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REPRESENTATIVE ELECTROMAGNETIC FIELD INTENSITIES NEAR THE CLAM LAKE (WI) AND REPUBLIC (MI) ELF FACILITIES

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5285 Port Royal Road
Springfield, VA 22161

REPORT DOCUMENTATION PAGE	1. REPORT NO.	2.	3. Recipient's Accession No. <i>AM40 798</i>
4. Title and Subtitle Representative Electromagnetic Field Intensities Near the Clam Lake (WI) and Republic (MI) ELF Facilities		5. Report Date January 1984	
7. Author(s) IIT Research Institute		8. Performing Organization Rept. No.	
9. Performing Organization Name and Address IIT Research Institute 10 West 35th Street Chicago, IL 60616		10. Project/Task/Work Unit No.	
		11. Contract(C) or Grant(G) No. (C) N00039-84-C-0070 (G)	
12. Sponsoring Organization Name and Address Naval Electronic Systems Command PME 110E Washington, DC 20363		13. Type of Report & Period Covered Technical Analysis	
		14.	
15. Supplementary Notes			
Abstract (Limit: 200 words) → Extremely low frequency electromagnetic fields produced by ELF antennas and commercial power lines at Clam Lake, WI, and by commercial power lines at Republic, MI, have been measured at residences, businesses and forest recreational areas for the continuing assessment of the Navy's ELF Communications Program. The ELF fields from existing antennas at Clam Lake, and from power lines in both states are low. Introducing ELF antenna fields at Republic, MI in several years will not significantly change the electromagnetic environment there. The existing field intensities are interpreted and compared with independent expert judgment, professional standards-setting and judicial and administrative law opinions regarding safe exposure of the public to ELF electromagnetic fields.			
17. Document Analysis a. Descriptors Extremely Low Frequency Electromagnetic Fields Environmental Research			
b. Identifiers/Open-Ended Terms ELF Communications Program			
c. COSATI Field/Group Environmental Pollution and Control (Health and Safety)			
18. Availability Statement Release Unlimited		19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 60
		20. Security Class (This Page) UNCLASSIFIED	22. Price \$5.25 (P)

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REPRESENTATIVE ELECTROMAGNETIC FIELD INTENSITIES
NEAR THE CLAM LAKE (WI) AND REPUBLIC (MI)
ELF FACILITIES

PURPOSE

Electromagnetic field intensities produced by Extremely Low Frequency (ELF) communications antennas and commercial power distribution systems have been measured at numerous places near the Navy's ELF Communications Facility at Clam Lake, Wisconsin and near a planned new facility at Republic, Michigan. The purpose of the measurements and this report is to describe, through a representative sampling, the field intensities where people live and work, and at places residents and visitors use for recreation.

This report supersedes data presented in an earlier document.¹ Graphical presentations have been changed somewhat, based on experience with and comments received on the earlier report.

ELF ELECTROMAGNETIC FIELD SOURCES

Electromagnetic fields are produced by currents and voltages on ELF antennas and commercial power lines. The currents produce magnetic flux densities which are the same in air and earth. The magnetic flux densities also produce electric fields in earth. The voltages on ELF antennas and power lines produce electric fields in air that have different intensities and direction than the electric fields produced in earth. All of these components (magnetic flux density, electric field in earth, electric field in air) which make up the ELF electromagnetic environment exist at the operating frequencies of the sources, which are 76 Hz for ELF antennas and 60 Hz for commercial power lines. The fields at these frequencies do not combine in air or earth to produce other fields at other frequencies. They simply exist simultaneously in time and space when ELF antennas are operated and customers use electric service. The data in this report describe magnetic fields and electric fields in air and earth at their source frequencies and their intensities at representative places in the Clam Lake, Wisconsin area. Also described are the 60 Hz ambient fields present at representative locations near Republic, Michigan prior to construction of the ELF facility there.

SELECTION OF MEASUREMENT LOCATIONS

Measurements were intentionally avoided directly under power distribution lines and the ELF antennas (the rights-of-way). Both the magnetic and electric fields have their maximum intensity within rights-of-way, but neither residences nor businesses are located within power systems or ELF antenna corridors. The rights-of-way for these systems are sometimes used for recreational purposes by the public, but generally are not a primary attraction, as are campgrounds, for example.

