18.9
1989	Ground	Plantation	24.0	91.0
1989	Ground	Plantation	41.5	23.3
1989	Ground	Plantation	61.1	74.1
1989	Ground	Plantation	70.7	6.7
1989	Antenna	Plantation	19.6	10.0
1989	Antenna	Plantation	32.5	35.0
1989	Antenna	Plantation	38.9	21.1
1989	Antenna	Plantation	56.9	41.1
1989	Antenna	Plantation	84.5	40.5
1989	Antenna	Plantation	93.1	13.6
1989	Control	Plantation	7.6	24.0
1989	Control	Plantation	34.8	27.2
1989	Control	Plantation	57.2	46.3
1989	Control	Plantation	64.8	23.4
1989	Control	Plantation	81.4	29.4
1989	Control	Plantation	102.7	29.6
1989	Antenna	Hardwoods	-5.5	3.5
1989	Antenna	Hardwoods	-31.4	8.9
1989	Antenna	Hardwoods	-43.2	8.0
1989	Antenna	Hardwoods	-59.9	14.3
1989	Antenna	Hardwoods	-75.2	21.8
1989	Antenna	Hardwoods	-99.7	24.6
1989	Control	Hardwoods	-6.2	18.5
1989	Control	Hardwoods	-23.5	14.9
1989	Control	Hardwoods	-41.0	11.1
1989	Control	Hardwoods	-61.8	19.1
1989	Control	Hardwoods	-83.7	20.3
1989	Control	Hardwoods	-100.2	10.7

Year	Site	Standtype	X	Y
1990	Ground	Plantation	16.0	30.0
1990	Ground	Plantation	16.4	71.9
1990	Ground	Plantation	22.2	91.8
1990	Ground	Plantation	36.1	18.3
1990	Ground	Plantation	65.4	74.8
1990	Ground	Plantation	72.5	13.1
1990	Antenna	Plantation	8.1	2.9
1990	Antenna	Plantation	17.7	28.4
1990	Antenna	Plantation	48.3	9.7
1990	Antenna	Plantation	57.9	34.0
1990	Antenna	Plantation	81.3	41.0
1990	Antenna	Plantation	88.9	9.1
1990	Control	Plantation	6.7	25.8
1990	Control	Plantation	32.9	30.5
1990	Control	Plantation	48.4	33.6
1990	Control	Plantation	64.4	39.5
1990	Control	Plantation	90.2	20.2
1990	Control	Plantation	106.4	29.8
1990	Antenna	Hardwoods	-6.5	10.5
1990	Antenna	Hardwoods	-24.5	1.3
1990	Antenna	Hardwoods	-48.3	13.5
1990	Antenna	Hardwoods	-65.0	21.1
1990	Antenna	Hardwoods	-74.1	17.4
1990	Antenna	Hardwoods	-96.2	7.5
1990	Control	Hardwoods	-3.3	9.2
1990	Control	Hardwoods	-9.7	17.1
1990	Control	Hardwoods	-44.6	27.4
1990	Control	Hardwoods	-58.3	17.7
1990	Control	Hardwoods	-79.4	18.7
1990	Control	Hardwoods	-92.7	18.7

Year	Site	Standtype	X	Y
1991	Ground	Plantation	10.4	70.0
1991	Ground	Plantation	33.0	73.1
1991	Ground	Plantation	40.8	24.3
1991	Ground	Plantation	50.5	41.0
1991	Ground	Plantation	55.1	34.7
1991	Ground	Plantation	65.7	77.3
1991	Antenna	Plantation	5.0	4.4
1991	Antenna	Plantation	8.9	33.7
1991	Antenna	Plantation	52.8	4.1
1991	Antenna	Plantation	66.5	33.7
1991	Antenna	Plantation	77.2	26.5
1991	Antenna	Plantation	111.3	6.3
1991	Control	Plantation	6.0	32.8
1991	Control	Plantation	10.9	12.6
1991	Control	Plantation	51.7	38.3
1991	Control	Plantation	66.5	26.5
1991	Control	Plantation	93.1	13.7
1991	Control	Plantation	112.1	37.0
1991	Antenna	Hardwoods	-3.7	3.5
1991	Antenna	Hardwoods	-6.0	22.5
1991	Antenna	Hardwoods	-38.8	5.0
1991	Antenna	Hardwoods	-67.5	22.2
1991	Antenna	Hardwoods	-76.2	20.3
1991	Antenna	Hardwoods	-99.4	23.9
1991	Control	Hardwoods	-2.2	8.3
1991	Control	Hardwoods	-3.8	21.7
1991	Control	Hardwoods	-57.8	24.6
1991	Control	Hardwoods	-65.6	11.2
1991	Control	Hardwoods	-88.3	7.7
1991	Control	Hardwoods	-105.8	24.1

Year	Site	Standtype	X	Y
1992	Ground	Plantation	9.4	78.3
1992	Ground	Plantation	10.5	12.0
1992	Ground	Plantation	15.2	27.3
1992	Ground	Plantation	27.3	93.2
1992	Ground	Plantation	56.3	76.4
1992	Ground	Plantation	58.2	40.1
1992	Antenna	Plantation	2.2	21.2
1992	Antenna	Plantation	33.4	30.8
1992	Antenna	Plantation	43.6	30.3
1992	Antenna	Plantation	64.5	42.7
1992	Antenna	Plantation	82.3	42.1
1992	Antenna	Plantation	105.6	31.4
1992	Control	Plantation	12.7	28.1
1992	Control	Plantation	16.4	34.8
1992	Control	Plantation	54.9	10.0
1992	Control	Plantation	64.0	39.0
1992	Control	Plantation	90.0	23.8
1992	Control	Plantation	102.8	15.9
1992	Antenna	Hardwoods	-22.2	18.0
1992	Antenna	Hardwoods	-25.5	0.7
1992	Antenna	Hardwoods	-37.5	5.7
1992	Antenna	Hardwoods	-64.7	20.6
1992	Antenna	Hardwoods	-75.1	23.4
1992	Antenna	Hardwoods	-100.1	26.7
1992	Control	Hardwoods	-5.4	2.0
1992	Control	Hardwoods	-14.7	11.8
1992	Control	Hardwoods	-38.9	10.5
1992	Control	Hardwoods	-40.2	21.8
1992	Control	Hardwoods	-78.7	19.0
1992	Control	Hardwoods	-97.0	16.2

Year	Site	Standtype	X	Y
1993	Ground	Plantation	20.5	82.1
1993	Ground	Plantation	21.1	15.3
1993	Ground	Plantation	25.7	31.5
1993	Ground	Plantation	34.7	73.5
1993	Ground	Plantation	60.6	19.6
1993	Ground	Plantation	65.3	74.6
1993	Antenna	Plantation	11.7	43.9
1993	Antenna	Plantation	31.8	11.4
1993	Antenna	Plantation	57.0	3.3
1993	Antenna	Plantation	71.8	32.4
1993	Antenna	Plantation	85.9	32.3
1993	Antenna	Plantation	98.8	5.2
1993	Control	Plantation	0.8	11.3
1993	Control	Plantation	17.4	15.9
1993	Control	Plantation	52.2	11.5
1993	Control	Plantation	63.2	29.0
1993	Control	Plantation	93.5	12.3
1993	Control	Plantation	110.4	19.7
1993	Antenna	Hardwoods	-12.2	6.2
1993	Antenna	Hardwoods	-26.0	8.0
1993	Antenna	Hardwoods	-36.5	12.6
1993	Antenna	Hardwoods	-65.0	17.9
1993	Antenna	Hardwoods	-86.9	30.4
1993	Antenna	Hardwoods	-98.1	23.0
1993	Control	Hardwoods	-14.5	9.9
1993	Control	Hardwoods	-34.6	15.8
1993	Control	Hardwoods	-43.7	24.2
1993	Control	Hardwoods	-59.4	17.1
1993	Control	Hardwoods	-81.1	21.1
1993	Control	Hardwoods	-91.8	26.5

NOTE: Origins of Cartesian coordinate systems for Ground Site, Antenna Site, and Control Site plantations were northwest, east, south corners, respectively. Origins of Cartesian coordinate systems for Antenna and Control hardwood stands were north and east corners, respectively. (See maps Appendix B, pages B-24 through B-26).

APPENDIX B

Introduction to the ELF EM fields,
and
spatio-temporal patterns of ELF EM field exposure
over the duration of the Ecological Monitoring Program studies
at the Litter Decomposition and Soil Microflora study sites.

With permission from IITRI, this Appendix consists wholly of excerpts from IITRI Technical Report D06209-1 (Haradem *et al.*, 1994). This Appendix is provided solely to assist in the review of this report. For convenience, page numbers from the original IITRI report remain in the lower center of each page.

3. EM FIELD MEASUREMENTS

3.1 Description of EM Fields of Interest

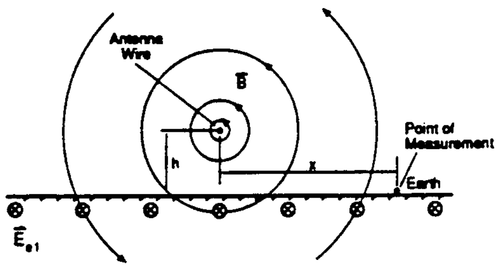
The three EM fields under investigation in this program are the magnetic field, the earth electric field, and the air electric field.

Magnetic fields of primary interest are those generated by current passing through a conductor, as occurs with the ELF antennas and power lines. These fields alternate polarity with a frequency equal to that of their source current. Also of interest is the earth's static (non-alternating) magnetic field, which has been reported both to be used by animals for navigation and to have possible effects through interaction with other magnetic field sources. Magnetic fields are generally unaffected by environmental factors such as weather, vegetation, soil, and nonferrous structures. They behave predictably and are generally unchanged at such boundaries as air/earth or air/water. Thus, measurement techniques need not consider shielding, enhancements, or perturbations of the magnetic field by these factors. This local uniformity of the magnetic field allows precise measurements over time, provided that the field sources--particularly the ELF antenna and power line currents--remain constant. Marked variations in the earth's magnetic field occur only over geological periods.

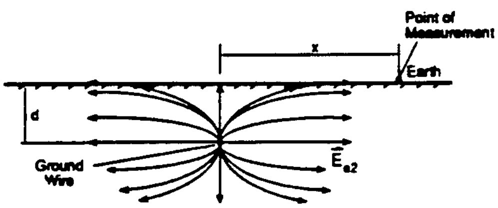
The electric field in the earth is measured as a difference in longitudinal potential in the upper 20 cm of the earth. The two sources of 76 Hz earth electric field associated with the ELF Communications System are (1) that induced by the magnetic field and (2) that generated by the ground terminal currents. The 60 Hz earth electric field is induced by power line magnetic fields and is also generated by unbalanced 60 Hz earth return currents associated with power distribution systems. The uniformity of earth electric fields is affected by the conductivity of soil and by conductivity anomalies such as large rocks, tree roots, and pools of water. The intensity of earth electric fields is fairly uniform, and measurements are repeatable when anomalies are avoided. Some year-to-year variations in this field may occur because of temporal changes in soil moisture content, which affect soil conductivity.

The 76 Hz electric field in the air is generated as a result of the voltage differences between the ELF antenna wire and the ground, and also as a by-product of the magnetically induced earth electric field. Power lines also generate a transverse or vertical air electric field in a manner similar to that of the overhead antenna wire. The vertical fields are limited to the ROW and other nearby cleared areas. In forested areas and locations more distant to the ROW, a predominantly horizontal air electric field is set up as a by-product of the earth electric field and is consequently of similar magnitude to the earth electric field. Both the horizontal and vertical air electric fields are perturbed by vegetation, people, and instrumentation. The perturbations of the field may take the form of an enhancing of the ambient field near objects or as a shielding effect on the surroundings. This results in a high variability of the air electric field over a small area. Efforts were made to measure the air electric field in open areas in order to determine the magnitude of the unperturbed field.

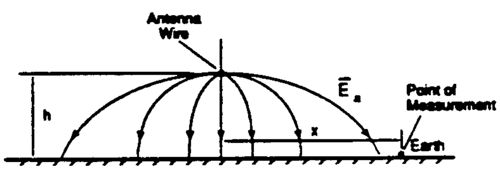
Annual or historic EM field measurements consist of a survey of 60 Hz and 76 Hz air electric fields, earth electric fields, and magnetic flux densities at defined locations within study sites, laboratories, and other special-use areas. Annual EM field measurement equipment, protocols, and summaries are described in Sections 3.2, 3.3, and 3.4. Section 3.5 describes supplemental EM field measurement equipment, including a dc magnetic field meter, a magnetic field monitoring system, and an earth electric field monitoring system.



(a) Magnetic Field and Earth Electric Field from Antenna Wire



(b) Earth Electric Field from Ground Wire



(c) Air Electric Field from Antenna Wire

$$|B| = \frac{\mu_0 I}{2\pi\sqrt{x^2 + h^2}} \qquad (5)$$

$$|E_{e1}| = -jf\, I\mu_0 \ln\left(\frac{1.85}{x\sqrt{2\pi f \mu_0 \sigma_b}}\right) - \frac{\pi f\, I\mu_0}{4} \qquad (6)$$

$$|E_{e2}| = \left(\frac{I}{\pi l \sigma_s}\right)\left(\frac{x}{x^2 + d^2}\right) \qquad (7)$$

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

Profiles of the 76 Hz air electric field and magnetic flux density along two transects perpendicular to the upland flora antenna and ground ROWs appear in Figures 21 to 24. Each figure has multiple profiles relating to normal operation with both antennas for the years 1989-1993 and one profile for the period of NS antenna operation only in 1991. The historic measurement points that comprise each profile are shown above the horizontal axis. Measurement points 4T2-26 and -33 through -36 were not established in 1989, and this profile is therefore missing for that year. Discontinuities at zero distance shown in the curves in Figure 21 and less apparent in Figure 23 are due to elevation differences in the laterally separated transects (see Figure D-3). Air electric field profiles are missing for 1992 because of a malfunctioning probe.

The air electric fields in the pine plantations at both the antenna and ground sites decrease in a uniform fashion with increasing distance from the antenna or ground feed wire. At the ground site there is a dip in the field profiles near the plot center, which occurs in all years. This is caused by an interaction between, and partial cancellation of, the fields produced by the overhead and buried ground wires. The profiles for both sites may be used to provide good estimates of the air electric field intensity at any point in the pine plantations by graphical interpolation, given the distance of the point from the antenna or ground wires. Air electric fields at the pine plantations show a marked decrease in 1993 from 1991 levels. This reflects the shielding effect of substantial tree growth (~3 feet) between the two years.

The air electric field profile for the pole stand and herbaceous reserve plots is not as uniform as that for the pine plantations. The air electric field, normally set up by the difference in potential between the antenna wire and the earth, is shielded by the tall trees at these plots. The air electric fields that do appear at these plots are the by-product of the earth electric field and are subject to the same variables as the earth electric field. Because these fields vary unpredictably across the pole stand and herbaceous reserve plots, the historic profile data can only be used to bound expected values at these plots. The data cannot be used to accurately predict field intensity levels at other points within the plots.

The magnetic flux density for a given current is dependent only on the distance of the measurement point from the source. The profiles for this field are therefore the most predictable and stable of those measured. As shown in Figures 23 and 24, the fields decrease uniformly with increasing distance from their sources. At the ground site, a dip in the magnetic flux density profile near the plot center, similar to that seen for the air electric field, occurs in all years. This, again, is caused by a partial cancellation of the fields generated by the overhead and buried ground wires. These profiles may be used to estimate the magnetic flux density at any point within the treatment sites with very good accuracy.

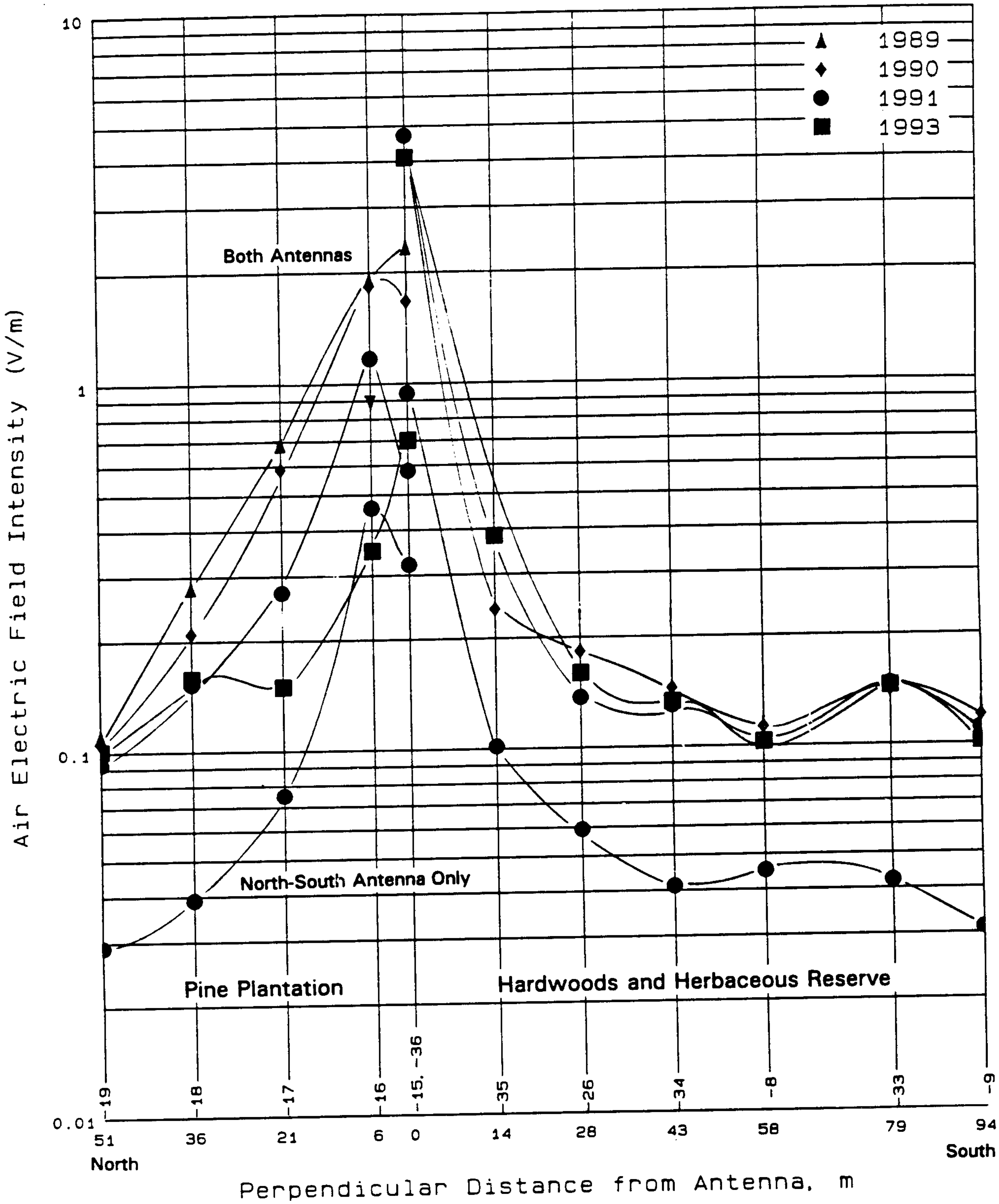


FIGURE 21. 76 HZ AIR ELECTRIC FIELD PROFILES, MARTELL'S LAKE (OVERHEAD) ML; 4T2-8, 9, 15-18, 26, 33-36.

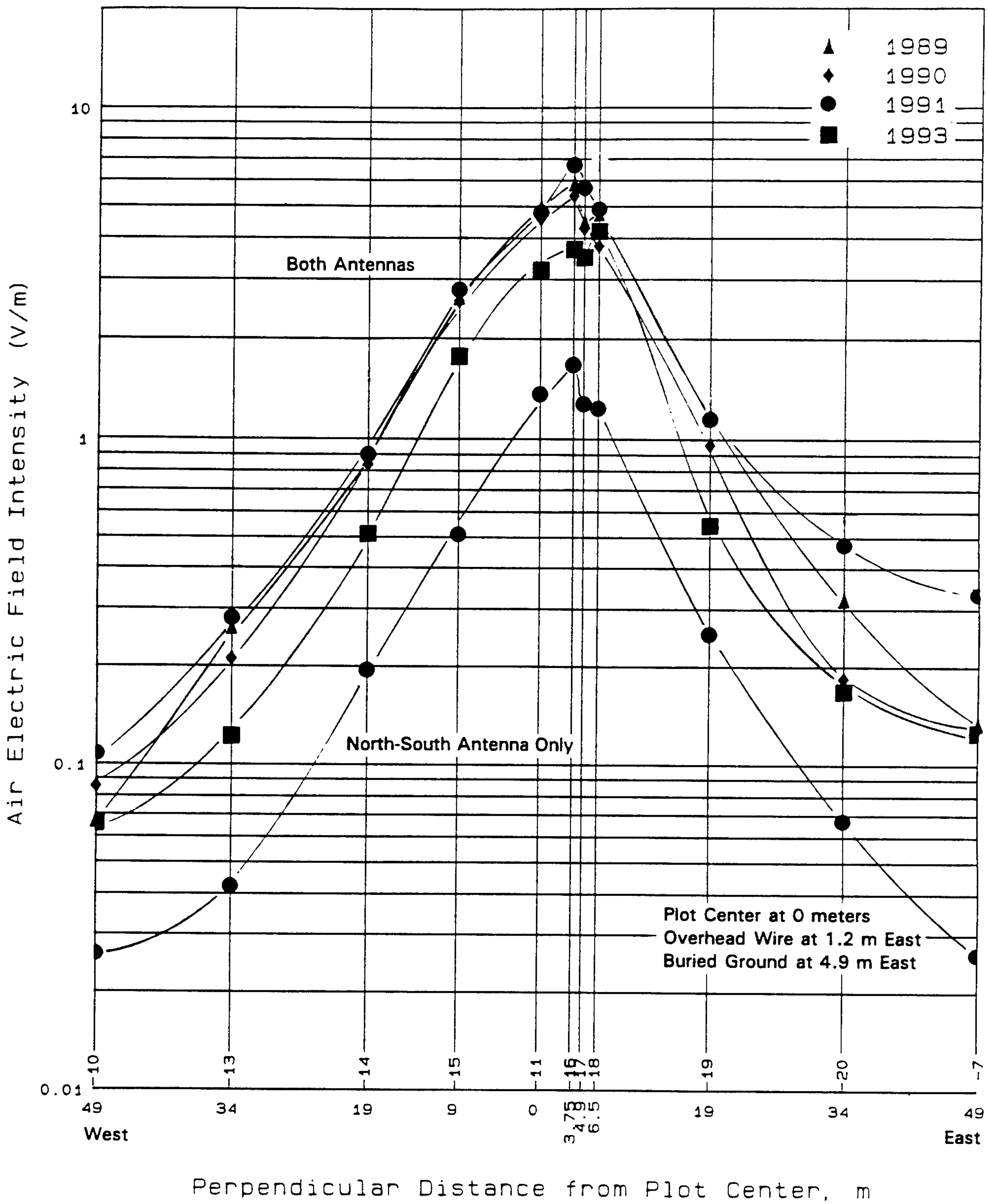


FIGURE 22. 76 HZ AIR ELECTRIC FIELD PROFILES, MARTELL'S LAKE (BURIED) EP; 4T4-7, 10, 11, 13-20.