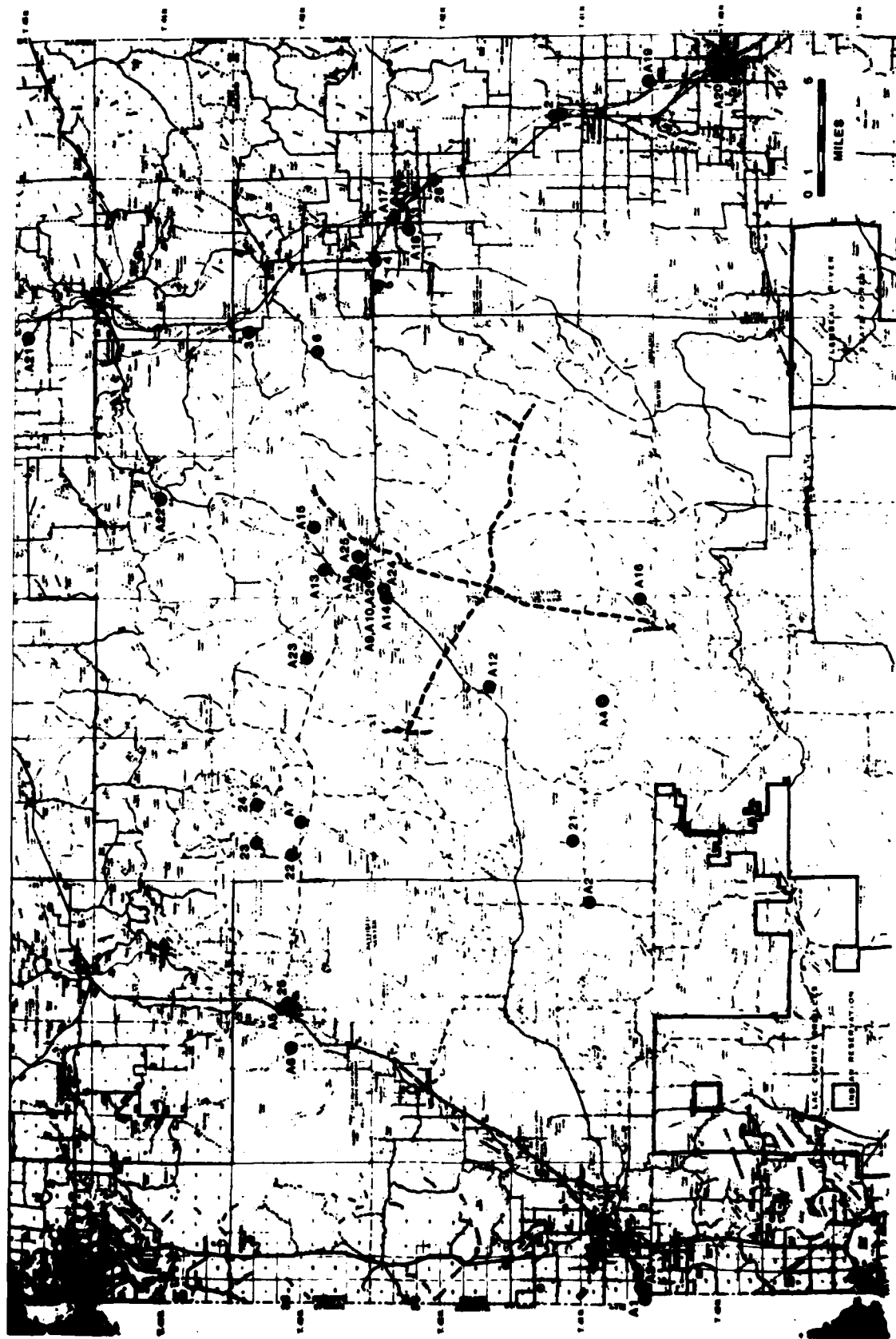
Measurement locations were essentially locations of opportunity -- residences of persons participating in the development of the Navy's ELF Communications System or otherwise interested in its development, local commercial establishments dealing with the Navy's program, utilities and government offices with which the Navy coordinates its activities, and recreational resources maintained for public use.

Instruments (see Appendix A) were placed approximately in the centers of rooms or other unobstructed spaces for indoor measurements, with close proximity to electric appliances avoided. The data were obtained at various times of the day during early Winter in Wisconsin, and during late Spring in Michigan. Outdoor measurements near buildings were made near front entrances without regard to power line proximity.

Outdoor measurements at casually-occupied places (recreational resources) were obtained throughout the year in Wisconsin, but mainly during Summer. Similar measurements in Michigan were made during Spring and Summer.