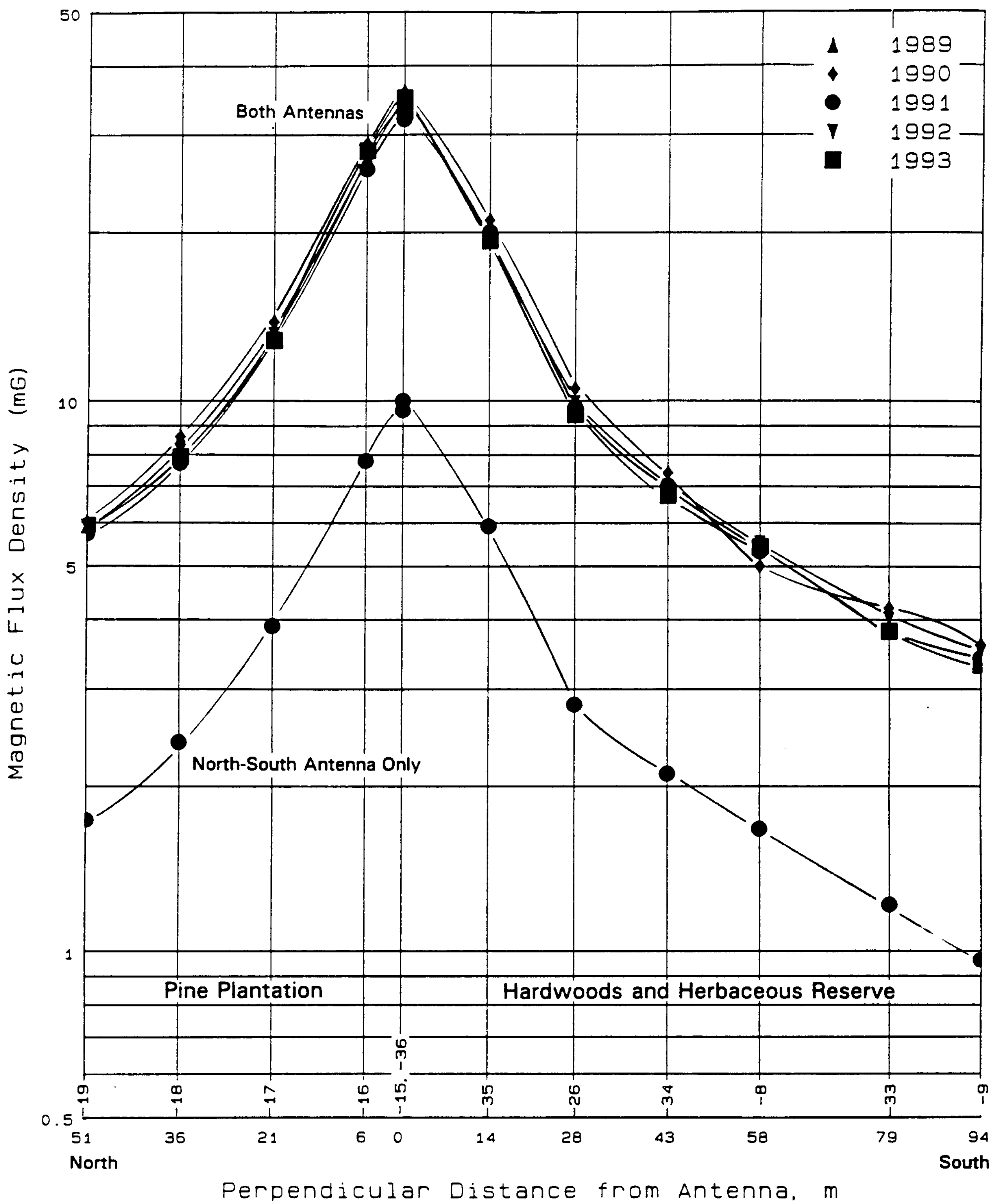


FIGURE 23. 76 HZ MAGNETIC FLUX DENSITY PROFILES, MARTELL'S LAKE (OVERHEAD) ML; 4T2-8, 9, 15-19, 26, 33-36.

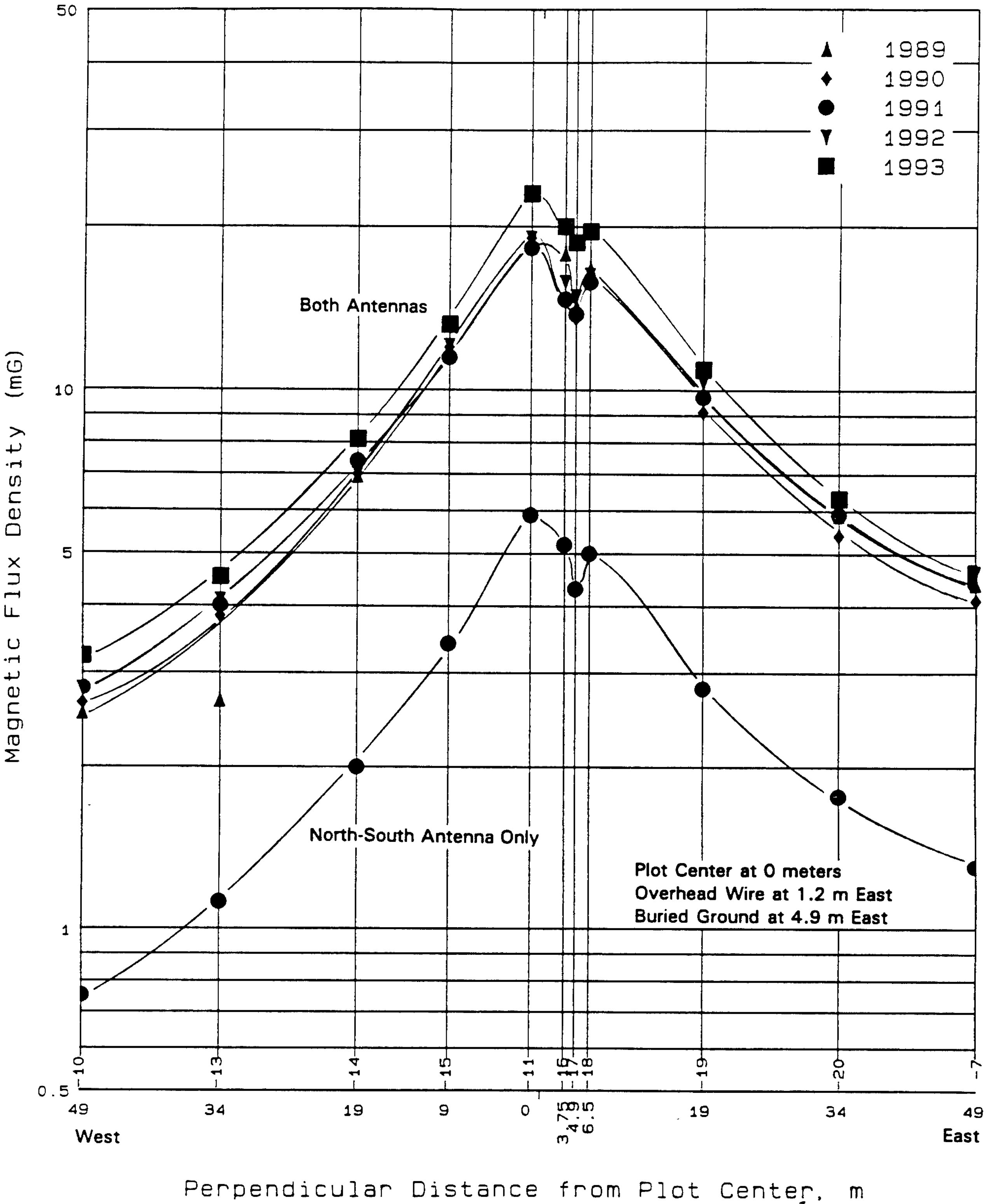


FIGURE 24. 76 HZ MAGNETIC FLUX DENSITY PROFILES, MARTELL'S LAKE (BURIED) EP; 4T4-7, 10, 11, 13-20.

In 1993, earth electric field values for the upland flora and soil microflora treatment sites were obtained from three measurement sources:

- annual survey (once)
- fixed probes (biweekly)
- data logger monitors (hourly)

For comparative purposes, values used to construct profiles across the treatment and control sites (for locations see Figures D-3 and D-4) are summarized in Table 10 and plotted in Figures 25 and 26. Average values determined by fixed probe measurements closely agree with those recorded by the data loggers. Annual survey values, however, were just as likely to fall within as outside one standard deviation of the values recorded by the loggers.

The data also show that the earth electric fields at the antenna site (4T2) do not consistently decrease with distance from the antenna as might be expected from Equation 6. This inconsistency may be due to subterranean rock or grounding structures associated with meteorological monitoring equipment (see Section 4.4.2.4 for further discussion). At the ground site (4T4), the electric fields were distributed as predicted by Equation 7, with a null directly over the buried grounding wire and relatively high peaks on either side of the wire.

Because the earth electric field behaves unpredictably across these treatment sites, the annual historic, data logger, and fixed probe data will not provide very accurate estimates of the earth fields at other points at these sites. To improve on these estimates, an extensive set of earth electric field measurements was made at these sites in 1990. These measurements, made at locations on a uniformly spaced grid, were used to create contour maps of the field.[11] Results of this effort are presented in Appendix D.

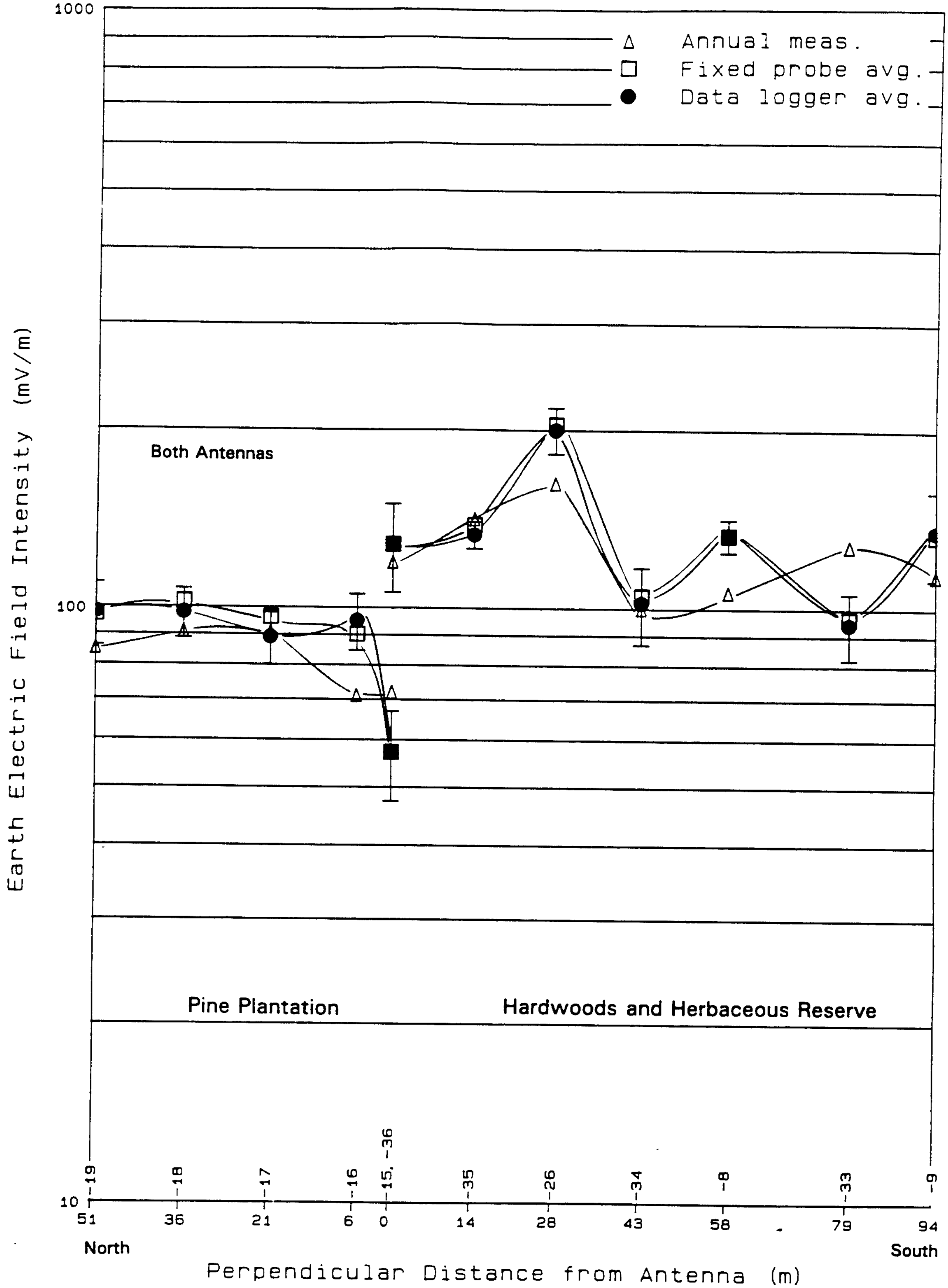


FIGURE 25. COMPARISON OF 1993 76 HZ EARTH ELECTRIC FIELD MEASUREMENTS AT SITE 4T2.

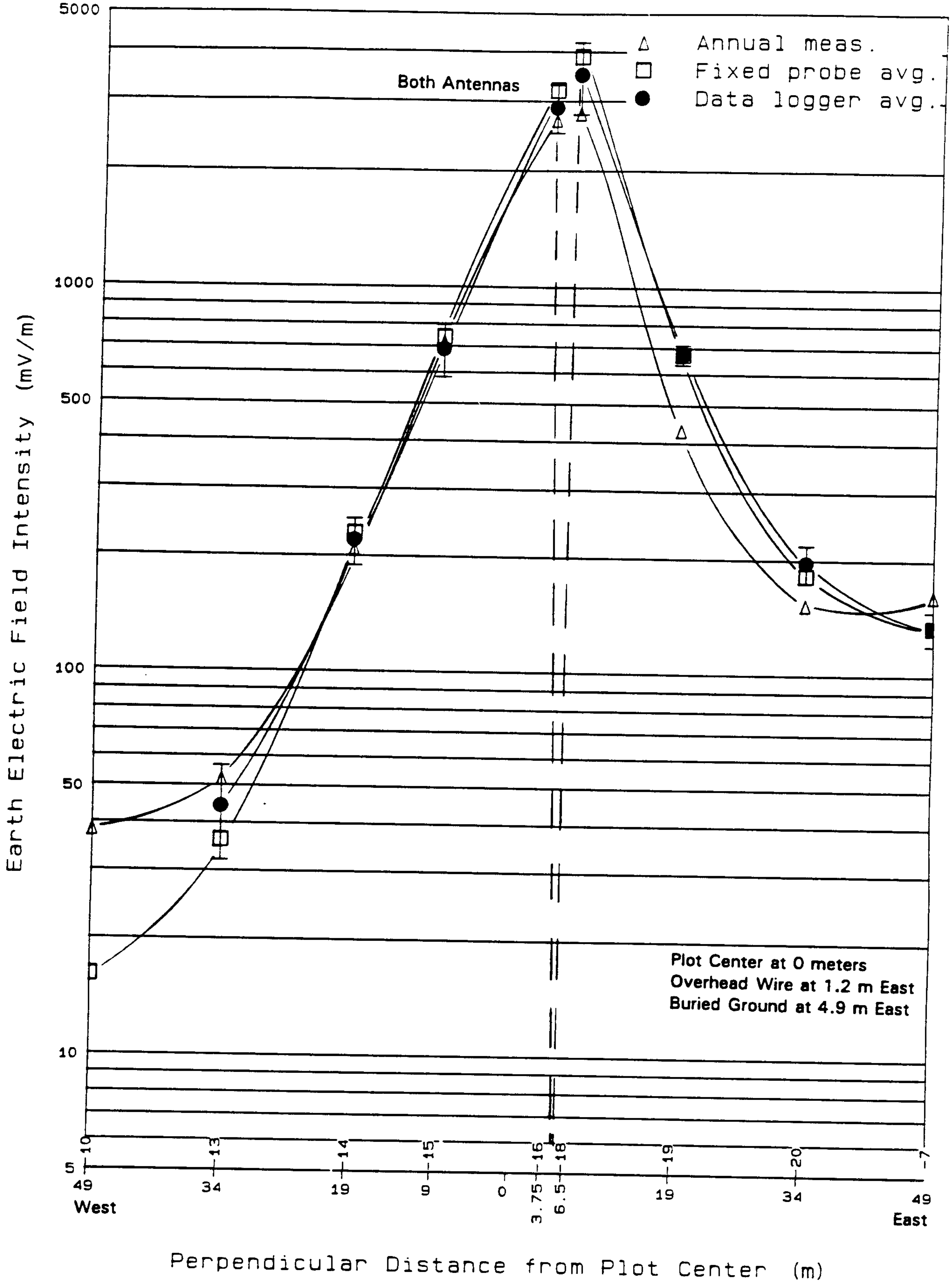


FIGURE 26. COMPARISON OF 1993 76 HZ EARTH ELECTRIC FIELD MEASUREMENTS AT SITE 4T4.

4.5 Transmitter Operations--Analysis and Data Base

4.5.1 Operating Log Data Base

In order to calculate the EM exposure regimes, study investigators must have both field intensity values at their study sites as well as the duration of exposure. Field intensity measurements were discussed in Section 3, and data tables are presented in Appendixes A through G. Data on the duration of antenna operations were provided to IITRI by the Navy's Submarine Communications Project Office. In addition, information on operating frequency, modulation, power, and phasing between antenna elements were provided. This information was entered into a computer data base from which both graphic and tabular operating condition summaries were formed. Graphic summaries for the NRTF-Republic are presented in this section; more detailed tabular summaries appear in Appendix J. IITRI provides the data bases to the study investigators on request.

4.5.2 Summary of NRTF-Republic Operations, 1986-1993

The NRTF-Republic has gone through several stages of development. These stages have been marked by changes in the operating times, currents, and antenna element configurations. The antenna elements at the NRTF-Republic were first energized in March 1986. Initial tests used a low-current (4, 6, or 10 A) unmodulated signal, and the antenna elements were operated individually. In 1987, antenna currents were increased to 15 A, and the NEW and SEW antenna elements were permanently connected in parallel, constituting the EW antenna. In 1988, antenna currents were increased to 75 A. In May 1989, currents were increased to full power (150 A), the NS and EW antennas were operated simultaneously, and a modulated signal was used. Operating times increased dramatically as the NRTF-Republic became an on-line Naval Communications Facility in the latter half of 1989. Normal full-power operation continued through 1993, with the exception of periods in 1991 and 1992 when the EW antenna was off for special maintenance. Operation of the NS antenna continued at full power during these special maintenance periods.

During the 15 and 75 A testing periods in 1987, 1988, and 1989, virtually all transmitter operations were conducted according to a 15-minute rotational schedule commencing on the hour. Each cycle consisted of the following:

- 5 minutes--both antennas off
- 5 minutes--NS antenna only on
- 5 minutes--EW antenna only on

NRTF-Republic operational logs supplied to IITRI list specific times at which such cycles begin and end. The actual operating times were estimated by assuming a 33 percent duty cycle for each antenna during the testing period. The rotational schedule was not used after 150 A testing began in May 1989.

Figures 36 and 37 show the hours of operation for each antenna or antenna element on a month-by-month basis. The hours of operation for 1986-1988 are shown in Figure 36. During 1986-1988, the NS and EW antennas were never operated simultaneously. Furthermore, in 1986 the NEW and SEW elements, which comprise the EW antenna, were always operated individually. From 1987 on, these elements were connected in parallel and referred to as the EW antenna. The hours of operation for 1989-1993 are shown in Figure 37. They are broken down into periods of operation with both antennas, the NS antenna only, and EW antenna only.

The pie charts in Figure 38 present NRTF-Republic annual operating summaries for 1986-1993. For each year, a pie wedge representing the total percent time of all transmissions is exploded in a second pie, which details this operating time by antenna or antenna element. This figure clearly illustrates the gradation of annual operation times from 1.5 percent in 1986 to near 90 percent in 1990 through 1993. The exploded pie wedges provide a "snapshot" history of major operating configuration changes, from solo operation of the NS antenna and EW antenna elements in 1986 to nearly exclusive simultaneous operation of both antennas in 1989 through 1993.

NRTF-Republic operations in 1986-1993 can be summarized as follows:

<u>1986</u>

- The NRTF-Republic was transmitting about 1.5 percent of the time (about 160 hours) (see Figures 36 and 38).
- About 98 percent of "on" time was with an unmodulated 76 Hz signal.
- The NS antenna and the NEW and SEW antenna elements were always operated individually.
- Primary operating currents were 4 and 6 A for the NS antenna and the NEW antenna element, respectively, and both 6 and 10 A for the SEW antenna element.

<u>1987</u>

- The NRTF-Republic was transmitting about 4.5 percent of the time (about 400 hours) (see Figures 36 and 38).
- 100 percent of "on" time was with an unmodulated 76 Hz signal.
- The NS and EW antennas were always operated individually.
- 99.6 percent of the operating time was with a 15 A current.

<u>1988</u>

- The NRTF-Republic was transmitting about 11.6 percent of the time (about 1000 hours) (see Figures 36 and 38).
- About 98 percent of "on" time was with an unmodulated 76 Hz or 44 Hz signal.

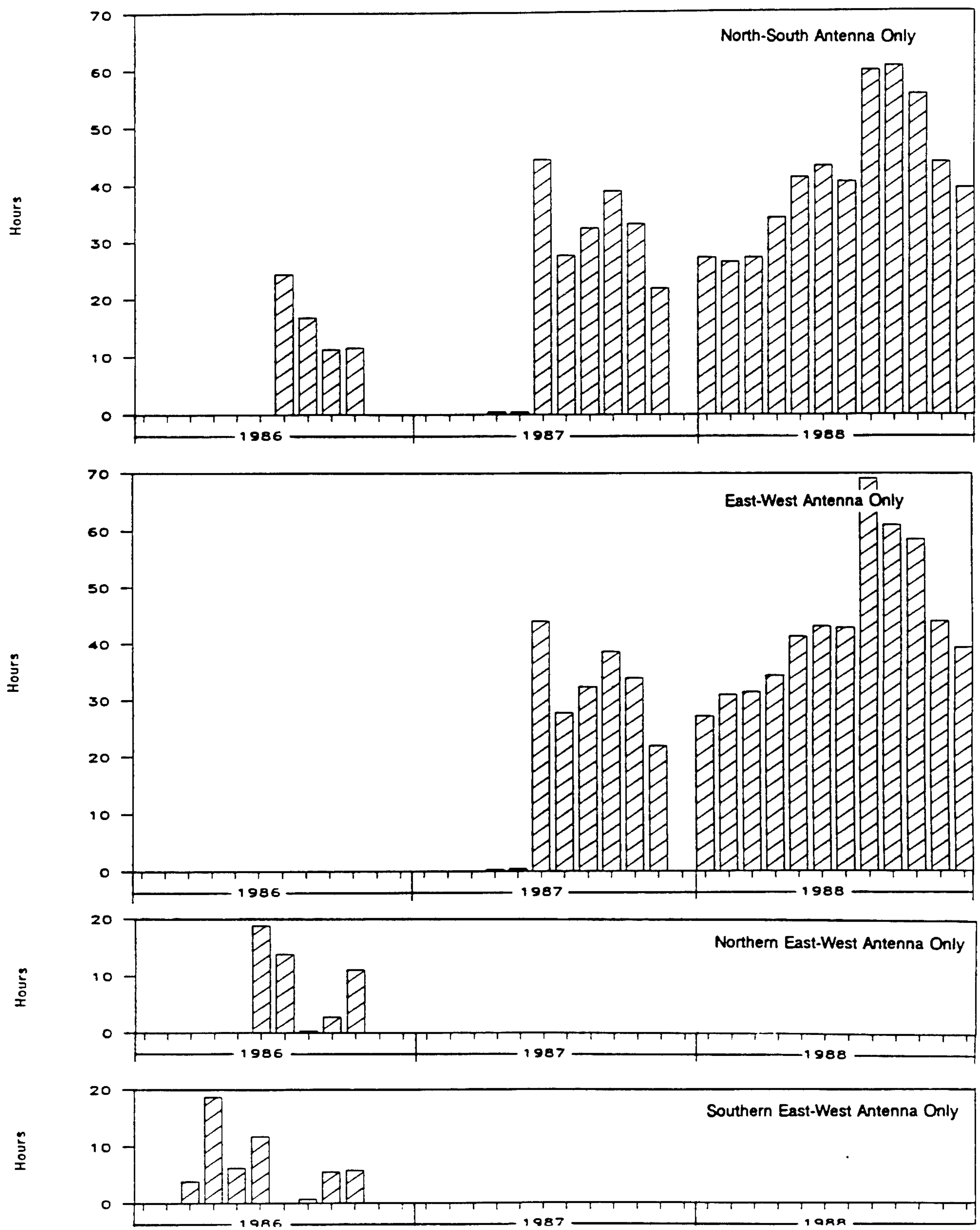


FIGURE 36. NRTF-REPUBLIC MONTHLY OPERATING SUMMARY, 1986-1988.

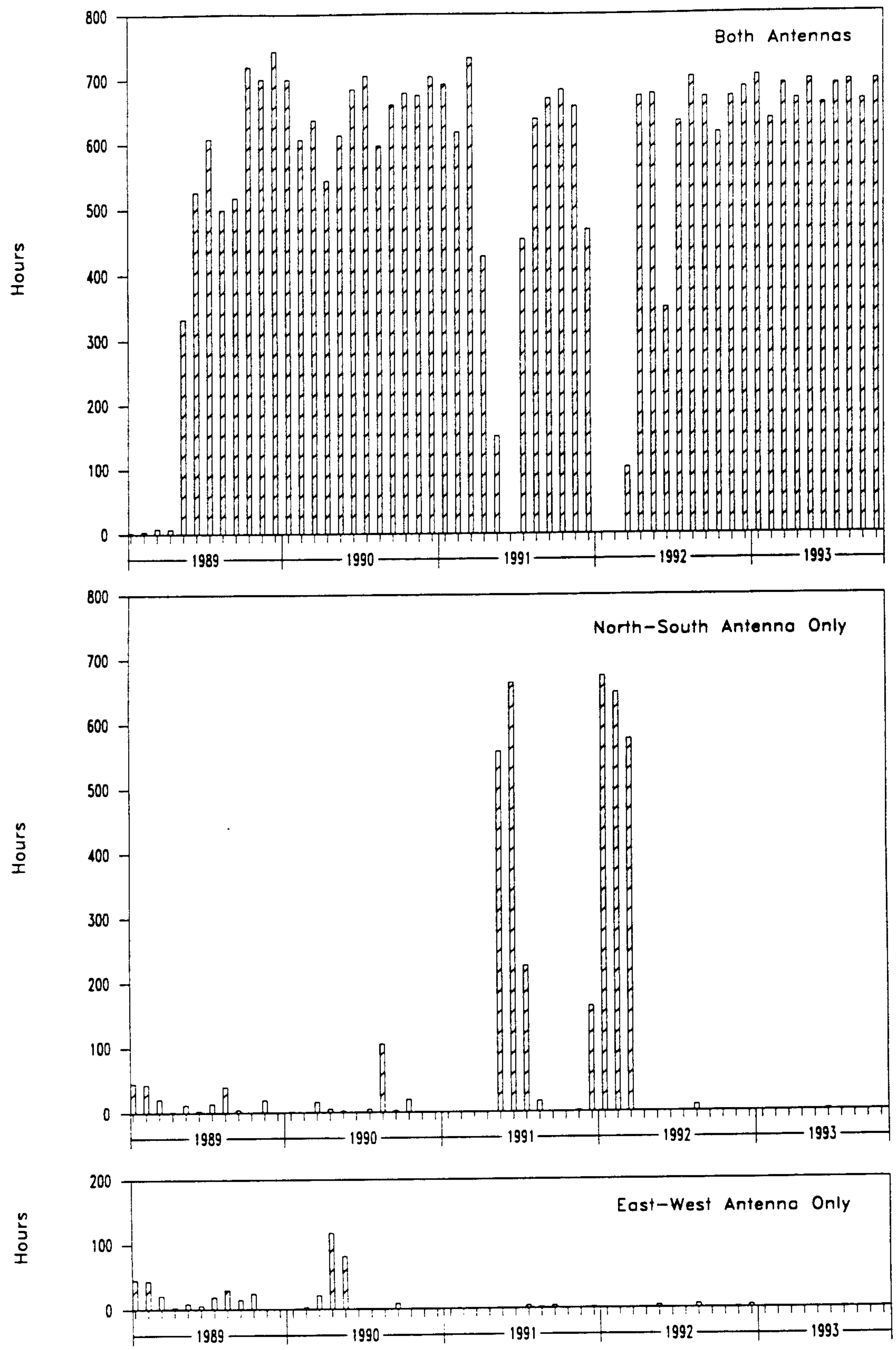


FIGURE 37. NRTF-REPUBLIC MONTHLY OPERATING SUMMARY, 1989-OCT. 1993.

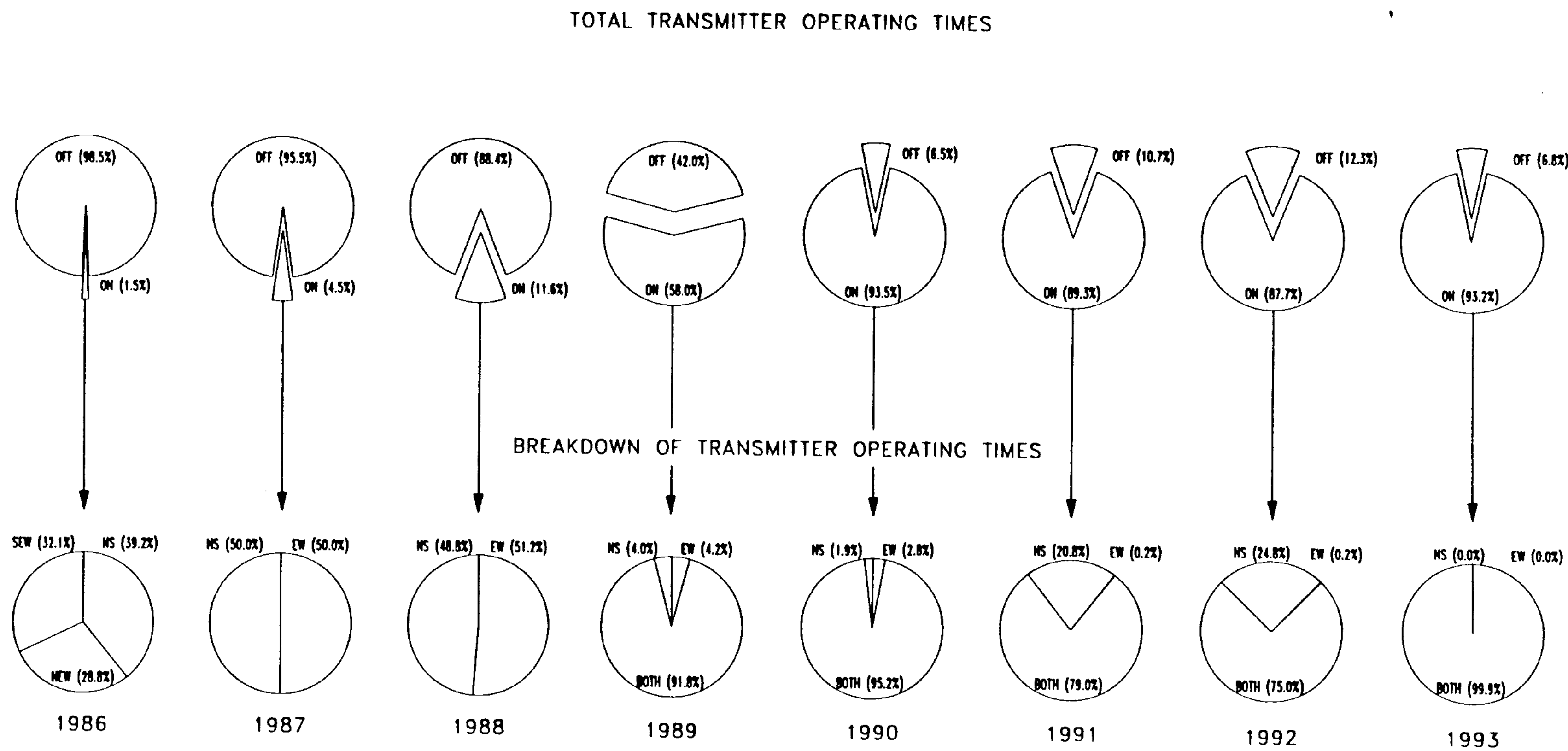


FIGURE 38. NRTF-REPUBLIC OPERATING SUMMARY: PERCENTAGE OF TIME PER ANTENNA ELEMENT, 1986-OCT. 1993.

- The NS and EW antennas were always operated individually.
- Primary operating currents were 15 and 75 A. 40.6 percent of "on" time was at 15 A, and 59.2 percent of "on" time was at 75 A.

1989

- The NRTF-Republic was transmitting about 58 percent of the time (about 5100 hours) (see Figures 37 and 38).
- About 57 percent of "on" time was with a modulated 76 Hz signal, and 28 percent of "on" time was with an unmodulated 76 Hz signal.
- The NS and EW antennas were operated simultaneously for 91.8 percent of the "on" time.
- Primary operating currents were 75 and 150 A. 95 percent of "on" time was at 150 A.

1990

- The NRTF-Republic was transmitting about 93.5 percent of the time (about 8200 hours) (see Figures 37 and 38).
- About 95 percent of "on" time was with a modulated 76 Hz signal and both antennas operating simultaneously.
- The NS and EW antennas were operated simultaneously for 95.2 percent of the "on" time.
- All operations were at 150 A.

1991

- The NRTF-Republic was transmitting about 89 percent of the time (about 7825 hours) (see Figures 37 and 38).
- About 79 percent of "on" time was with a modulated 76 Hz signal and both antennas operating simultaneously.
- About 21 percent of "on" time was with a modulated 76 Hz signal and only the NS antenna operating.
- Essentially all operations were at 150 A with a modulated 76 Hz signal.

1992

- The NRTF-Republic was transmitting about 88 percent of the time (about 7680 hours) (see Figures 37 and 38).
- About 75 percent of "on" time was with a modulated 76 Hz signal and both antennas operating simultaneously.
- About 25 percent of "on" time was with a modulated 76 Hz signal and only the NS antenna operating.
- Essentially all operations were at 150 A with a modulated 76 Hz signal.

Jan.-Oct. 1993

- The NRTF-Republic was transmitting about 93 percent of the time (about 8160 hours) (see Figures 37 and 38).

- Essentially all "on" time was with a modulated 76 Hz signal and both antennas operating simultaneously.
- All operations were at 150 A.

Finally, cumulative exposure data for the duration of the Ecological Monitoring Program are plotted on a normalized scale in Figure 39 for the NS and EW antennas. This cumulative exposure is based on antenna operating times provided to IITRI by the Navy. The operating times for each antenna were multiplied by the operating current and plotted as cumulative sums in this figure. The current parameter was chosen because intensities of the EM fields of interest are proportional to antenna current. The data in Figure 39 are normalized to the NS antenna cumulative total (5.3 million ampere-hours). Relative exposure levels for any period can be estimated as the first derivative (slope) of the exposure curve.

The exposure curve in Figure 39 may be useful in defining a preoperational/operational break-point for data analyses. The break-point chosen for most analyses was May 1989 when antenna currents increased to 150 A. Other antenna operational change points of interest include July 1986 when operations began at low currents, June 1987 when operating currents were increased to 15 A, and July 1988 when operating currents were increased again to 75 A. The large plateaus for the EW antenna in 1991 and 1992 correspond to times when this antenna was off for extended maintenance (see Section 3.4.3). Overall, cumulative operations for the EW antenna totaled 4.77 million ampere-hours, or 90 percent of the NS antenna total. The 10-percent difference appears from Figure 39 to be explained solely by the two EW antenna maintenance periods.

UPLAND FLORA AND SOIL MICROFLORA STUDIES

The major themes of the upland flora and microflora studies are the functional and structural aspects of organic material cycling. These studies investigate and characterize trees, herbaceous plants, and microflora (fungi and streptomycetes) populations. The electric and magnetic fields in the earth are considered important electromagnetic (EM) factors influencing soil biota and processes. The electric and magnetic fields in the air may influence any object extending above the surface of the earth. The electric field in the air is greatly distorted and shielded by trees or plants on a study plot. Such perturbations were avoided as much as possible when characterizing the air electric field intensities.

The treatment sites for these studies straddle the EW antenna and one of the grounding elements of the NRTF-Republic; the control site is located more than 28 miles from the nearest antenna element. The antenna treatment 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 ground treatment site consists of only three plots cleared and planted with red pine. No overstory tree plots or herbaceous reserves were established at the ground treatment site because the required buffer strips would have resulted in the biota being at too great a distance from the grounding elements for meaningful EM field exposure. Dropped foliage for decomposition studies is collected at the control site and at two sites in Houghton County.

In 1993, IITRI field crews made ELF EM field measurements at 47 historic measurement points within the two treatment sites and one control site. The measurement regime differed from 1992 in that measurements were not made at the three foliage collection points. Foliage was last collected at these points in 1992 for distribution at the study sites during the 1993 field season. Annual EM field measurement dates for 1993 and previous years appear in Table D-1.

The positions of the study sites relative to the NRTF-Republic are shown on the composite map in Figure D-1. The site numbers listed on the map are those used by IITRI. Table D-2 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. The annual (historic) measurement point locations are shown in Figures D-2 through D-6. Figures D-3 and D-4 also identify data logger (E) and fixed probe (F) measurement locations, many of which coincide with the historic (H) measurement points.

Annual EM field measurements for 1993 and previous years are found in Tables D-3 through D-8. Tables D-3, D-4, and D-5 present 60 Hz data for the air electric field, earth electric field, and magnetic flux density, respectively. Tables D-6, D-7, and D-8 present 76 Hz data for these fields as well as the

TABLE D-1. EM FIELD MEASUREMENT DATES
Upland Flora and Soil Microflora Studies

Year	Measurement Dates		
1983	Jun 7, 14		
1984	May 15, 21	Aug 6, 9	
1985	Jul 15, 17, 19		
1986	Oct 1, 2, 14		
1987	Sep 22, 23	Oct 5, 7	
1988	Sep 22	Oct 5-7	
1989	Sep 19	Oct 11, 12	
1990	Jun 27-30	Aug 9	Oct 1
1991	Jun 19, 20	Oct 3, 15-17	
1992	Sep 28, 29, 30	Oct 1	
1993	Jul 12, 14, 15, 28		

TABLE D-2. SITE NUMBER CROSS-REFERENCE
Upland Flora and Soil Microflora Studies

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

corresponding operating current of the NRTF-Republic for each year. Paired-site EM field intensity ratios, which were recalculated using 1993 measurement data, appear in Table D-9.*

Considerable year-to-year variability in the 60 Hz EM fields is evident. The primary factors in this variability at treatment sites are changes in power line loading conditions (which are unknown) and

* Earth electric field measurements, which were performed regularly at several fixed probe since 1990, appear in Tables D-10 through D-13.

differences in the configuration of the antennas at the time of measurement. The 60 Hz measurements at treatment sites in 1986 through 1993 (excluding 1989 and 1990) were made while the antennas were off, and are representative of 60 Hz levels present during maintenance periods. In 1989 and 1990, the antenna status (modulated signal) precluded 60 Hz EM field measurements at the treatment sites. However, measurements were possible at treatment sites for other studies in 1989 during unmodulated operation of the antennas. These measurements indicate that 60 Hz EM fields present during operation of the antennas are comparable to those present when the antennas are off.

Annual variations in the 60 Hz fields measured at the control study site are also caused by differences in power line loading, but are not dependent on the antennas or their configuration because of the distance of this site from the antennas. The 60 Hz fields at the control site show lower spatial variation compared to those at the treatment sites because the antenna is not present to establish a field gradient. In 1992 the 60 Hz EM fields at the control site were found to be many times greater than in previous years. It was expected that these elevated fields resulted from a difference in the loading of a nearby transmission line owned and operated by Wisconsin Electric Power Company (WEPCo). WEPCo personnel informed IITRI, however, that there had been no significant changes in the loading of this or any nearby line that might explain the elevated field intensities. In 1993, the 60 Hz fields were found to be consistent with fields measured in years prior to 1992. Based on these measurements and information received from WEPCo, the elevated field intensities measured in 1992 are believed to correspond to very short exposure times.