THE CLAM LAKE AREA

The Navy's Clam Lake ELF Communications Facility is located within the Chequamegon National Forest in northwestern Wisconsin, see Figure 1. The transmitter station, the antennas and the ground terminals are located entirely on public land. The small, unincorporated village of Clam Lake is the closest population center, and is slightly more than a mile west of the north leg of the ELF antenna system. The town of Cable, with a population of several hundred is about 15 miles west of the nearest ELF antenna.



**FIGURE 1 CLAM LAKE (WI) ELF COMMUNICATIONS FACILITY
AND ELECTROMAGNETIC FIELD MEASUREMENT LOCATIONS**

Hayward, also west of the Navy facility (about 25 miles), has a permanent population of several thousand, with seasonal increases as high as tens of thousands.

The small towns of Glidden and Butternut are about the size of Cable and lie about 10 miles east of the ELF Facility. The City of Park Falls, with a population of several thousand, is about 20 miles to the southeast.

There are seasonal and year-round dwellings along highways between towns, and clusters of homes around lakes. Most are five or more miles from the nearest ELF antenna. All are served by electric utilities, but there are no high voltage transmission lines in the immediate region.

Electromagnetic field intensities were measured at private residences in Clam Lake, Cable, Glidden and Butternut. Utility offices, government offices, retail business places, a resort and a lumber supply outlet represented work places visited by the public.

Electromagnetic field intensities also were measured at places used for recreation or other occasional activity. They included campgrounds in the Chequamegon National Forest, a rest area along a highway, a summer student encampment, a pipeline right of way popular with hunters and hikers, and forests and meadows.

THE REPUBLIC AREA

The new Republic ELF Communications Facility will be constructed within the Escanaba River and Copper Country State Forests in the west-central portion of Michigan's Upper Peninsula, see Figure 2. The transmitter station, the antennas and the ground terminals will be located almost entirely on public land.

There are no population centers within four miles of the planned antennas. Several small communities, each with a few hundred residents, and the towns of Republic/South Republic, Palmer, Gwinn and Channing (with populations of 500-1000), are four to six miles from the antenna routes. The cities of Ishpeming and Negaunee, each with several thousand residents are about 10 miles from the antenna routes, as is K.I. Sawyer Air Force Base. Other, more distant population centers include Marquette or Iron Mountain. Both are about 15 to 20 miles from the planned antennas and have populations in excess of 10,000.

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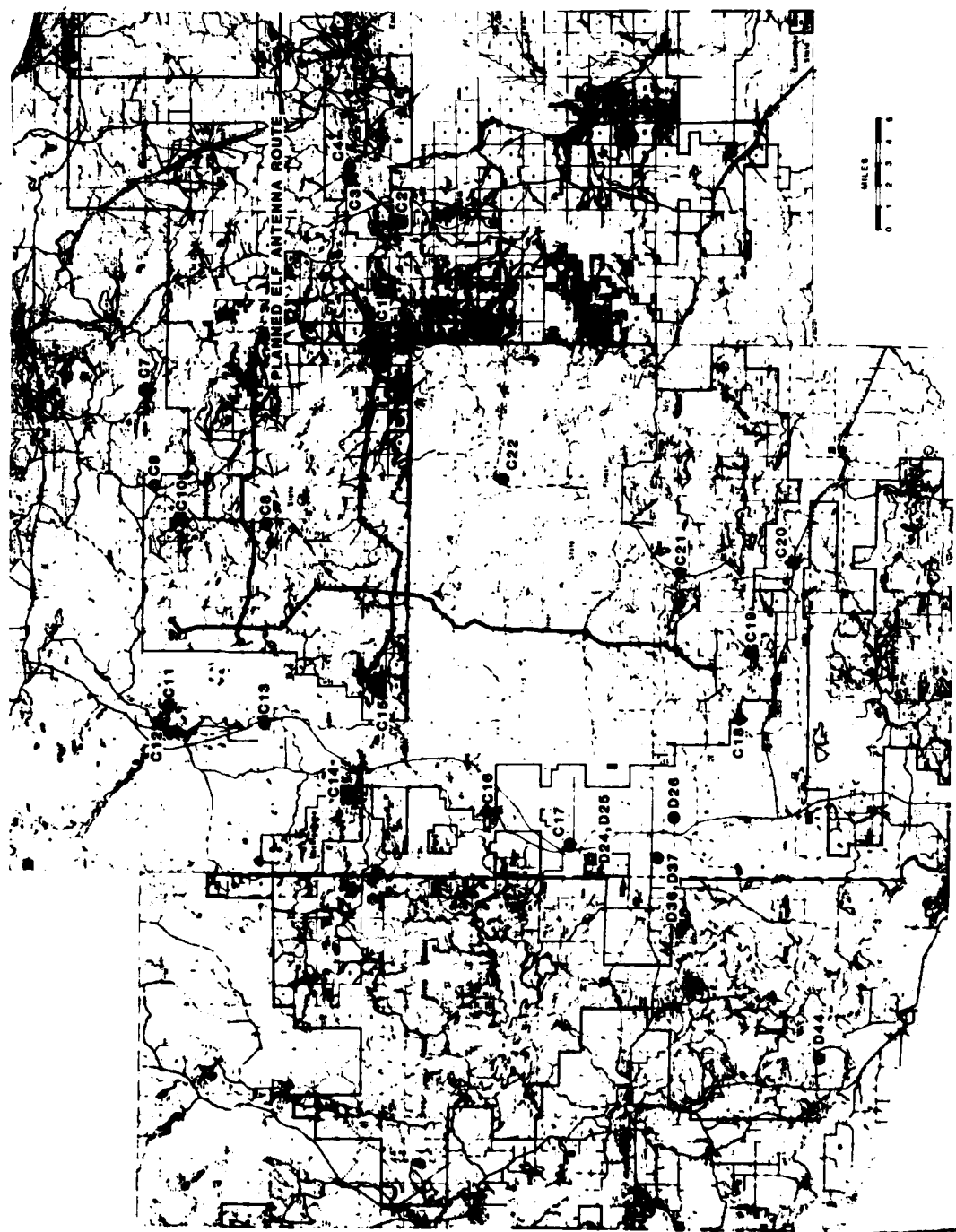


FIGURE 2 REPUBLIC (MI) ELF COMMUNICATIONS FACILITY AND ELECTROMAGNETIC FIELD MEASUREMENT LOCATIONS

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A number of year-round and seasonal dwellings are located along highways between towns and near recreation areas. With the exception of a group of homes on County Hwy 581, most are five or more miles from the nearest antenna route.

The region has extensive electric utility service to residents, including high voltage power transmission lines.

Ambient 60 Hz electromagnetic intensities were measured at private residences in Marquette, Gwinn and Channing. Measurements were also made at utility facilities and government offices, and at places used for recreation or other occasional purposes. They included campgrounds and water access sites in the state forests, a rest area along a highway, and forested areas and meadows used for recreation.

MEASUREMENT RESULTS

Wisconsin

Results of magnetic flux density and electric field intensity measurements at 76 Hz and 60 Hz in Wisconsin are illustrated graphically in Figures 3 through 14. The 76 Hz fields are produced by the ELF antennas, and by 76 Hz voltages and currents induced on power lines (see discussion of results). The ELF System was operated without modulation to accommodate field logistics and measurement instrument characteristics (see Appendix A). The intensities measured under unmodulated conditions at 76 Hz are the same as produced under modulated conditions. The 60 Hz fields are produced by commercial power distribution systems and electrical equipment and appliances used by consumers. Methods of measurement and tabular data are included in Appendix A.

Michigan

Results of 60 Hz magnetic flux density and electric field intensity measurements in Michigan are illustrated graphically in Figures 15 through 20. The 60 Hz fields are produced by commercial power systems and by equipment and appliances used by consumers. No 76 Hz electromagnetic fields generated by the Wisconsin ELF Facility could be measured in Michigan with state-of-the-art instruments.

Methods of measurement and tabular data are included in Appendix A.