Overall, the 60 Hz EM fields measured at all study sites in 1993 are consistent with previous field values and with the expected differences in power line loads and antenna configuration. Regardless of the variability in EM intensities associated with the measurement condition, 76 Hz EM fields at treatment sites consistently dominate the 60 Hz EM fields at treatment and control sites.

The 76 Hz EM field measurements in 1993 were made with 150 A antenna currents, the predominant operating current of the NRTF-Republic since May 1989. The energized antenna elements and currents at the time of measurement are given below the year in the column headings of Tables D-6 through D-8. The annual increases in field magnitudes reflect the level of antenna current at the time of measurement: 4 or 6 A in 1986, 15 A in 1987, 75 A in 1988, and 150 A in 1989 through 1993. The 1993 measurement values for full-power operation with both antennas are consistent with those obtained in 1989 through 1992 under the same antenna conditions and are proportional to the measurements made in 1986, 1987, and 1988 at lower currents.

The extended shutdown of the EW antenna for repairs in 1991 and 1992 had a significant impact on the 76 Hz EM exposure levels at the treatment sites for this study, which are located along the SEW antenna element and ground 5. A complete set of EM field measurements was made in 1991 at both treatment sites during operation of the NS antenna only. These data are included in Tables D-6 through

D-8. It was found that the EM exposures at all locations at the treatment sites were reduced to about one-third of those with both antennas energized. The relatively high levels along the de-energized EW antenna are caused by cross-coupling from the energized NS antenna. Although EW antenna shutdown continued through 27 March 1992, EM field measurements could not be made during this period because of weather restrictions. Also, comprehensive data collected during 1991 under this condition sufficiently describe field reduction levels.

Measurements were not made in 1991 or 1992 at the control site with the EW antenna shutdown. However, 76 Hz EM field contributions from the NS and EW antennas are known to be of similar magnitude at this site, as evidenced by the 1987 and 1988 measurements during individual antenna operation. EM exposures at the control site, therefore, were likely reduced to about one-half of their normal levels when only the NS antenna was operating. While the actual amount of exposure reduction at the control site is unknown, any reduction in the EM fields here is desirable from the standpoint of maintaining proper EM exposure ratios.

Regular measurements continued to be made at the fixed electric field probes, which were established at numerous locations at the treatment sites in 1990. Fixed probe measurement locations are designated by an "F" in the measurement point symbols in Figures D-3 and D-4. All fixed probe locations established in 1990 are still in use. The fixed probe measurement set was expanded in 1991 to include the electrode pairs monitored by the data loggers. Data for all fixed probe measurements made in 1990 through 1993 are presented in Tables D-10 through D-13. Measurements made during shutdown of the EW antenna are labeled "NS Only" in the column headings. Summary statistics computed for each probe for each year are also included in these tables. Statistics for 1991 and 1992 do not include data for NS antenna operation only.

Special efforts were made in 1990 to provide a detailed characterization of the earth electric field gradients at the treatment study sites. Resulting earth electric field contour maps for the two treatment sites and the survey data used in their generation are presented in Figures D-7 through D-10 for convenient reference. Discussion of these data may be found in a previous report.* In 1991-1993, efforts were made to characterize both the spatial and temporal variability of these fields. EM field profiles comparing annual, fixed probe, and data logger data for these sites are presented in Section 4.4.1.2 of this report.

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* Haradem, D. P.; Gauger, J. R.; Zapotosky, J. E. ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1990. IIT Research Institute, Technical Report E06628-3, 87 pp. plus appendixes, 1991.

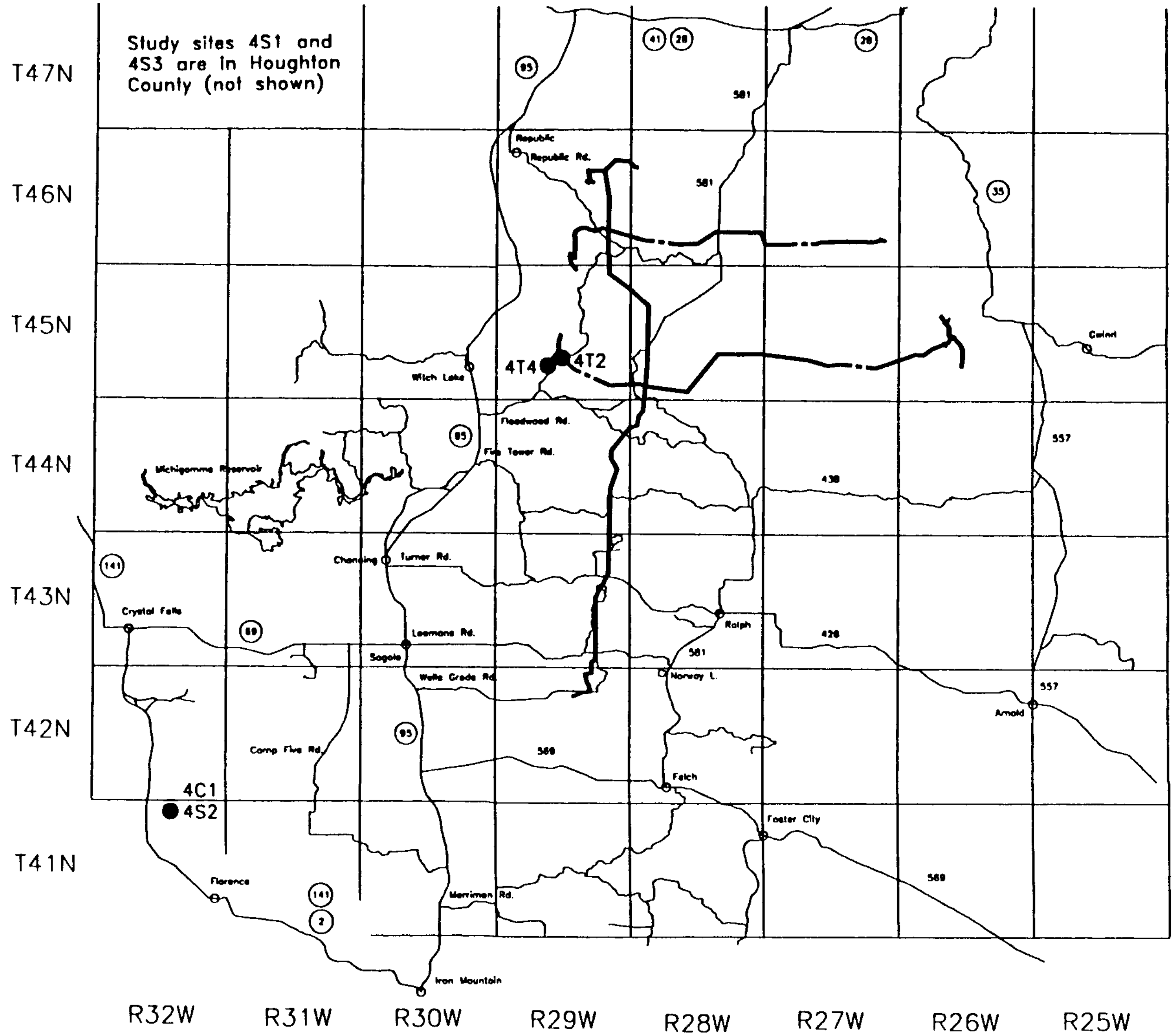


FIGURE D-1. POSITIONS OF UPLAND FLORA AND SOIL MICROFLORA STUDY SITES RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

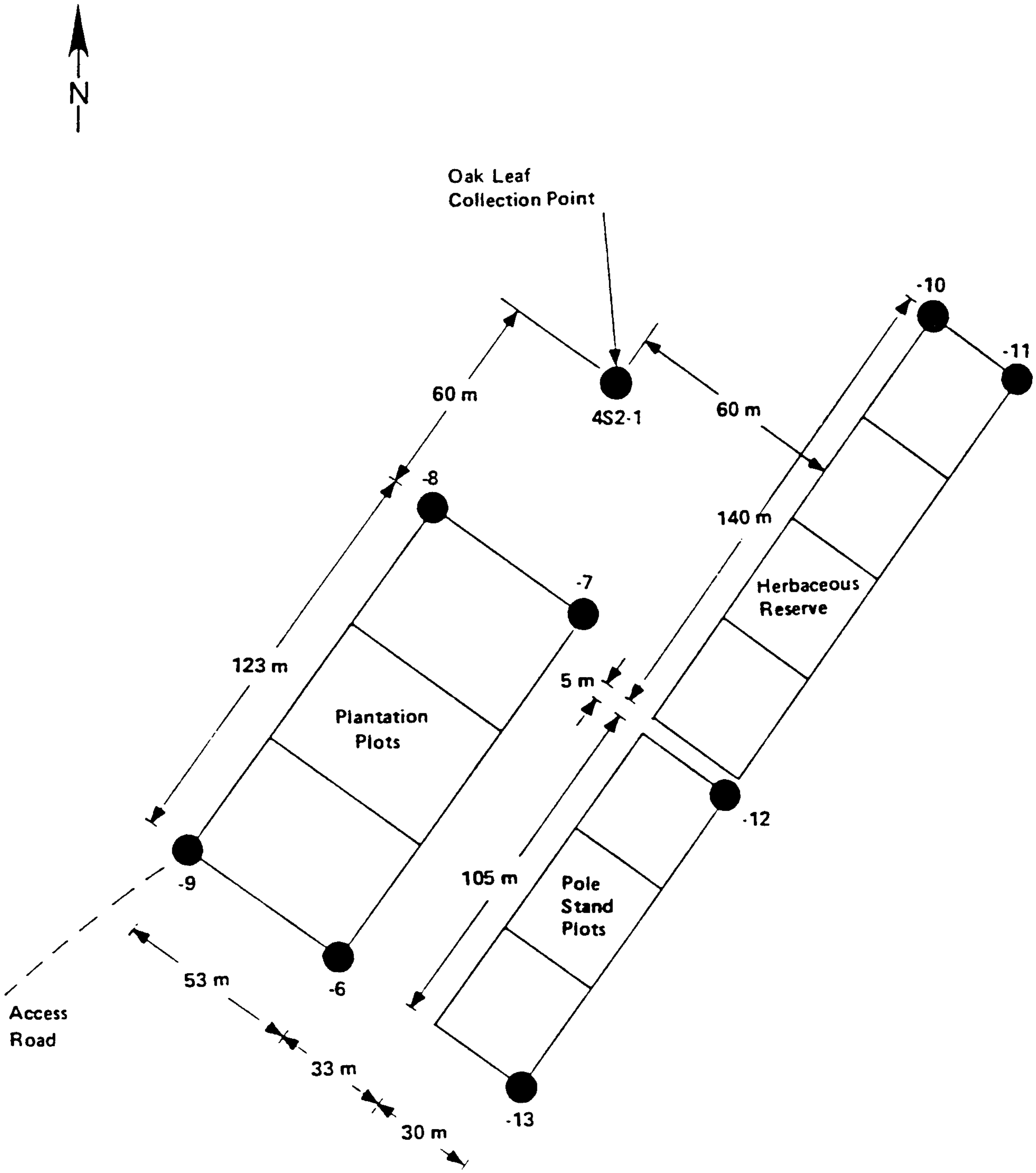


FIGURE D-2. MEASUREMENT POINTS AT PAINT POND ROAD CONTROL; 4C1-6 THROUGH 13, AND OAK LEAF COLLECTION SITE; 4S2-1.

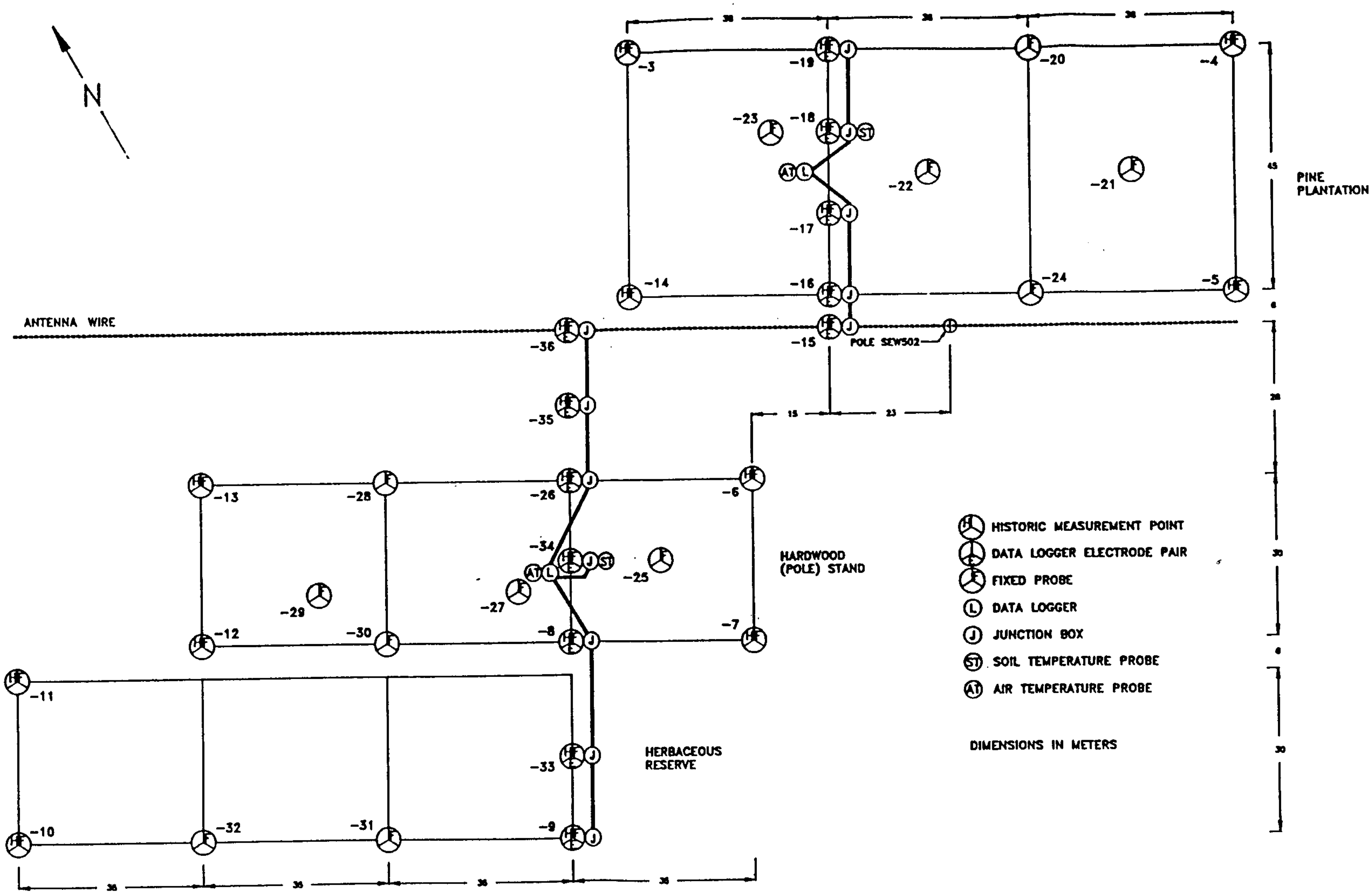


FIGURE D-3. HISTORIC AND FIXED MEASUREMENT POINTS AT MARTELL'S LAKE (OVERHEAD): ML; 4T2-3 THROUGH 19.

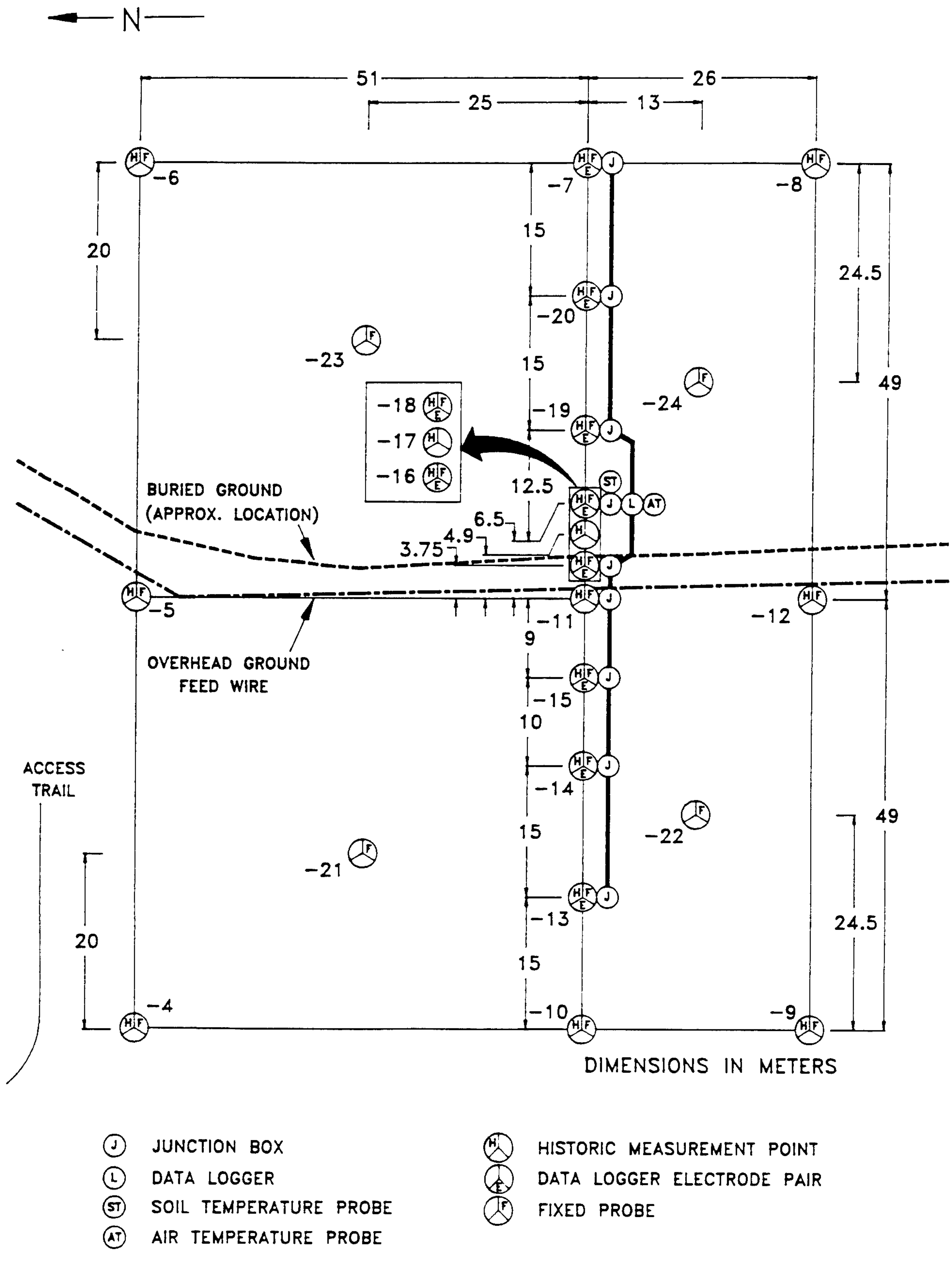


FIGURE D-4. HISTORIC AND FIXED MEASUREMENT POINTS AT MARTELL'S LAKE (BURIED): EP; 4T4-4 THROUGH 24.

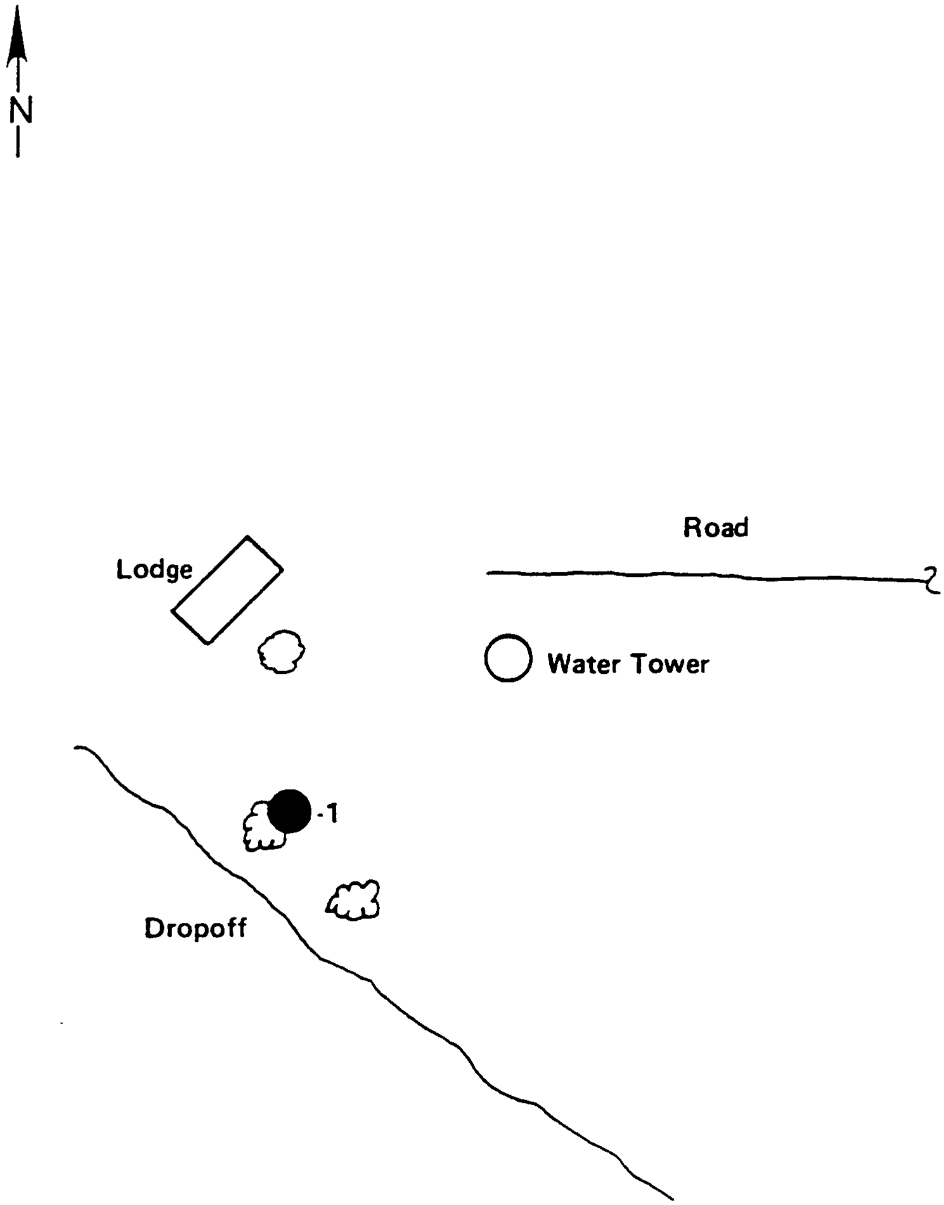


FIGURE D-5. MEASUREMENT POINT AT RED MAPLE LEAF COLLECTION SITE; 4S1-1.