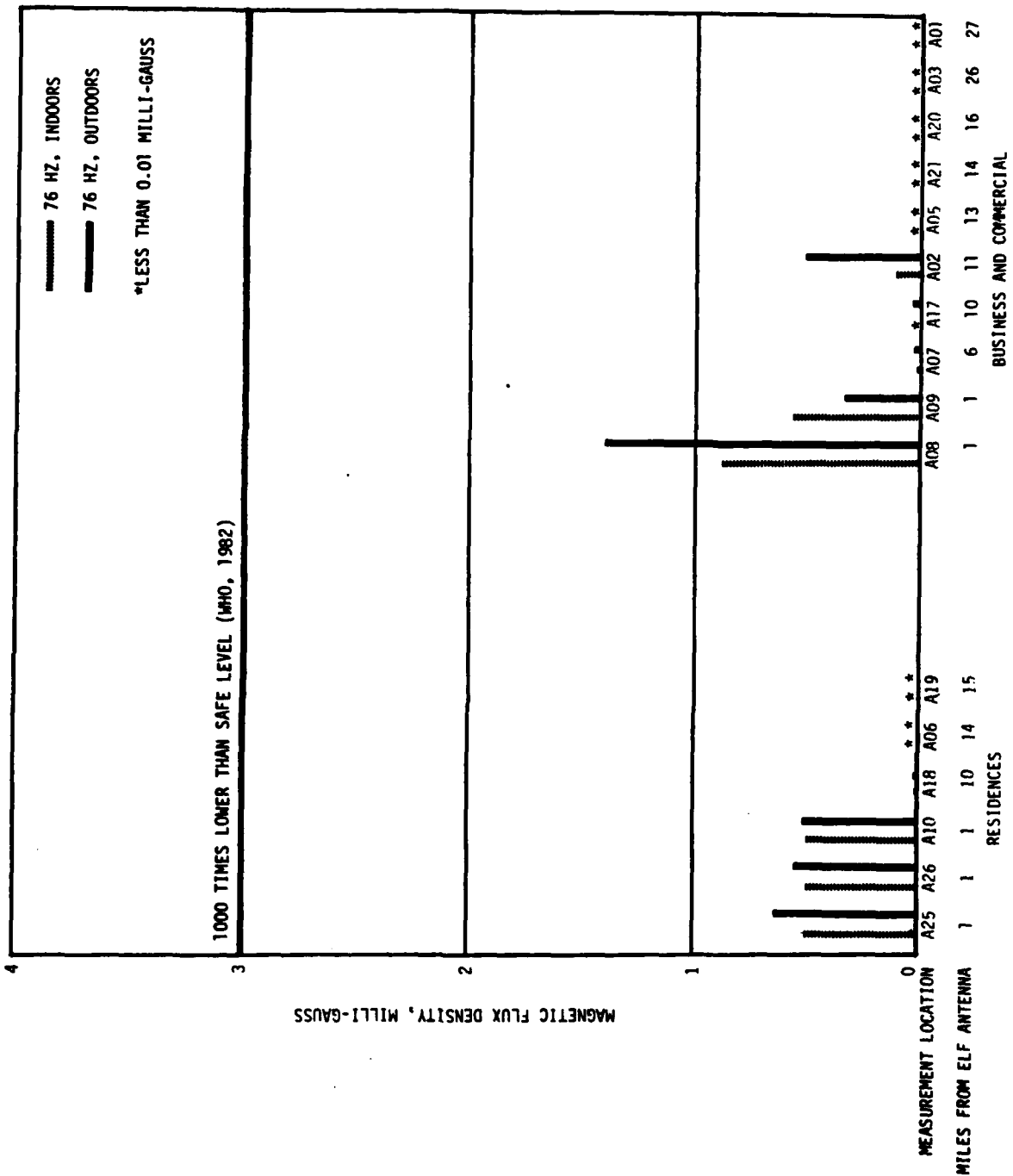


FIGURE 3 - MEASURED 76 Hz MAGNETIC FLUX DENSITIES AT OCCUPIED PLACES
 NEAR THE CLAM LAKE (WI) ELF FACILITY