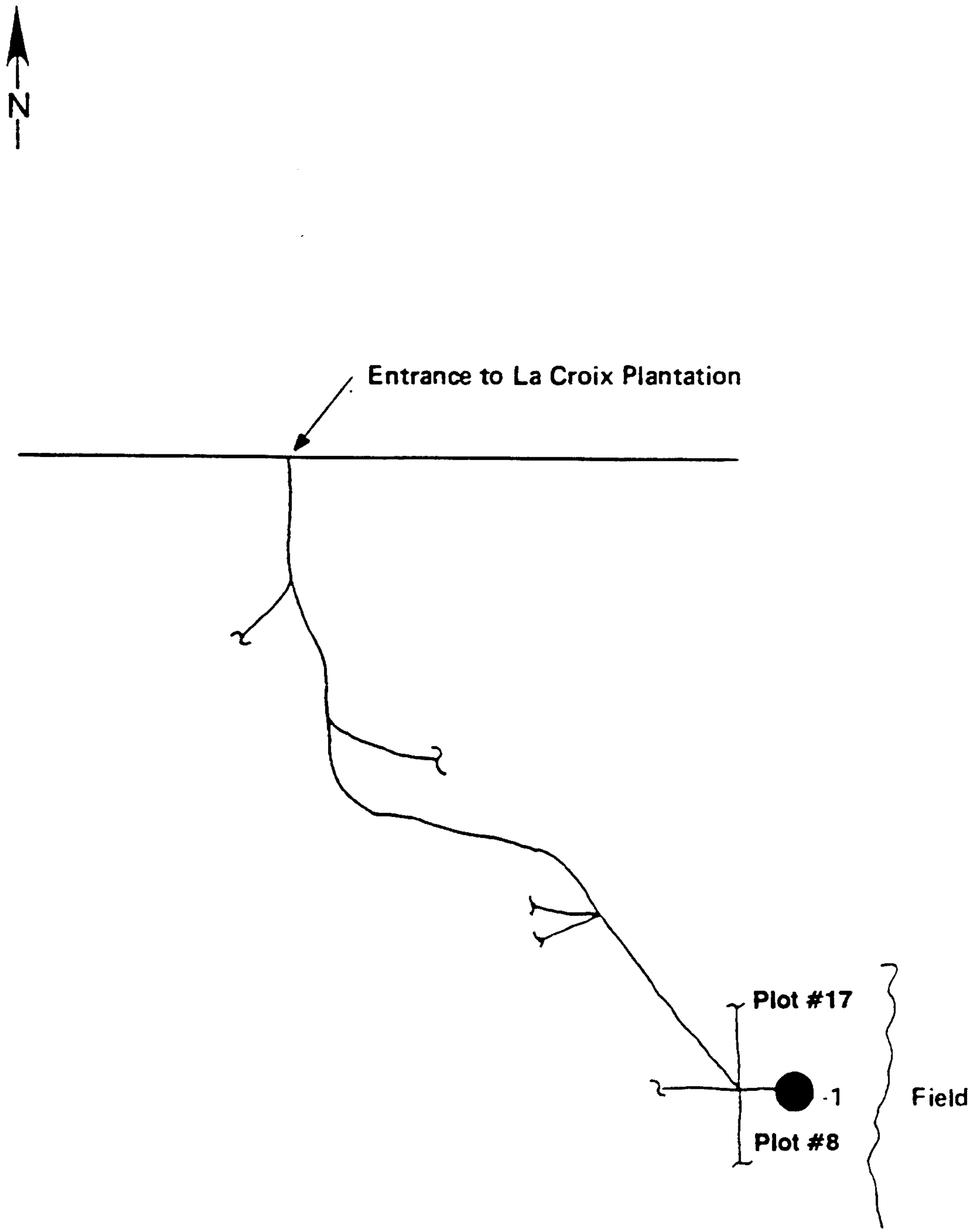


FIGURE D-6. MEASUREMENT POINT AT THE PINE NEEDLE COLLECTION SITE; 4S3-1.

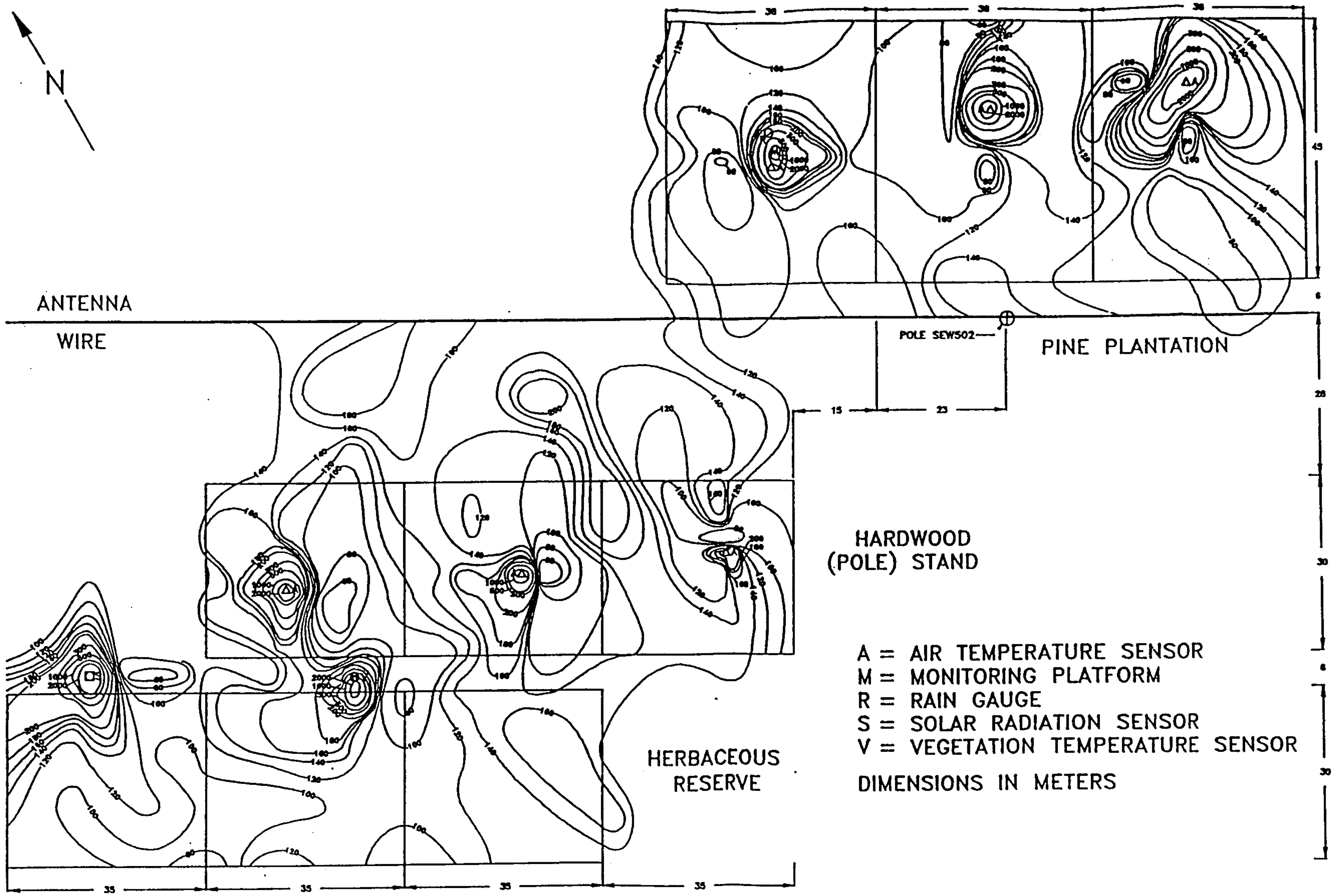
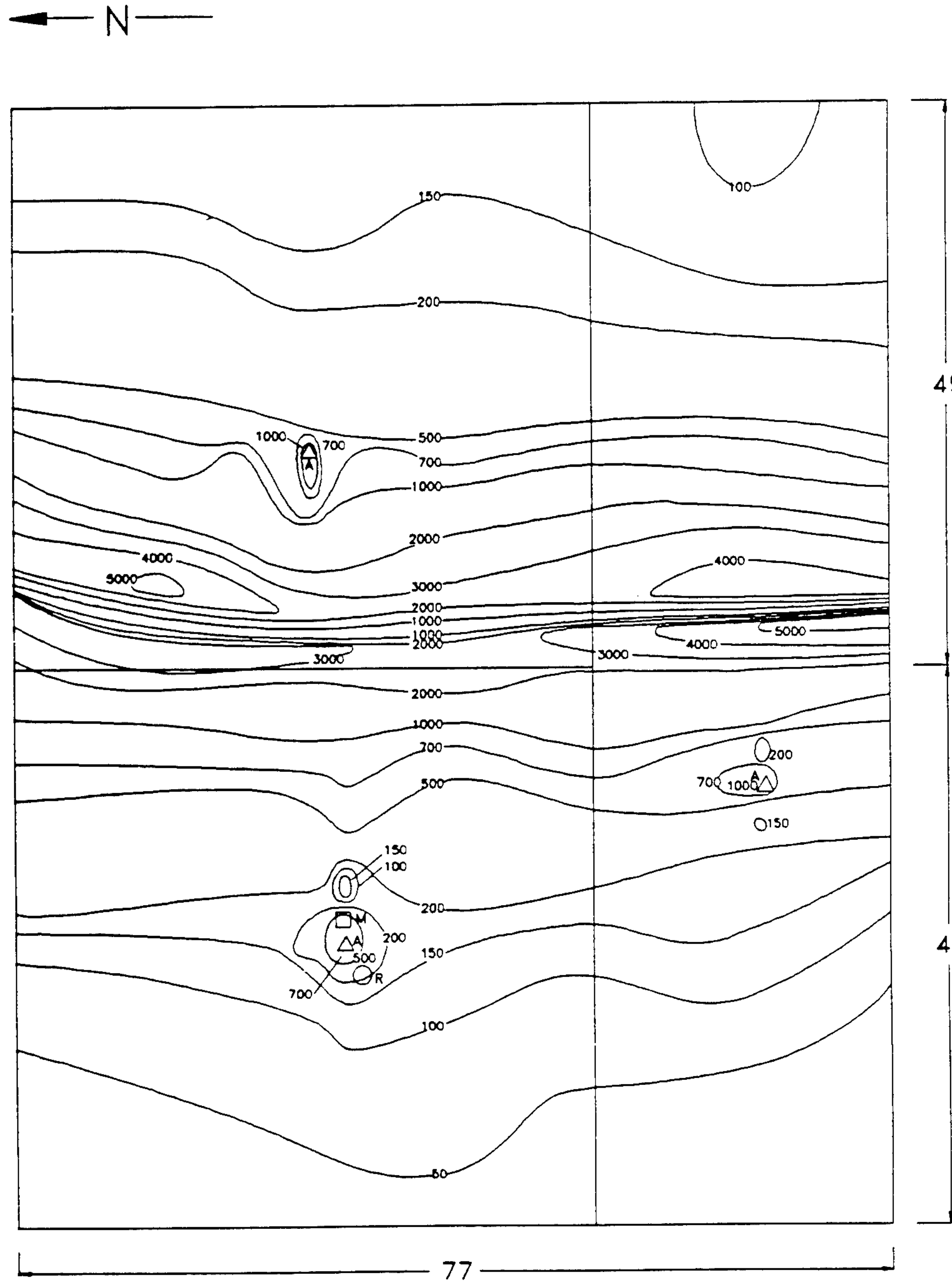


FIGURE D-7. EARTH ELECTRIC FIELD CONTOURS (mV/m), MARTELL'S LAKE (OVERHEAD): ML; JUNE 1990.



A=AIR TEMPERATURE SENSOR
R=RAIN GAUGE
M=MONITORING PLATFORM

DIMENSIONS IN METERS

FIGURE D-8. EARTH ELECTRIC FIELD CONTOURS (mV/m), MARTELL'S LAKE (BURIED): EP; JUNE 1990.

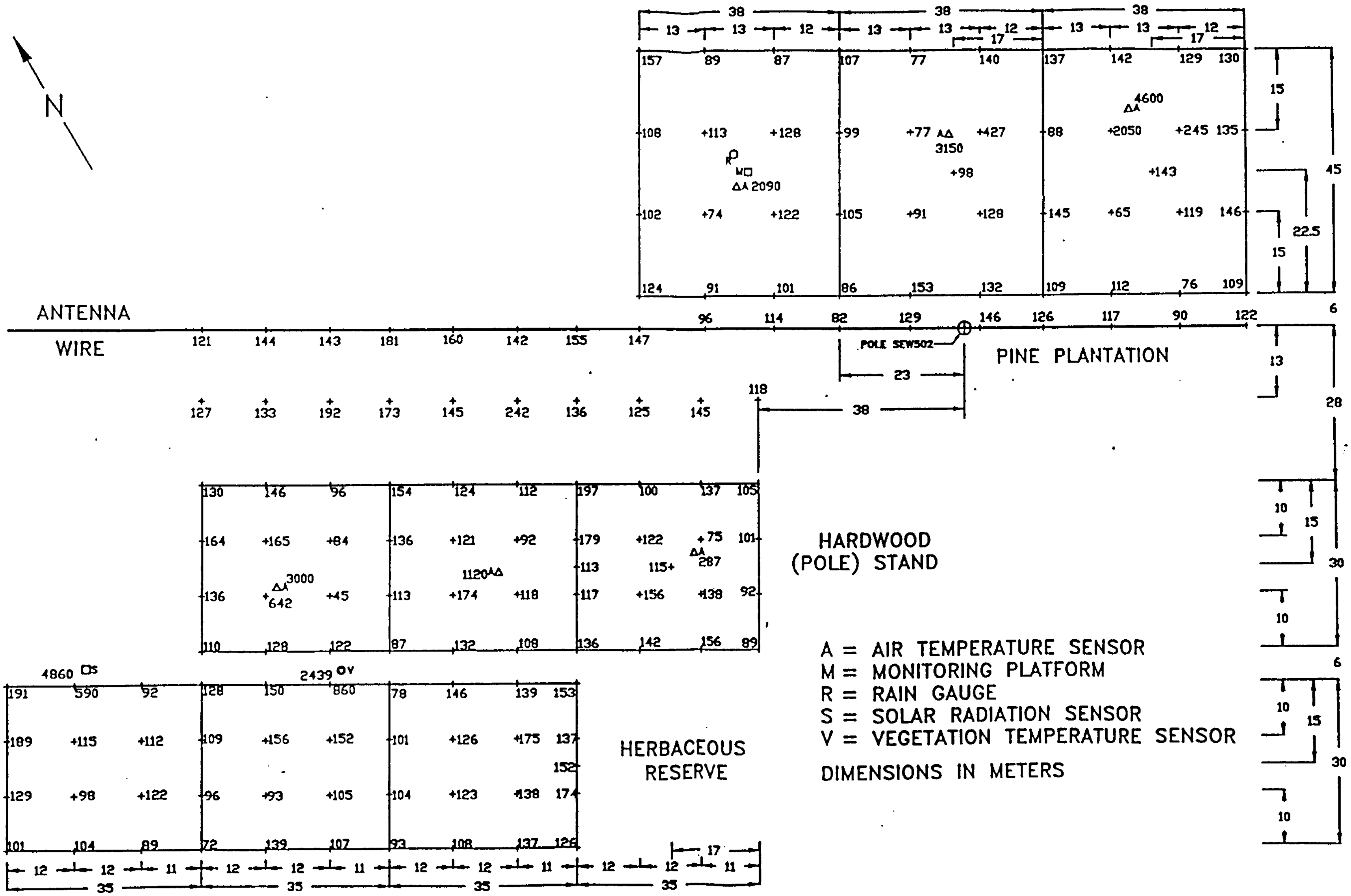
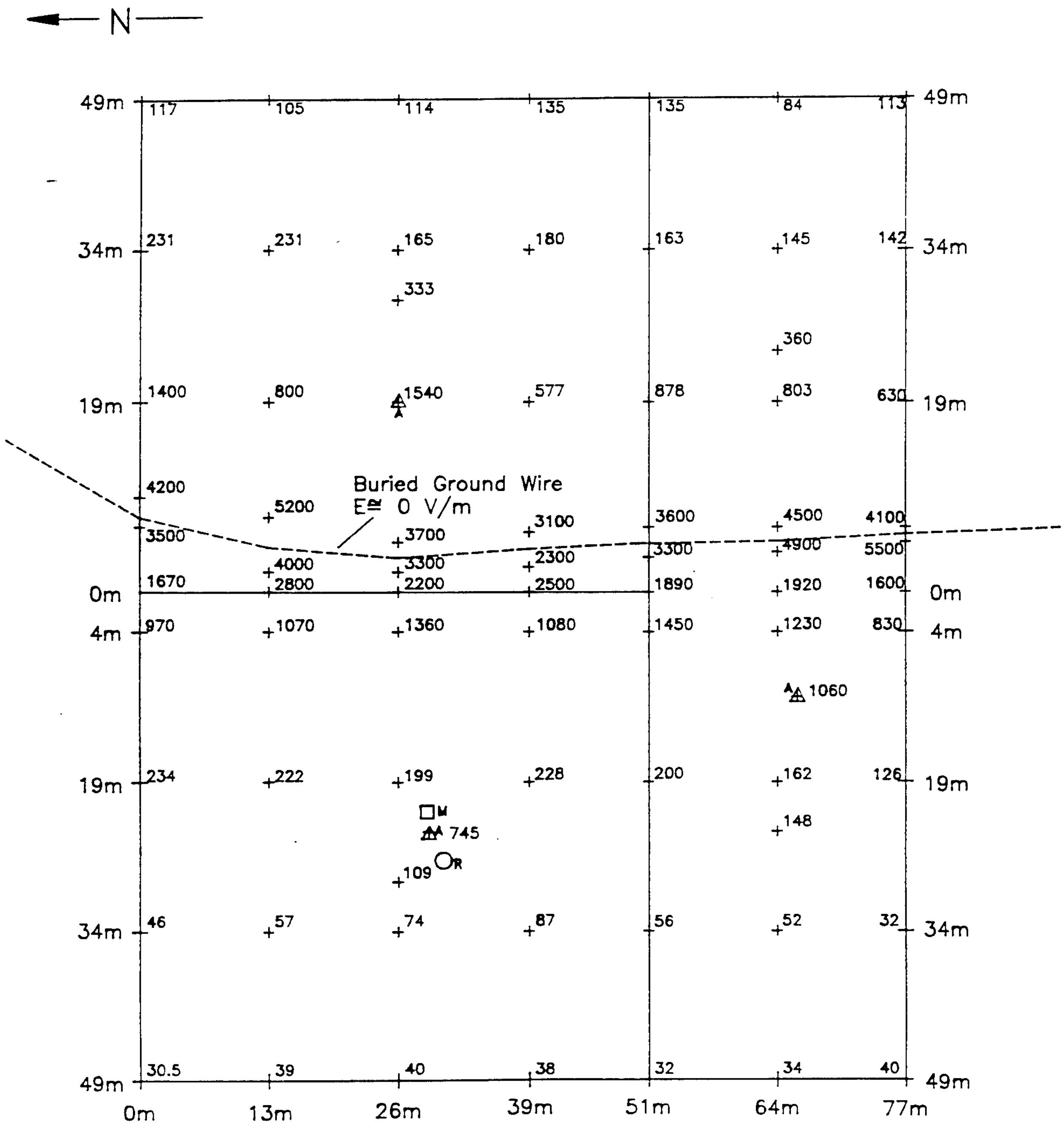


FIGURE D-9. EARTH ELECTRIC FIELD SURVEY (mV/m), MARTELL'S LAKE (OVERHEAD): ML; JUNE 1990.

IITRI D06209-1



A=AIR TEMPERATURE SENSOR
R=RAIN GAUGE
M=MONITORING PLATFORM

DIMENSIONS IN METERS

FIGURE D-10. EARTH ELECTRIC FIELD SURVEY (mV/m), MARTELL'S LAKE (BURIED): EP; JUNE 1990.

TABLE D-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Upland Flora and Soil Microflora Studies
(page 1 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989	1990	1991	1992	1993
4C1-6	-	0.003	<	<	<	<	<[d]	<[b]	<[d]	/	<[d]
4C1-7	-	0.006	<	<	<	<	<[d]	<[b]	<[d]	/	<[d]
4C1-8	-	0.004	<	<	<	<	<[d]	<[b]	<[d]	/	<[d]
4C1-9	-	0.002	<	<	<	<	<[d]	<[b]	<[d]	/	<[d]
4C1-10	-	-	<	<	<	<	<[d]	<[b]	<[d]	/	<[d]
4C1-11	-	-	<	<	<	<	<[d]	<[b]	<[d]	/	<[d]
4C1-12	-	-	<	<	<	<	<[d]	<[b]	<[d]	/	<[d]
4C1-13	-	-	<	<	<	<	<[d]	<[b]	<[d]	/	<[d]
4T2-3	-	0.001	<	<	<	/	#[d]	#[d]	/	<[b]	<[b]
4T2-4	-	-	<	<	<	/	#[d]	#[d]	/	<[b]	<[b]
4T2-5	-	-	<	<	<	/	#[d]	#[d]	/	<[b]	<[b]
4T2-6	-	-	<	<	<	/	#[d]	#[d]	/	<[b]	<[b]
4T2-7	-	-	<	<	<	/	#[d]	#[d]	/	<[b]	<[b]
4T2-8	-	-	<	<	<	/	#[d]	#[d]	/	<[b]	<[b]
4T2-9	-	-	<	<	<	<	#[d]	#[d]	/	<[b]	<[b]
4T2-10	-	-	<	<	<	<	#[d]	#[d]	/	<[b]	<[b]
4T2-11	-	-	<	<	<	<	#[d]	#[d]	/	<[b]	<[b]
4T2-12	-	-	<	<	<	/	#[d]	#[d]	/	<[b]	<[b]
4T2-13	-	-	<	<	<	/	#[d]	#[d]	/	<[b]	<[b]
4T2-14	-	-	<	<	<	/	#[d]	#[d]	/	/	<[b]
4T2-15	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4T2-16	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4T2-17	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4T2-18	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4T2-19	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4T2-26	-	-	-	-	-	-	-	#[d]	/	<[b]	<[b]
4T2-33	-	-	-	-	-	-	-	#[d]	/	<[b]	<[b]
4T2-34	-	-	-	-	-	-	-	#[d]	/	<[b]	<[b]
4T2-35	-	-	-	-	-	-	-	#[d]	/	<[b]	<[b]
4T2-36	-	-	-	-	-	-	-	#[d]	/	<[b]	<[b]

TABLE D-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Upland Flora and Soil Microflora Studies
(page 2 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989	1990	1991	1992	1993
4T4-4	-	0.003	<	<	<0.001	/	#[d]	#[d]	/	<[b]	<[b]
4T4-5	-	-	<	<	0.006	/	#[d]	#[d]	/	<[b]	<[b]
4T4-6	-	-	<	<	<	<	#[d]	#[d]	/	<[b]	<[b]
4T4-7	-	-	<	<	<	<	#[d]	#[d]	/	<[b]	<[b]
4T4-8	-	-	<	<	<	<	#[d]	#[d]	/	<[b]	<[b]
4T4-9	-	-	<	<	<	<	#[d]	#[d]	/	<[b]	<[b]
4T4-10	-	-	<	<	<	<	#[d]	#[d]	/	<[b]	<[b]
4T4-11	-	-	<	<	0.010	/	#[d]	#[d]	/	<[b]	<[b]
4T4-12	-	-	-	<	0.005	/	#[d]	#[d]	/	<[b]	<[b]
4T4-13	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4T4-14	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4T4-15	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4T4-16	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4T4-17	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4T4-18	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4T4-19	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4T4-20	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4S1-1	-	-	-	-	0.013	0.033	0.011[b]	0.017[b]	0.018[b]	0.007[b]	/
4S2-1	-	-	-	-	<	<	<[d]	<[b]	<[d]	<[d]	/
4S3-1	-	-	-	-	<0.001	<0.001	<0.001[b]	<0.001[b]	/	<[b]	/

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 ampere current.

- = measurement point not established.
/ = measurement not taken.
= measurement precluded by antenna operation.
< = measurement estimated <0.001 V/m based on earth electric field.

TABLE D-4. 60 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Studies
(page 1 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989	1990	1991	1992	1993
4C1-6	-	0.022	0.016	0.005	0.043	0.023	0.016[d]	0.024[b]	0.012[d]	1.51[d]	0.022[d]
4C1-7	-	0.143	0.123	0.077	0.178	0.118	0.030[d]	0.039[b]	0.043[d]	6.7[d]	0.064[d]
4C1-8	-	0.104	0.117	0.077	0.131	0.078	0.018[d]	0.063[b]	0.020[d]	6.1[d]	0.049[d]
4C1-9	-	0.011	0.019	0.024	0.034	0.032	0.023[d]	0.023[b]	0.018[d]	1.64[d]	0.022[d]
4C1-10	-	-	0.090	0.068	0.118	0.106	0.054[d]	0.041[b]	0.030[d]	7.5[d]	0.059[d]
4C1-11	-	-	0.160	0.107	0.132	0.146	0.066[d]	0.068[b]	0.048[d]	9.1[d]	0.077[d]
4C1-12	-	-	0.104	0.101	0.075	0.093	0.042[d]	0.042[b]	0.033[d]	4.2[d]	0.055[d]
4C1-13	-	-	0.040	0.030	0.046	0.065	0.025[d]	0.039[b]	0.014[d]	2.9[d]	0.026[d]
4T2-3	-	0.51	0.39	0.194	0.27	0.28	#[d]	#[d]	0.52[b]	0.20[b]	0.25[b]
4T2-4	-	-	0.27	0.24	0.30	0.25	#[d]	#[d]	0.59[b]	0.24[b]	0.199[b]
4T2-5	-	-	0.43	0.32	0.20	0.20	#[d]	#[d]	0.77[b]	0.25[b]	0.24[b]
4T2-6	-	-	0.66	0.46	0.192	0.22	#[d]	#[d]	0.84[b]	0.30[b]	0.31[b]
4T2-7	-	-	0.42	0.52	0.197	0.28	#[d]	#[d]	0.71[b]	0.22[b]	0.32[b]
4T2-8	-	-	0.47	0.190	0.22	/	#[d]	#[d]	0.79[b]	0.24[b]	0.28[b]
4T2-9	-	-	0.49	0.31	0.183	0.25	#[d]	#[d]	0.62[b]	0.23[b]	0.26[b]
4T2-10	-	-	0.44	0.32	0.155	0.166	#[d]	#[d]	0.71[b]	0.25[b]	0.33[b]
4T2-11	-	-	0.51	0.40	0.31	0.43	#[d]	#[d]	0.72[b]	0.34[b]	0.33[b]
4T2-12	-	-	0.47	0.38	0.24	/	#[d]	#[d]	0.73[b]	0.28[b]	0.35[b]
4T2-13	-	-	0.76	0.31	0.31	0.25	#[d]	#[d]	0.87[b]	0.27[b]	0.28[b]
4T2-14	-	-	0.61	0.29	0.35	0.21	#[d]	#[d]	0.78[b]	0.28[b]	0.29[b]
4T2-15	-	-	-	-	-	-	#[d]	#[d]	1.01[b]	0.35[b]	0.59[b]
4T2-16	-	-	-	-	-	-	#[d]	#[d]	0.66[b]	0.23[b]	0.30[b]
4T2-17	-	-	-	-	-	-	#[d]	#[d]	0.93[b]	0.173[b]	0.31[b]
4T2-18	-	-	-	-	-	-	#[d]	#[d]	0.73[b]	0.158[b]	0.29[b]
4T2-19	-	-	-	-	-	-	#[d]	#[d]	0.64[b]	0.25[b]	0.36[b]
4T2-26	-	-	-	-	-	-	-	#[d]	0.61[b]	0.26[b]	0.30[b]
4T2-33	-	-	-	-	-	-	-	#[d]	0.75[b]	0.27[b]	0.34[b]
4T2-34	-	-	-	-	-	-	-	#[d]	0.81[b]	0.28[b]	0.35[b]
4T2-35	-	-	-	-	-	-	-	#[d]	0.73[b]	0.26[b]	0.35[b]
4T2-36	-	-	-	-	-	-	-	#[d]	0.60[b]	0.30[b]	0.32[b]

TABLE D-4. 60 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Studies
(page 2 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989	1990	1991	1992	1993
4T4-4	-	0.72	0.42	0.185	0.56	0.079	#[d]	#[d]	0.40[b]	0.30[b]	0.32[b]
4T4-5	-	-	0.58	0.58	4.3	1.12	#[d]	#[d]	3.1[b]	3.2[b]	2.6[b]
4T4-6	-	-	0.22	0.16	0.61	0.188	#[d]	#[d]	0.35[b]	0.45[b]	0.37[b]
4T4-7	-	-	0.44	0.29	0.64	0.22	#[d]	#[d]	0.28[b]	0.32[b]	0.48[b]
4T4-8	-	-	0.42	0.193	0.40	0.23	#[d]	#[d]	0.27[b]	0.28[b]	0.30[b]
4T4-9	-	-	0.50	0.21	0.27	0.073	#[d]	#[d]	0.31[b]	0.36[b]	0.24[b]
4T4-10	-	-	0.42	0.22	0.29	0.063	#[d]	#[d]	0.23[b]	0.28[b]	0.30[b]
4T4-11	-	-	0.40	0.60	2.7	1.27	#[d]	#[d]	4.1[b]	3.8[b]	3.3[b]
4T4-12	-	-	-	0.75	3.4	1.35	#[d]	#[d]	0.34[b]	2.2[b]	1.78[b]
4T4-13	-	-	-	-	-	-	#[d]	#[d]	0.22[b]	0.26[b]	0.30[b]
4T4-14	-	-	-	-	-	-	#[d]	#[d]	0.53[b]	0.78[b]	0.38[b]
4T4-15	-	-	-	-	-	-	#[d]	#[d]	1.29[b]	1.86[b]	0.99[b]
4T4-16	-	-	-	-	-	-	#[d]	#[d]	4.4[b]	4.8[b]	4.4[b]
4T4-17	-	-	-	-	-	-	#[d]	#[d]	/	2.1[b]	/
4T4-18	-	-	-	-	-	-	#[d]	#[d]	4.6[b]	4.7[b]	4.7[b]
4T4-19	-	-	-	-	-	-	#[d]	#[d]	1.17[b]	1.02[b]	0.75[b]
4T4-20	-	-	-	-	-	-	#[d]	#[d]	0.27[b]	0.33[b]	0.33[b]
4S1-1	-	-	-	-	8.5	12.2	11.6[b]	15.7[b]	9.1[b]	3.3[b]	/
4S2-1	-	-	-	-	0.155	0.109	0.032[b]	0.068[b]	0.060[b]	7.2[b]	/
4S3-1	-	-	-	-	0.65	1.73	0.73[b]	0.87[b]	0.69[b]	0.43[b]	/

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 ampere current.

\- = measurement point not established.
/ = measurement not taken.
\# = measurement precluded by antenna operation.

TABLE D-5. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Upland Flora and Soil Microflora Studies
(page 1 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989	1990	1991	1992	1993
4C1-6	-	0.003	0.003	0.003	0.002	0.003	0.002[d]	0.002[b]	0.001[d]	0.28[d]	0.004d
4C1-7	-	0.003	0.002	0.001	0.003	0.002	0.001[d]	0.002[b]	0.001[d]	0.25[d]	0.001d
4C1-8	-	0.003	0.003	0.002	0.003	0.002	0.001[d]	0.002[b]	0.002[d]	0.24[d]	0.002d
4C1-9	-	0.003	0.003	0.002	0.001	0.002	0.002[d]	0.002[b]	0.001[d]	0.29[d]	0.004d
4C1-10	-	-	0.002	0.002	0.002	0.002	0.002[d]	0.002[b]	0.001[d]	0.22[d]	0.002d
4C1-11	-	-	0.002	0.002	0.002	0.002	0.001[d]	0.002[b]	0.001[d]	0.23[d]	0.002d
4C1-12	-	-	0.002	0.003	0.001	0.002	0.001[d]	0.002[b]	0.001[d]	0.26[d]	0.002d
4C1-13	-	-	0.002	0.003	0.001	0.003	0.002[d]	0.002[b]	0.001[d]	0.30[d]	0.003d
4T2-3	-	0.002	0.001	0.001	0.003	0.005	#[d]	#[d]	0.004[b]	0.002[b]	0.002b
4T2-4	-	-	0.001	0.001	0.003	0.006	#[d]	#[d]	0.005[b]	0.002[b]	0.003b
4T2-5	-	-	0.001	0.007	0.017	0.030	#[d]	#[d]	0.029[b]	0.004[b]	0.011b
4T2-6	-	-	0.001	0.006	0.006	0.014	#[d]	#[d]	0.017[b]	0.001[b]	0.005b
4T2-7	-	-	0.001	0.004	0.004	0.007	#[d]	#[d]	0.010[b]	0.001[b]	0.003b
4T2-8	-	-	0.001	0.002	0.004	/	#[d]	#[d]	0.010[b]	0.001[b]	0.002b
4T2-9	-	-	0.001	0.003	0.003	0.005	#[d]	#[d]	0.007[b]	0.001[b]	0.002b
4T2-10	-	-	0.001	0.003	0.003	0.005	#[d]	#[d]	0.007[b]	0.001[b]	0.002b
4T2-11	-	-	0.001	0.004	0.005	0.007	#[d]	#[d]	0.009[b]	0.002[b]	0.003b
4T2-12	-	-	0.002	0.004	0.005	/	#[d]	#[d]	0.010[b]	0.002[b]	0.003b
4T2-13	-	-	0.001	0.005	0.008	0.013	#[d]	#[d]	0.016[b]	0.002[b]	0.004b
4T2-14	-	-	0.002	0.011	0.018	0.029	#[d]	#[d]	0.035[b]	0.004[b]	0.011b
4T2-15	-	-	-	-	-	-	#[d]	#[d]	0.043[b]	0.005[b]	0.013b
4T2-16	-	-	-	-	-	-	#[d]	#[d]	0.033[b]	0.004[b]	0.011b
4T2-17	-	-	-	-	-	-	#[d]	#[d]	0.016[b]	0.003[b]	0.005b
4T2-18	-	-	-	-	-	-	#[d]	#[d]	0.009[b]	0.002[b]	0.003b
4T2-19	-	-	-	-	-	-	#[d]	#[d]	0.004[b]	0.002[b]	0.003b
4T2-26	-	-	-	-	-	-	-	#[d]	0.015[b]	0.001[b]	0.004b
4T2-33	-	-	-	-	-	-	-	#[d]	0.008[b]	0.001[b]	0.002b
4T2-34	-	-	-	-	-	-	-	#[d]	0.012[b]	0.001[b]	0.003b
4T2-35	-	-	-	-	-	-	-	#[d]	0.030[b]	0.001[b]	0.009b
4T2-36	-	-	-	-	-	-	-	#[d]	0.042[b]	0.003[b]	0.014b

TABLE D-5. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Upland Flora and Soil Microflora Studies
(page 2 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989	1990	1991	1992	1993
4T4-4	-	0.004	0.002	0.001	0.003	0.003	#[d]	#[d]	0.003[b]	0.002[b]	0.002b
4T4-5	-	-	0.002	0.006	0.010	0.017	#[d]	#[d]	0.008[b]	0.008[b]	0.008b
4T4-6	-	-	0.002	0.001	0.004	0.007	#[d]	#[d]	0.002[b]	0.003[b]	0.003b
4T4-7	-	-	0.001	0.001	0.004	0.005	#[d]	#[d]	0.002[b]	0.003[b]	0.002b
4T4-8	-	-	0.002	0.001	0.004	0.005	#[d]	#[d]	0.002[b]	0.003[b]	0.002b
4T4-9	-	-	0.002	0.001	0.002	0.003	#[d]	#[d]	0.001[b]	0.002[b]	0.002b
4T4-10	-	-	0.001	0.001	0.002	0.002	#[d]	#[d]	0.001[b]	0.002[b]	0.002b
4T4-11	-	-	0.002	0.002	0.002	0.019	#[d]	#[d]	0.008[b]	0.010[b]	0.011b
4T4-12	-	-	-	0.002	0.010	0.016	#[d]	#[d]	0.006[b]	0.008[b]	0.007b
4T4-13	-	-	-	-	-	-	#[d]	#[d]	0.001[b]	0.002[b]	0.003b
4T4-14	-	-	-	-	-	-	#[d]	#[d]	0.001[b]	0.003[b]	0.004b
4T4-15	-	-	-	-	-	-	#[d]	#[d]	0.003[b]	0.005[b]	0.007b
4T4-16	-	-	-	-	-	-	#[d]	#[d]	0.012[b]	0.015[b]	0.010b
4T4-17	-	-	-	-	-	-	#[d]	#[d]	0.013[b]	0.016[b]	0.009b
4T4-18	-	-	-	-	-	-	#[d]	#[d]	0.009[b]	0.011[b]	0.008b
4T4-19	-	-	-	-	-	-	#[d]	#[d]	0.003[b]	0.005[b]	0.004b
4T4-20	-	-	-	-	-	-	#[d]	#[d]	0.002[b]	0.004[b]	0.003b
4S1-1	-	-	-	-	0.035	0.043	0.052[b]	0.052[b]	0.032[b]	0.012[b]	/
4S2-1	-	-	-	-	0.003	0.002	0.002[d]	0.001[b]	0.001[d]	0.23[d]	/
4S3-1	-	-	-	-	0.036	0.095	0.028[b]	0.030[b]	0.035[b]	0.020[b]	/

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 ampere current.

\- = measurement point not established.
/ = measurement not taken.
= measurement precluded by antenna operation.

TABLE D-6. 76 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Upland Flora and Soil Microflora Studies
(page 1 of 2)

Site No.,	1986				1987		1988		1989	1990	1991		1992	1993
Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	NS 150 A	B 150 A	B 150 A	B 150 A
4C1-6	<	<	<	*	<	<	<	<	<	<	/	/	<	<
4C1-7	<	<	<	*	<	<	<	<	<	<	/	/	<	<
4C1-8	<	<	<	*	<	<	<	<	<	<	/	/	<	<
4C1-9	<	<	<	*	<	<	<	<	<	<	/	/	<	<
4C1-10	<	<	<	*	<	<	<	<	<	<	/	/	<	<
4C1-11	<	<	<	*	<	<	<	<	<	<	/	/	<	<
4C1-12	<	<	<	*	<	<	<	<	<	<	/	/	<	<
4C1-13	<	<	<	*	<	<	<	<	<	<	/	/	<	<
4T2-3	<	<	0.004	0.007	0.002	0.014	/	/	0.142	0.110	0.047	0.122	/	0.100
4T2-4	<	<	0.005	0.008	0.001	0.014	/	/	0.149	0.122	0.041	0.095	/	0.092
4T2-5	0.018	<	0.092	0.153	0.003	0.23	/	/	1.31	1.16	0.30	1.08	/	1.07
4T2-6	<	<	0.005	0.008	0.003	0.013	/	/	0.138	0.148	0.051	0.123	/	0.155
4T2-7	<	<	0.007	0.012	0.001	0.018	/	/	0.173	0.177	0.044	0.150	/	0.20
4T2-8	<	<	0.004	0.007	0.002	0.012	/	/	0.124	0.112	0.045	0.103	/	0.102
4T2-9	<	<	0.005	0.008	0.002	0.010	/	/	0.116	0.119	0.031	0.110	/	0.101
4T2-10	<	<	0.004	0.007	0.002	0.011	/	/	0.113	0.076	0.034	0.112	/	0.104
4T2-11	<	<	0.003	0.005	0.002	0.012	/	/	0.22	0.180	0.042	0.132	/	0.104
4T2-12	<	<	0.002	0.003	0.002	0.014	/	/	0.095	0.096	0.041	0.086	/	0.087
4T2-13	<	<	0.005	0.008	0.002	0.012	/	/	0.125	0.130	0.036	0.125	/	0.117
4T2-14	0.030	<	0.155	0.26	0.003	0.186	/	/	1.66	1.94	0.23	1.68	/	1.14
4T2-15	-	-	-	-	-	-	-	-	2.3	1.67	0.32	0.58	/	0.70
4T2-16	-	-	-	-	-	-	-	-	1.92	1.84	0.46	1.17	/	0.35
4T2-17	-	-	-	-	-	-	-	-	0.69	0.59	0.075	0.27	/	0.149
4T2-18	-	-	-	-	-	-	-	-	0.28	0.21	0.039	0.152	/	0.157
4T2-19	-	-	-	-	-	-	-	-	0.107	0.105	0.029	0.092	/	0.100
4T2-26	-	-	-	-	-	-	-	-	-	0.182	0.059	0.136	/	0.159
4T2-33	-	-	-	-	-	-	-	-	-	0.141	0.042	0.146	/	0.144
4T2-34	-	-	-	-	-	-	-	-	-	0.144	0.041	0.129	/	0.132
4T2-35	-	-	-	-	-	-	-	-	-	0.24	0.101	0.38	/	0.38
4T2-36	-	-	-	-	-	-	-	-	-	4.7	0.94	4.7	/	4.1

TABLE D-6. 76 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Upland Flora and Soil Microflora Studies
(page 2 of 2)

Site No., Meas. Pt.	1986 NS 4 A	1986 NEW 6 A	1986 SEW 6 A	1986 SEW 10 A, EX	1987 NS 15 A	1987 EW 15 A	1988 NS 75 A	1988 EW 75 A	1989 B 150 A	1990 B 150 A	1991 NS 150 A	1991 B 150 A	1992 B 150 A	1993 B 150 A
4T4-4	<	<	0.006	0.010	0.002	0.005	/	/	0.067	0.058	0.015	0.071	/	0.043
4T4-5	0.033	0.008	0.20	0.33	0.019	0.27	/	/	4.8	3.8	1.37	4.4	/	14.1
4T4-6	0.005	<	0.023	0.038	0.002	0.021	/	/	0.175	0.117	0.040	0.186	/	0.144
4T4-7	<	<	0.006	0.010	0.002	0.015	/	/	0.133	0.129	0.026	0.33	/	0.124
4T4-8	<	<	0.008	0.013	0.002	0.016	/	/	0.145	0.145	0.032	0.130	/	0.118
4T4-9	<	<	0.009	0.015	0.001	0.008	/	/	0.095	0.072	0.017	0.130	/	0.080
4T4-10	<	<	0.007	0.012	0.001	0.001	/	/	0.112	0.085	0.026	0.107	/	0.065
4T4-11	<	0.005	0.38	0.63	0.025	0.43	/	/	5.0	4.6	1.37	4.8	/	3.2
4T4-12	0.055	0.005	0.43	0.72	0.017	0.30	/	/	4.5	3.8	1.26	4.6	/	5.1
4T4-13	-	-	-	-	-	-	-	-	0.26	0.21	0.042	0.28	/	0.121
4T4-14	-	-	-	-	-	-	-	-	0.88	0.84	0.194	0.90	/	0.51
4T4-15	-	-	-	-	-	-	-	-	2.7	2.6	0.51	2.8	/	1.77
4T4-16	-	-	-	-	-	-	-	-	5.9	5.4	1.68	6.7	/	3.7
4T4-17	-	-	-	-	-	-	-	-	4.5	4.3	1.28	5.7	/	3.5
4T4-18	-	-	-	-	-	-	-	-	4.8	3.8	1.24	4.9	/	4.2
4T4-19	-	-	-	-	-	-	-	-	1.16	0.96	0.25	1.15	/	0.54
4T4-20	-	-	-	-	-	-	-	-	0.32	0.183	0.067	0.47	/	0.166
4S1-1	-	-	-	-	/	/	/	/	/	/	/	/	/	/
4S2-1	-	-	-	-	<	<	<	<	<	<	<	<	<	/
4S3-1	-	-	-	-	/	/	/	/	/	/	/	/	/	/

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

\- = measurement point not established.
/ = measurement not taken.
< = measurement estimated <0.001 V/m based on earth electric field.
* = data cannot be extrapolated.