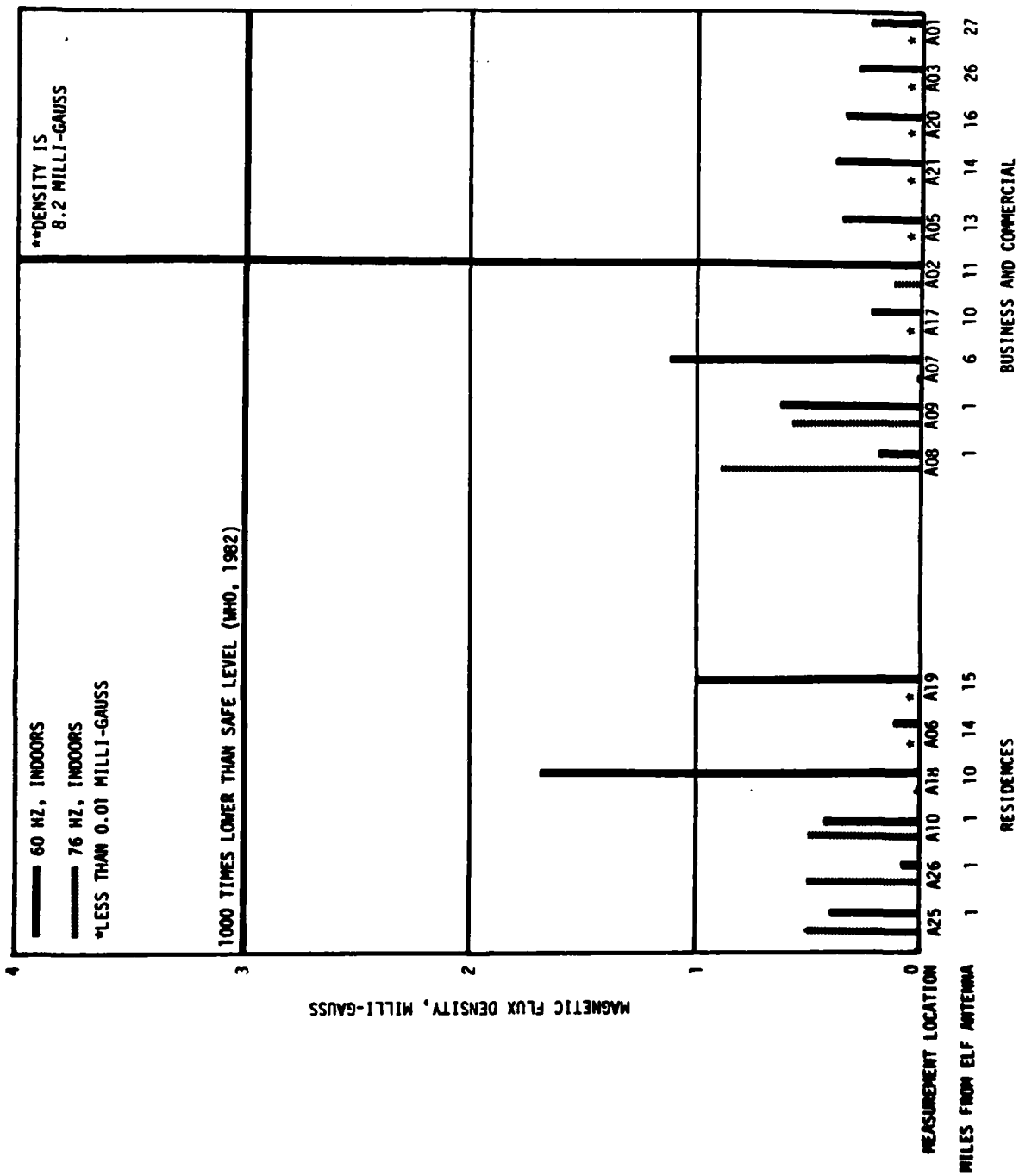


FIGURE 5 - MEASURED 76 HZ AND 60 HZ MAGNETIC FLUX DENSITIES INSIDE OCCUPIED PLACES NEAR THE CLAM LAKE (WI) ELF FACILITY

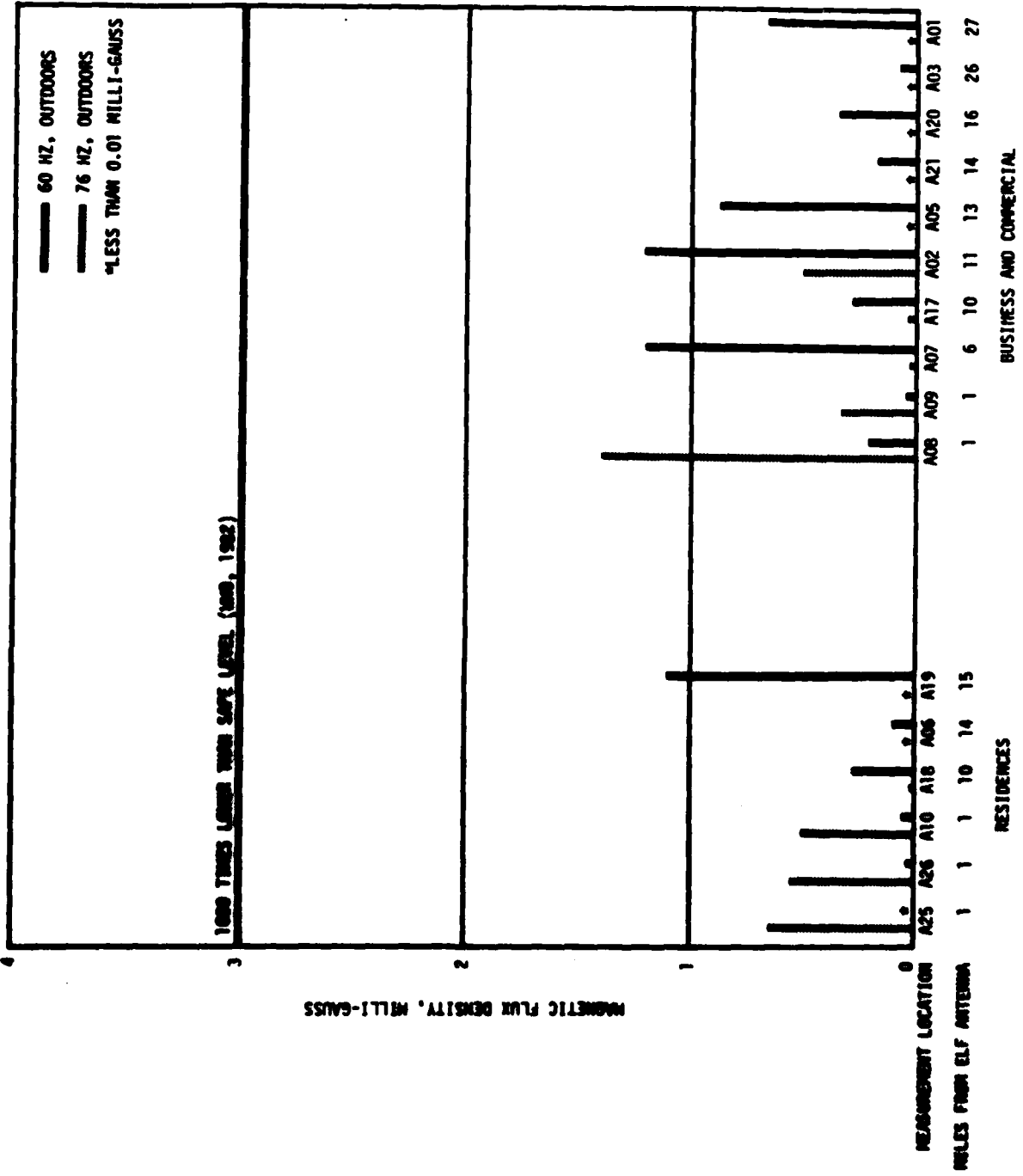


FIGURE 6 - MEASURED 76 HZ AND 60 HZ MAGNETIC FLUX DENSITIES OUTSIDE OCCUPIED PLACES NEAR THE CLAM LAKE (WI) ELF FACILITY

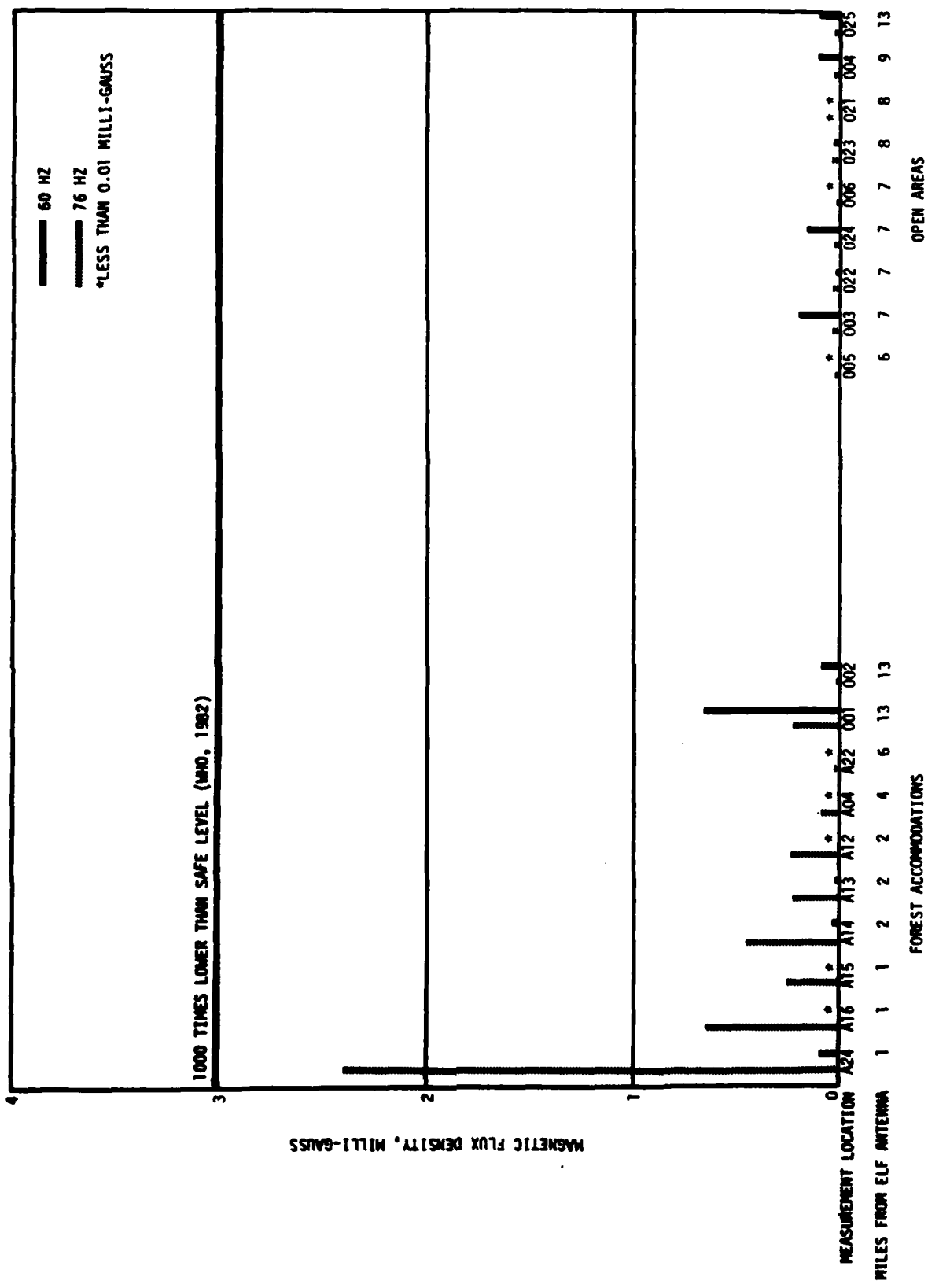