TABLE D-7. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m) Upland Flora and Soil Microflora Studies (page 1 of 2)

Site No.,	1986				1987		1988		1989	1990	1991		1992	1993
Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	NS 150 A	B 150 A	B 150 A	B 150 A
4C1-6	<0.001	<0.001	<0.001	*	0.002	0.002	0.007	0.005	0.030	0.028	/	0.026	0.029	0.030
4C1-7	<0.001	<0.001	<0.001	*	0.005	0.006	0.024	0.023	0.091	0.085	/	0.079	0.096	0.096
4C1-8	<0.001	<0.001	<0.001	*	0.004	0.004	0.017	0.016	0.076	0.067	/	0.069	0.085	0.083
4C1-9	<0.001	<0.001	<0.001	*	0.002	0.002	0.007	0.006	0.030	0.022	/	0.028	0.021	0.029
4C1-10	<0.001	<0.001	<0.001	*	0.005	0.004	0.026	0.023	0.087	0.079	/	0.089	0.095	0.094
4C1-11	<0.001	<0.001	<0.001	*	0.006	0.005	0.028	0.028	0.113	0.103	/	0.101	0.108	0.104
4C1-12	<0.001	<0.001	<0.001	*	0.004	0.003	0.016	0.016	0.068	0.072	/	0.053	0.063	0.062
4C1-13	<0.001	<0.001	<0.001	*	0.002	0.002	0.012	0.011	0.051	0.044	/	0.037	0.047	0.045
4T2-3	1.31	0.22	6.3	10.5	1.36	15.2	7.7	76	131	140	22	126	142	127
4T2-4	1.05	0.22	5.0	8.3	1.70	10.7	6.2	68	135	129	44	134	151	113
4T2-5	1.18	0.24	5.3	8.8	1.46	12.7	8.2	62	86	105	41	123	142	130
4T2-6	1.11	0.27	4.4	7.3	2.2	12.4	10.4	56	105	101	39	114	112	98
4T2-7	1.13	0.23	5.3	8.8	1.31	9.7	8.8	71	90	89	28	94	89	71
4T2-8	1.32	0.25	5.7	9.5	1.81	15.8	/	/	141	135	40	139	133	107
4T2-9	1.17	0.21	5.1	8.5	1.46	13.7	7.1	63	119	125	40	121	133	114
4T2-10	0.97	0.22	4.1	6.8	1.84	10.5	8.1	50	96	91	35	98	101	87
4T2-11	1.14	0.21	5.0	8.3	2.2	10.7	9.6	122	182	170	38	155	178	88
4T2-12	1.06	0.21	4.3	7.2	1.93	13.5	/	/	99	114	45	119	113	117
4T2-13	1.12	0.64	5.4	9.0	1.74	14.9	8.2	71	138	144	36	142	145	151
4T2-14	1.07	0.175	5.1	8.5	1.66	14.3	6.6	56	124	121	42	138	133	122
4T2-15	-	-	-	-	-	-	-	-	73	82	32	82	87	72
4T2-16	-	-	-	-	-	-	-	-	88	86	33	92	103	71
4T2-17	-	-	-	-	-	-	-	-	104	105	29	107	106	91
4T2-18	-	-	-	-	-	-	-	-	95	99	29	124	108	91
4T2-19	-	-	-	-	-	-	-	-	107	107	31	103	111	85
4T2-26	-	-	-	-	-	-	-	-	-	210	57	189	220	163
4T2-33	-	-	-	-	-	-	-	-	-	113	41	130	126	128
4T2-34	-	-	-	-	-	-	-	-	-	152	36	127	140	100
4T2-35	-	-	-	-	-	-	-	-	-	136	45	137	169	142
4T2-36	-	-	-	-	-	-	-	-	-	155	44	133	125	120

TABLE D-7. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Studies
(page 2 of 2)

Site No., Meas. Pt.	1986 NS 4 A	1986 NEW 6 A	1986 SEW 6 A	1986 SEW 10 A, EX	1987 NS 15 A	1987 EW 15 A	1988 NS 75 A	1988 EW 75 A	1989 B 150 A	1990 B 150 A	1991 NS 150 A	1991 B 150 A	1992 B 150 A	1993 B 150 A
4T4-4	0.33	0.181	1.46	2.4	1.63	3.7	7.2	16.5	42	31	10.2	25	28	45
4T4-5	13.8	2.0	81	135	14.0	194	68	910	2100	1670	510	1790	1740	1450
4T4-6	1.22	0.22	6.2	10.3	2.2	12.9	10.3	62	140	117	29	141	152	132
4T4-7	0.94	0.175	5.5	9.2	2.0	14.1	9.1	62	119	135	30	101	153	161
4T4-8	0.91	0.188	5.3	8.8	1.36	10.7	6.8	65	106	113	31	111	113	108
4T4-9	0.29	0.130	1.32	2.2	1.08	3.0	7.5	18.1	47	42	4.5	18	21	39
4T4-10	0.29	0.169	1.63	2.7	1.35	3.9	5.1	16.0	39	43	8.1	30	29	38
4T4-11	0.59	1.82	89	148	10.7	178	50	850	1870	1890	630	2200	2100	1730
4T4-12	21	2.2	118	197	13.8	260	40	760	1950	1600	380	1380	1550	1070
4T4-13	-	-	-	-	-	-	-	-	64	56	15.2	59	66	52
4T4-14	-	-	-	-	-	-	-	-	220	200	59	320	290	210
4T4-15	-	-	-	-	-	-	-	-	760	760	220	820	880	720
4T4-16	-	-	-	-	-	-	-	-	3000	3800	690	3300	3000	2700
4T4-17	-	-	-	-	-	-	-	-	130	30	/	/	/	/
4T4-18	-	-	-	-	-	-	-	-	3200	3600	1000	4100	3400	2800
4T4-19	-	-	-	-	-	-	-	-	750	880	196	880	930	430
4T4-20	-	-	-	-	-	-	-	-	200	163	49	200	210	152
4S1-1	-	-	-	-	/	/	/	/	/	/	/	/	/	/
4S2-1	-	-	-	-	0.005	0.005	0.026	0.026	0.126	0.103	/	0.097	0.096	/
4S3-1	-	-	-	-	/	/	/	/	/	/	/	/	/	/

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

\- = measurement point not established.
/ = measurement not taken.
* = data cannot be extrapolated.

TABLE D-8. 76 Hz MAGNETIC FLUX DENSITIES (mG) Upland Flora and Soil Microflora Studies (page 1 of 2)

Site No., Meas. Pt.	1986 NS 4 A	1986 NEW 6 A	1986 SEW 6 A	1986 SEW 10 A, EX	1987 NS 15 A	1987 EW 15 A	1988 NS 75 A	1988 EW 75 A	1989 B 150 A	1990 B 150 A	1991 NS 150 A	1991 B 150 A	1992 B 150 A	1993 B 150 A
4C1-6	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	0.001	0.003	0.003	/	0.003	0.003	0.003
4C1-7	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	<0.001	0.002	0.002	/	0.002	0.002	0.002
4C1-8	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	<0.001	0.002	0.002	/	0.002	0.002	0.002
4C1-9	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	0.001	0.003	0.003	/	0.003	0.003	0.003
4C1-10	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	<0.001	0.002	0.002	/	0.002	0.002	0.002
4C1-11	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	<0.001	0.002	0.002	/	0.002	0.002	0.002
4C1-12	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	<0.001	0.002	0.002	/	0.002	0.002	0.002
4C1-13	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	0.001	0.003	0.003	/	0.003	0.003	0.003
4T2-3	0.047	0.001	0.22	0.37	0.008	0.55	0.040	2.8	5.7	5.9	1.69	5.5	5.7	5.6
4T2-4	0.049	0.001	0.24	0.40	0.008	0.57	0.041	2.9	5.8	5.9	1.74	5.7	6.0	5.6
4T2-5	0.197	<0.001	1.00	1.67	0.011	2.4	0.061	12.4	24	27	6.9	23	26	26
4T2-6	0.058	0.001	0.44	0.73	0.006	1.16	0.020	5.0	10.3	11	3.0	10.3	10.3	10.3
4T2-7	0.046	0.001	0.22	0.37	0.006	0.59	0.024	2.6	5.4	5.8	1.63	5.4	5.4	5.5
4T2-8	0.045	0.001	0.22	0.37	0.006	0.59	/	/	5.6	5.8	1.67	5.3	5.5	5.4
4T2-9	0.029	0.001	0.138	0.23	0.007	0.38	0.027	1.72	3.4	3.6	0.96	3.3	3.5	3.3
4T2-10	0.033	0.001	0.149	0.25	0.006	0.39	0.027	1.78	3.5	3.7	1.14	3.4	3.6	3.5
4T2-11	0.043	0.001	0.21	0.35	0.006	0.56	0.025	2.6	5.0	5.3	1.54	4.9	5.1	5.0
4T2-12	0.047	0.001	0.23	0.38	0.006	0.61	/	/	5.6	5.9	1.71	5.7	5.7	5.5
4T2-13	0.086	<0.001	0.43	0.72	0.005	1.14	0.020	5.1	10.1	10.8	3.1	10.4	10.5	10.2
4T2-14	0.21	<0.001	1.03	1.72	0.012	2.5	0.061	11.9	25	28	7.7	26	27	25
4T2-15	-	-	-	-	-	-	-	-	33	36	9.6	32	33	33
4T2-16	-	-	-	-	-	-	-	-	28	29	7.8	26	27	28
4T2-17	-	-	-	-	-	-	-	-	13.6	13.9	3.9	13.0	13.2	12.9
4T2-18	-	-	-	-	-	-	-	-	8.6	8.6	2.4	7.7	8.1	7.9
4T2-19	-	-	-	-	-	-	-	-	5.9	6.0	1.73	5.7	5.9	5.9
4T2-26	-	-	-	-	-	-	-	-	-	10.5	2.8	9.7	9.9	9.4
4T2-33	-	-	-	-	-	-	-	-	-	4.2	1.21	3.8	4.0	3.8
4T2-34	-	-	-	-	-	-	-	-	-	7.4	2.1	7.0	7.0	6.7
4T2-35	-	-	-	-	-	-	-	-	-	21	5.9	20	19.1	19.3
4T2-36	-	-	-	-	-	-	-	-	-	36	10.0	33	34	35

TABLE D-8. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Upland Flora and Soil Microflora Studies
(page 2 of 2)

Site No.,	1986				1987		1988		1989	1990	1991		1992	1993
Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	NS 150 A	B 150 A	B 150 A	B 150 A
4T4-4	0.019	<0.001	0.096	0.160	0.005	0.24	0.027	1.15	2.5	2.3	0.63	2.3	2.4	2.6
4T4-5	0.114	0.001	0.57	0.95	0.008	1.40	0.033	6.9	13.9	13.3	4.2	13.7	14.2	16.3
4T4-6	0.045	0.001	0.22	0.37	0.008	0.53	0.034	2.7	5.3	5.1	1.60	5.3	5.6	5.9
4T4-7	0.038	0.001	0.186	0.31	0.008	0.45	0.033	2.3	4.4	4.1	1.30	4.4	4.6	4.6
4T4-8	0.035	0.001	0.179	0.30	0.007	0.43	0.033	2.1	4.2	4.1	1.25	4.2	4.4	4.7
4T4-9	0.025	0.001	0.118	0.197	0.005	0.29	0.027	1.41	2.8	2.7	0.79	2.8	3.0	3.2
4T4-10	0.022	<0.001	0.116	0.193	0.005	0.27	0.027	1.33	2.7	2.6	0.75	2.8	2.8	3.2
4T4-11	0.161	0.001	0.80	1.33	0.011	1.89	0.042	8.9	18.7	19.1	5.9	18.3	19.1	23
4T4-12	0.115	0.001	0.58	0.97	0.010	1.37	0.041	7.1	14.5	13.4	4.4	14.0	14.7	18.2
4T4-13	-	-	-	-	-	-	-	-	2.7	3.8	1.12	4.0	4.1	4.5
4T4-14	-	-	-	-	-	-	-	-	7.0	7.0	2.0	7.4	7.0	8.1
4T4-15	-	-	-	-	-	-	-	-	11.9	12.0	3.4	11.5	12.1	13.2
4T4-16	-	-	-	-	-	-	-	-	18	14.6	5.2	14.7	15.8	20
4T4-17	-	-	-	-	-	-	-	-	14.3	13.6	4.3	13.8	14.9	18.7
4T4-18	-	-	-	-	-	-	-	-	16.8	15.7	5.0	15.8	16.3	19.6
4T4-19	-	-	-	-	-	-	-	-	9.8	9.1	2.8	9.7	10.3	10.9
4T4-20	-	-	-	-	-	-	-	-	5.9	5.4	1.76	5.9	6.0	6.3
4S1-1	-	-	-	-	/	/	/	/	/	/	/	/	/	/
4S2-1	-	-	-	-	<0.001	<0.001	0.001	<0.001	0.002	0.001	/	0.002	0.002	/
4S3-1	-	-	-	-	/	/	/	/	/	/	/	/	/	/

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

- = measurement point not established.
/ = measurement not taken.
* = data cannot be extrapolated.

TABLE D-9. 1993 PAIRED SITE EM FIELD INTENSITY RATIOS
Upland Flora and Soil Microflora Studies

Compared Sites	Air Electric Field				Earth Electric Field				Magnetic Flux Density			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
4T2PIN/4C1PIN	92	92	92	1.00	740	240	1110	3.1 - 16.4	1870	1870	1400	0.50 -11.0
4T4PIN/4C1PIN	43	43	43	1.00	400	126	590	3.8 - 210	870	1300	650	0.50 -11.0
4T2HDW/4C1HDW	87	87	87	1.00	1150	220	1290	5.1 - 13.5	1800	1830	1800	0.67 - 2.5
4T2HER/4C1HER	101	101	101	1.00	850	260	1140	3.4 - 5.8	1650	1650	1650	1.00 - 1.50

R1: T(76)/C(76)
R2: T(76)/T(60)
R3: T(76)/C(60)
R4: T(60)/C(60)

T(76) = ELF Communications System EM fields at the treatment site.
C(76) = ELF Communications System EM fields at the control site.
T(60) = ambient EM fields at the treatment site.
C(60) = ambient EM fields at the control site.

TABLE D-10. 1990 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Antenna Site Fixed Test Points
(page 1 of 2)

Test Point	Measurement Date												Summary Statistics		
	6/28	7/10	7/24	8/7	8/21	9/4	9/18	10/2	10/22	11/7	12/5	12/21	Mean	SD	Coeff. of Variab.
4T2-3	140	135	139	145	142	141	139	141	143	147	153	157	144	6.0	0.042
4T2-4	129	128	124	125	126	127	126	126	126	125	120	121	125	2.5	0.020
4T2-5	105	99	97	94	102	99	104	105	111	108	110	106	103	5.0	0.049
4T2-6	101	100	96	97	100	94	96	97	106	104	104	105	100	3.9	0.039
4T2-7	89	86	84	82	80	84	81	85	87	87	88	83	85	2.7	0.032
4T2-8	135	130	142	143	132	138	133	137	141	143	141	145	138	4.7	0.034
4T2-9	125	122	119	116	120	118	117	119	122	122	136	141	123	7.4	0.060
4T2-10	91	87	88	88	87	89	88	92	97	95	96	98	91	4.0	0.043
4T2-11	170	168	160	158	168	165	168	168	177	171	123	125	160	16.8	0.105
4T2-12	114	144	113	114	110	110	106	108	114	116	154	163	122	18.8	0.154
4T2-13	144	142	144	145	144	146	146	143	147	146	156	160	147	5.2	0.035
4T2-14	121	115	117	113	118	117	122	124	127	126	122	125	121	4.3	0.036
4T2-16	91	88	85	81	90	91	90	96	97	99	94	95	91	5.0	0.054
4T2-19	107	106	106	103	106	105	106	106	107	107	105	106	106	1.10	0.010
4T2-20	107	107	102	108	107	105	106	107	111	110	114	121	109	4.7	0.043
4T2-21	143	139	122	132	139	142	139	140	149	144	141	144	140	6.6	0.047
4T2-22	98	92	91	85	93	86	89	93	90	89	85	85	90	3.9	0.043
4T2-23	114	108	109	107	112	109	115	115	126	122	113	115	114	5.4	0.047
4T2-24	120	121	114	112	117	117	120	123	127	126	128	123	121	4.8	0.040
4T2-25	115		117	121	116	114	115	114	118	120	129	129	119	5.2	0.044
4T2-26	210	200	200	210	210	199	198	197	210	220	230	220	210	9.4	0.045
4T2-27	118	112	124	130	119	116	115	116	129	133	124	131	122	6.9	0.056
4T2-28	151	151	153	157	152	153	152	153	149	151	152	149	152	2.0	0.013
4T2-29	55	55	61	63	53	53	54	53	53	59	53	54	56	3.4	0.060
4T2-30	106	105	113	122	110	107	112	113	115	124	120	122	114	6.3	0.055
4T2-31	94	96	98	99	99	100	101	100	102	102	103	104	100	2.8	0.028
4T2-32	75	73	73	72	74	74	75	74	75	73	72	75	74	1.10	0.015

TABLE D-10. 1990 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Antenna Site Fixed Test Points
(page 2 of 2)

Test Point	Measurement Date												Summary Statistics		
	6/28	7/10	7/24	8/7	8/21	9/4	9/18	10/2	10/22	11/7	12/5	12/21	Mean	SD	Coeff. of Variab.
4T4-4	31	29	27	28	31	31	32	32	12	9	8.7	8.3	23	9.9	0.42
4T4-5	1670	1800	1830	1950	2100	2000	2000	1980	1720	1740	1980	1910	1900	134	0.071
4T4-6	117	115	115	125	136	138	141	143	148	140	142	140	133	11.4	0.086
4T4-7	135	132	130	132	137	135	137	139	144	146	145	149	138	6.0	0.043
4T4-8	113	108	105	106	109	105	108	109	112	113	109	111	109	2.7	0.025
4T4-9	42	42	42	43	42	43	43	44	18	20	20	22	35	10.7	0.31
4T4-10	32	30	30	30	30	29	32	33	35	37	37	37	33	3.0	0.090
4T4-11	1890	1940	2200	2300	2000	2100	2000	2000	2200	2200	2400	2500	2200	185	0.086
4T4-12	1600	1610	1700	1820	1850	1820	1900	1960	1820	1770	1820	1860	1790	104	0.058
4T4-21	109	107	91	97	122	127	131	134	146	135	132	136	122	16.5	0.135
4T4-22	148	137	139	148	153	154	159	169	177	174	170	165	158	12.8	0.081
4T4-23	330	340	330	350	380	370	390	400	410	380	370	390	370	25	0.069
4T4-24	360	360	340	340	390	380	410	430	430	420	420	420	390	32	0.081

Table D-11. 1991 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Antenna Site Fixed Test Points
(page 1 of 2)

Test Point	Measurement Date																	Summary Statistics*		
						NS Antenna Only														
	1/4	1/18	2/19	3/18	4/25	5/29	6/21	7/8	7/25	8/16	8/28	9/9	9/30	10/11	10/23	11/8	12/6	Mean	SD	Coeff. of Variab.
4T2-3	147	144	146	153	152	48	49	49	153	159	160	150	150	148	149	149	140	150	5.1	0.034
4T2-4	112	117	112	128	131	44	44	43	135	136	138	139	136	130	135	124	129	129	8.9	0.069
4T2-5	108	111	132	130	111	35	34	35	118	112	108	118	120	120	119	122	122	118	7.1	0.061
4T2-6	112	119	113	112	109	38	37	40	109	121	120	112	113	116	114	114	116	114	3.6	0.031
4T2-7	95	101	102	97	97	27	26	26	83	84	84	87	90	89	91	90	93	92	5.9	0.065
4T2-8	149	150	150	146	147	43	42					137	134	139	140	144	153	145	5.9	0.041
4T2-9	137	134	141	138	128	37	38						165	164	156		140	145	12.7	0.088
4T2-10	100	99	98	101	100	35	35	35	96	102	103	95	103	103	105	103	102	101	2.8	0.028
4T2-11	139	131	136	128	167	50	41	55	173	144	106	167	166	165	162	172	119	148	21	0.143
4T2-12	161	162	165	151	132	39	45	39	124	131	132	129	120	123	124	136	160	139	16.1	0.115
4T2-13	180	169	167	149	139	41	43	41	150	149	146	148	147	149	150	149	149	153	10.6	0.070
4T2-14	113	121	119	126	131	39	39	39	128	128	133	127	133	130	135	123	128	127	5.8	0.046
4T2-15										58	60	65	66	64	65	63	59	63	2.9	0.046
4T2-16	81	85	87	100	101	33	34					108	118	114	120		100	101	13.1	0.129
4T2-17										99	92	111	109	111	111	111	100	106	7.0	0.066
4T2-18										118	116	112	108	110	110	110	103	111	4.3	0.039
4T2-19	98	103	99	106	104	33	33					107	116	101	108	124	103	106	7.3	0.069
4T2-20	129	122	123	121	117	39	39	38	116	113	114	112	112	114	114	113	106	116	5.6	0.048
4T2-21	141	128	135	140	145	57	52	54	144	135	82	140	131	130	127	132	120	131	15.1	0.116
4T2-22	86	89	94	91	109	43	40	43	98	86	86	99	104	94	97	88	94	94	6.7	0.072
4T2-23	106	107	108	120	117	40	35	39	116	116	114	129	129	127	129	123	107	118	8.4	0.071
4T2-24	121	130	132	133	133	37	36	36	122	115	120	124	124	125	126	118	124	125	5.4	0.043
4T2-25	138	135	132	125	107	28	15	4.5	88	69	76	57	61	65	63	124	103	96	30	0.31
4T2-26	250	240	230	220	230	67	62			200	192	220	210	210	210	240	240	220	15.8	0.071
4T2-27	149	146	146	134	138	37	30	37	129	135	131	122	126	132	130	155	130	136	9.2	0.068
4T2-28	178	168	164	154	153	52	55	54	162	167	155	156	153	157	153	153	150	159	7.6	0.048
4T2-29	70	70	78	73	72	15	14	15	64	66	66	54	54	58	56	64	58	65	7.3	0.114
4T2-30	130	129	131	124	128	40	38	40	116	125	67	107	114	121	120	132	120	119	16.0	0.134
4T2-31	103	104	105	104	98	37	39	38	106	97	91	108	108	107	109	103	100	103	4.9	0.047
4T2-32	58	63	61	77	80	28	28	28	76	74	74	82	79	77	80	76	84	74	7.7	0.104
4T2-33										114	138	116	116	114	117	126	122	120	7.7	0.064
4T2-34										97	100	118	110	111	112	114	119	110	7.4	0.067
4T2-35											162	155	155	161	158	179	163	162	7.6	0.047
4T2-36											128	142	140	136	135	136	142	137	4.6	0.033

Table D-11. 1991 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m) Upland Flora and Soil Microflora Antenna Site Fixed Test Points (page 2 of 2)

Test	Measurement Date																	Summary Statistics*		
						NS Antenna Only														Coeff. of
Point	1/4	1/18	2/19	3/18	4/25	5/29	6/21	7/8	7/25	8/16	8/28	9/9	9/30	10/11	10/23	11/8	12/6	Mean	SD	Variab.
4T4-4	6.8	7.1	8.3	10.3	9.2	10.6	9.9	10.4	11.1	11.3	11.5	12.8	12.6	12	13	12	11	10.6	2.0	0.185
4T4-5	2100	2100	2200	2200	1850	480	480	410	1780	1780	1850	1910	1900	1900	1850	1460	1580	1890	210	0.109
4T4-6	131	131	135	135	100	32	29	30	123	125	133	140	141	143	141	132	110	130	11.8	0.091
4T4-7	136	147	135	155	134	37	36										145	142	7.7	0.054
4T4-8	108	112	109	115	108	30	29	29	110	102	102	105	105	108	108	112	110	108	3.6	0.033
4T4-9	25	25	27	26	22	8.0	7.1	7.8	18.2	17.9	18.5	17.9	18.6	19	19	16	19	21	3.5	0.168
4T4-10	37	36	33	27	30	9.4	8.6	9.0	32	31	24	32	33	34	34	36	30	32	3.5	0.109
4T4-11	2600	2800	3200	2900	2400	550	550	480	2000	2200	2400	2100	2100	2100	2200	1790	2000	2300	390	0.167
4T4-12	2500	2300	2600	2700	1890	470	450	380	1550	1520	1580	1700	1800	1900	1830	1400	1520	1910	420	0.22
4T4-13													76	79				78	1.5	0.019
4T4-14												260	220	230	230	200	270	310	128	0.42
4T4-15										640	850	790	790	790	800	710	750	760	60	0.079
4T4-16										3500	3600	3100	3100	3200	3300	3400	3600	3300	194	0.058
4T4-18										4100	4400	4100	4200	4400	4400	4500	5000	4400	270	0.062
4T4-19												750	780	820	840	710	700	770	55	0.072
4T4-20																	220	220	0.0	0.0
4T4-21	128	123	120	149	92	39	34	33	113	89	100	124	130	128	130	111	98	117	16.5	0.141
4T4-22	154	148	143	161	123	52	44	46	133	149	152	156	152	157	160	151	129	148	11.2	0.076
4T4-23	390	380	400	390	310	91	88	83	340	370	390	400	390	400	400	340	320	370	30	0.081
4T4-24	450	440	450	470	350	115	104	100	370	350	360	410	430	430	430	310	370	400	49	0.121

*Summary statistics exclude data measured during solo operation of the NS antenna.

Table D-12. 1992 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m) Upland Flora and Soil Microflora Antenna Site Fixed Test Points (page 1 of 2)

Test Point	Measurement Date: NS Antenna Only															Summary Statistics*		
	1/3	2/5	3/4	4/1	4/27	5/29	7/8	7/22	8/5	8/19	9/2	9/16	10/5	10/14	11/9	12/7	Mean	SD	Coeff. of Variab.
4T2-3	45	40	40	132	153	162	156	155	156	149	148	142	154	150	136	130	148	9.6	0.065
4T2-4	41	40	43	126	137	142	137	142	141	141	150	155	148	150	127	122	140	9.6	0.069
4T2-5	35	32	34	123	126	129	133	137	130	138	137	136	139	140	133	123	133	5.7	0.043
4T2-6	39	38	40	115	117	112	116	112	114	111	110	109	114	112	102	103	111	4.4	0.039
4T2-7	29	28	31	100	95	90	90	88	85	86	84	86	87	88	85	80	88	4.9	0.055
4T2-8	45	47	49	146	151	150	146	144	155	146	145	143	153	150	141	141	147	4.3	0.029
4T2-9	42	45	45	144	139	135	134	138	135	135	135	133	140	137	132	139	137	3.2	0.023
4T2-10	38	36	38	108	111	103	103	100	94	92	91	93	97	95	80	82	96	8.7	0.091
4T2-11	36	35	35	113	152	157	175	180	173	180	174	179	182	180	110	107	159	28	0.177
4T2-12	52	53	52	157	127	122	121	119	124	121	123	115	125	123	142	144	128	11.6	0.091
4T2-13	41	42	43	149	148	149	148	134	155	152	155	151	151	148	146	144	148	5.2	0.035
4T2-14	38	39	40	133	129	135	139	137	137	132	132	131	133	132	124	120	132	5.0	0.038
4T2-15	26	27	28	65	67	65	69	70	68	69	69	70	71	69	59	56	67	4.3	0.065
4T2-16	34	34	35	109	105	104	104	101	102	107	108	112	109	111	96	86	104	6.7	0.065
4T2-17	31	28	28	100	106	106	108	111	110	109	110	108	113	112	103	95	107	4.9	0.046
4T2-18	30	29	32	112	106	110	107	108	110	105	106	103	105	103	96	99	105	4.3	0.041
4T2-19	33	33	32	107	107	105	107	108	99	107	108	111	109	107	101	97	106	3.9	0.037
4T2-20	37	42	43	104	114	123	117	119	120	115	116	114	119	119	106	115	115	5.1	0.045
4T2-21	45	48	50	128	124	118	131	133	127	136	134	139	136	138	111	108	128	9.7	0.076
4T2-22	37	39	40	94	95	98	103	104	93	100	98	103	99	97	78	72	95	9.2	0.097
4T2-23	35	33	37	118	123	126	126	135	126	134	130	136	131	133	111	98	125	10.4	0.083
4T2-24	36	36	39	127	140	135	128	128	124	124	124	126	129	128	121	115	127	5.9	0.046
4T2-25	20	40	39	129	125	126	126	125	127	125	124	120	129	124	120	122	125	2.7	0.022
4T2-26	73	78	80	230	240	240	230	230	230	220	220	210	230	220	200	210	220	11.5	0.051
4T2-27	38	42	41	130	153	148	141	140	147	139	133	132	150	145	117	125	138	10.2	0.073
4T2-28	54	54	54	150	144	128	136	135	153	142	143	140	157	146	124	130	141	9.4	0.067
4T2-29	17.2	19.2	19.1	61	73	75	67	66	72	62	61	58	63	60	45	61	63	7.4	0.117
4T2-30	44	47	47	125	142	140	131	128	139	126	126	123	136	130	105	113	128	10.1	0.079
4T2-31	37	37	38	104	105	104	105	107	105	103	105	103	105	104	88	87	102	6.2	0.061
4T2-32	30	30	30	89	84	76	77	79	73	74	78	82	77	79	71	69	78	5.2	0.067
4T2-33	44	45	45	118	119	119	112	110	109	110	109	108	112	112	97	98	110	6.5	0.059
4T2-34	42	46	48	131	130	122	117	118	115	114	115	115	120	118	101	102	117	8.3	0.071
4T2-35	55	54	54	156	163	165	163	167	164	164	164	158	171	164	146	140	160	8.3	0.052
4T2-36	48	50	52	150	145	141	136	139	137	135	136	140	137	136	121	120	136	7.9	0.058

Table D-12. 1992 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Antenna Site Fixed Test Points
(page 2 of 2)

	Measurement Date																Summary Statistics*		
	NS Antenna Only																		
Test Point	1/3	2/5	3/4	4/1	4/27	5/29	7/8	7/22	8/5	8/19	9/2	9/16	10/5	10/14	11/9	12/7	Mean	SD	Coeff. of Variab.
4T4-4	9.2	8.4	9.1	10	11	11	12	12.4	11.4	12	12	13	13	12	36	35	15.4	8.6	0.56
4T4-5	500	550	580	2000	1980	1900	1870	1810	1830	1700	1730	1730	1620	1580	1340	1350	1730	200	0.117
4T4-6	29	31	36	129	98	115	133	136	136	140	144	145	150	146	139	108	132	15.2	0.115
4T4-7	31	33	64	130	119	126	139	141	134	135	136	138	139	139	143	124	134	7.0	0.052
4T4-8	28	28	27	115	109	113	117	117	115	113	113	113	115	114	119	113	114	2.4	0.021
4T4-9	7.3	8.1	8.4	19	23	21	15.9	16	17.2	16	16.5	15.7	15.1	16.2	61	65	24	16.6	0.68
4T4-10	8.7	9.2	10.4	33	25	26	31	32	30	30	31	31	33	33	19.4	16.1	29	5.2	0.182
4T4-11	670	720	770	2600	2500	2300	2200	2000	2200	2000	2000	2000	2100	2000	1710	1880	2100	230	0.111
4T4-12	520	580	620	2100	1870	1900	1710	1670	1720	1660	1670	1700	1690	1630	1290	1400	1690	195	0.115
4T4-13	25	19	168	54	30	42	58	59	55	59	60	64	64	63	39	31	52	11.8	0.23
4T4-14	85	94	101	380	230	290	320	320	330	310	330	330	330	320	240	200	300	48	0.159
4T4-15	230	280	300	980	770	820	870	840	840	810	830	850	850	830	660	650	820	82	0.101
4T4-16	1170	1260	1220	4200	4200	3600	3200	3100	3900	3100	3200	3000	3000	3000	2700	3500	3400	460	0.138
4T4-18	1590	1890	1890	5100	5000	4500	3800	3700	4500	3600	3700	3600	3700	3700	3300	4300	4000	550	0.137
4T4-19	210	220	22	880	780	850	860	820	790	790	790	820	830	810	700	610	790	68	0.086
4T4-20	50	48	94	178	160	194	230	230	230	230	240	240	240	240	220	167	220	29	0.132
4T4-21	31	34	37	124	83	108	130	131	112	124	126	135	134	134	90	60	115	23	0.197
4T4-22	41	44	51	163	101	140	168	160	145	150	148	148	158	154	108	76	140	26	0.189
4T4-23	86	95	102	380	310	370	410	400	400	400	400	410	420	400	360	310	380	35	0.091
4T4-24	106	119	134	450	340	400	430	430	400	420	420	440	430	420	360	310	400	40	0.100

*Summary statistics exclude data measured during solo operation of the NS antenna.

**Table D-13. 1993 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Antenna Site Fixed Test Points
(page 1 of 2)**

Test Point	Measurement Date 1/13	2/15	3/24	4/23	5/10	5/26	6/9	6/21	7/7	7/19	8/2	8/16	9/1	9/13	9/27	11/10	Summary Statistics* Mean	SD	Coeff. of Variab.
4T2-3	116	108	101	128	136	138	135	135	134	137	132	129	128	127	130	130	128	10.2	0.080
4T2-4	122	120	128	119	123	126	124	123	129	128	114	129	124	128	118	119	123	4.4	0.036
4T2-5	116	114	111	127	130	131	132	135	130	128	120	125	121	123	130	133	125	7.0	0.056
4T2-6	106	102	106	104	103	100	99	102	99	102	103	100	95	96	100	98	101	3.1	0.031
4T2-7	89	93	106	91	86	85	85	85	83	83	79	82	82	83	83	86	86	6.1	0.071
4T2-8	135	88	139	136	136	139	134	134	133	137	140	134	133	133	137	138	133	11.8	0.089
4T2-9	136	145	145	132	132	127	127	131	131	133	117	134	135	134	133	130	133	6.4	0.048
4T2-10	82	82	87	81	82	83	83	85	82	83	80	82	82	83	83	86	83	1.73	0.021
4T2-11	103	104	106	102	101	104	102	106	105	105	104	106	105	104	109	108	105	2.1	0.020
4T2-12	143	149	148	140	140	134	131	131	135	137	131	136	135	130	138	144	138	5.8	0.042
4T2-13	139	146	151	142	150	150	151	154	158	158	153	162	160	162	160	154	153	6.6	0.043
4T2-14	127	132	131	116	121	122	124	123	125	128	123	126	121	128	125	126	125	3.9	0.031
4T2-15	56	60	58	60	56	56	56	58	56	58	53	58	56	58	57	58	57	1.69	0.030
4T2-16	90	87	88	86	91	92	96	89	93	89	82	92	92	94	91	93	90	3.3	0.037
4T2-17	90	84	83	99	96	98	93	95	94	98	100	101	101	102	101	103	96	5.9	0.061
4T2-18	101	98	109	89	97	99	95	95	102	108	109	109	109	107	104	98	102	6.1	0.060
4T2-19	106	104	103	94	94	96	96	97	97	95	92	95	94	96	96	100	97	3.9	0.040
4T2-20	130	115	117	106	110	110	109	109	108	108	103	105	106	108	106	104	110	6.3	0.057
4T2-21	108	112	106	111	112	111	111	112	106	105	93	102	98	98	97	103	105	6.0	0.057
4T2-22	70	69	72	84	86	83	84	85	78	72	57	71	64	68	69	74	74	8.2	0.111
4T2-23	99	97	95	103	102	105	102	101	98	101	98	102	97	97	101	103	100	2.7	0.027
4T2-24	111	112	131	121	130	130	131	132	130	125	120	124	122	123	125	124	124	6.2	0.050
4T2-25	126	131	132	125	121	122	152	141	135	142	143	150	176	186	162	140	143	18.2	0.127
4T2-26	213	220	240	210	200	199	198	199	199	199	200	194	197	188	200	200	204	11.9	0.058
4T2-27	130	131	144	109	108	110	90	89	89	99	107	90	99	89	99	109	106	16.2	0.153
4T2-28	132	129	136	127	128	128	129	132	135	140	138	140	137	139	144	134	134	5.0	0.037
4T2-29	65	68	74	57	56	55	54	49	56	62	65	56	57	55	54	48	58	6.7	0.116
4T2-30	118	119	123	102	100	102	169	172	173	170	170	166	169	165	169	170	147	29	0.197
4T2-31	88	92	96	88	86	87	88	89	88	89	84	92	90	88	88	90	89	2.7	0.030
4T2-32	67	77	75	77	77	73	75	75	70	69	63	69	67	69	65	68	71	4.4	0.062
4T2-33	99	103	109	96	98	97	96	96	92	92	87	87	93	93	95	100	96	5.4	0.056
4T2-34	106	116	143	104	105	106	103	102	96	97	96	97	102	101	100	106	105	11.0	0.105
4T2-35	137	133	127	138	141	143	139	140	139	138	129	138	137	139	143	141	138	4.3	0.031
4T2-36	124	139	168	127	128	128	126	124	122	123	120	129	127	127	120	119	128	11.3	0.088

Table D-13. 1993 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Antenna Site Fixed Test Points
(page 2 of 2)

Test Point	Measurement Date																Summary Statistics*		
	1/13	2/15	3/24	4/23	5/10	5/26	6/9	6/21	7/7	7/19	8/2	8/16	9/1	9/13	9/27	11/10	Mean	SD	Coeff. of Variab.
4T4-4	37	38	38	34	35	35	36	36	35	35	37	38	38	38	36	36	36	1.32	0.037
4T4-5	1630	1800	1950	1640	1480	1550	1430	1470	1450	1510	1570	1650	1630	1700	1430	1410	1580	144	0.091
4T4-6	107	109	117	111	101	110	111	116	109	114	122	134	136	130	138	137	119	11.8	0.099
4T4-7	133	130	148	129	127	123	129	132	128	132	130	134	137	136	136	138	133	5.6	0.042
4T4-8	114	112	111	119	115	118	119	122	120	125	120	120	114	116	116	120	118	3.7	0.031
4T4-9	73	80	77	60	63	64	62	62	62	86	72	69	69	67	67	66	67	5.5	0.082
4T4-10	17	16.3	19.2	16.8	15.3	14.6	14.4	15.1	14.7	14.1	16.8	14.9	14.4	15.2	17.4	19	16.0	1.56	0.098
4T4-11	2000	2300	2500	1990	1910	1920	1770	1750	1760	1890	2200	2000	2000	2000	1900	1860	1980	195	0.098
4T4-12	1610	1730	2100	1500	1410	1540	1370	1390	1290	1310	1450	1390	1420	1500	1440	1360	1490	192	0.129
4T4-13	38	40	41	35	31	31	32	32	32	34	31	38	39	40	38	41	36	3.8	0.106
4T4-14	230	250	220	210	180	198	200	210	210	220	240	260	250	270	250	240	230	25	0.109
4T4-15	820	970	1000	710	650	720	660	690	650	680	720	700	700	700	710	680	740	102	0.138
4T4-16	3800	3900	4800	3200	3000	2900	2600	2500	2700	3000	3700	3000	3200	3200	2800	2900	3200	570	0.178
4T4-18	4700	5900	7000	3800	3600	3500	3200	3000	3300	3400	4300	3400	3500	3500	3100	3500	3900	1060	0.270
4T4-19	660	710	740	710	640	700	670	690	660	660	650	650	640	630	680	690	670	30	0.045
4T4-20	160	156	172	170	160	169	169	176	171	181	183	198	196	210	210	210	181	18.0	0.099
4T4-21	68	72	87	74	58	69	70	75	67	68	60	78	80	83	85	85	74	8.5	0.115
4T4-22	91	105	110	91	75	84	79	90	85	/	93	97	99	106	113	113	95	11.7	0.123
4T4-23	330	350	340	341	310	340	340	340	340	350	390	400	400	400	400	370	360	29	0.081
4T4-24	360	400	480	330	307	350	330	350	330	350	340	380	380	390	390	380	370	39	0.105

* Summary statistics exclude data measured during solo operation of the NS antenna.