FIGURE 7 - MEASURED 76 Hz AND 60 Hz MAGNETIC FLUX DENSITIES AT CASUALLY-OCCUPIED PLACES NEAR THE CLAM LAKE (WI) FACILITY

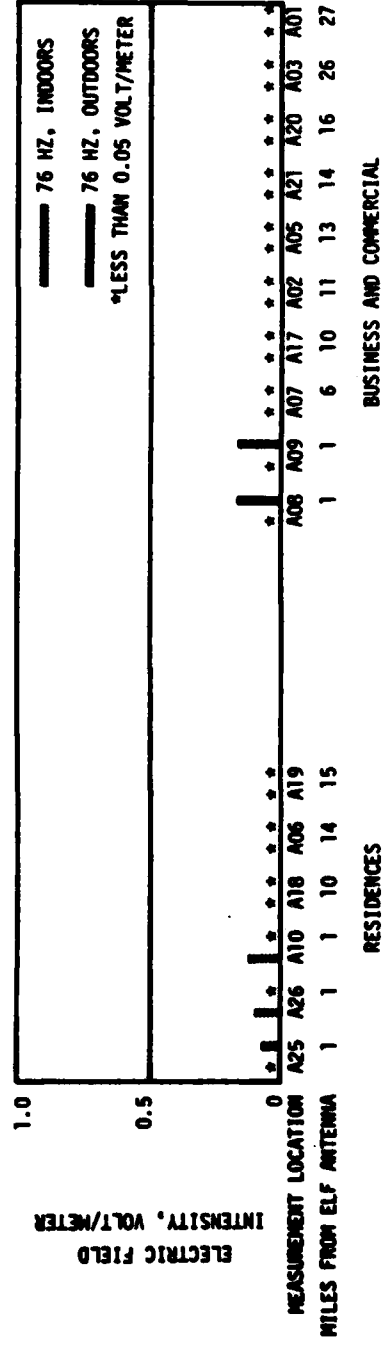
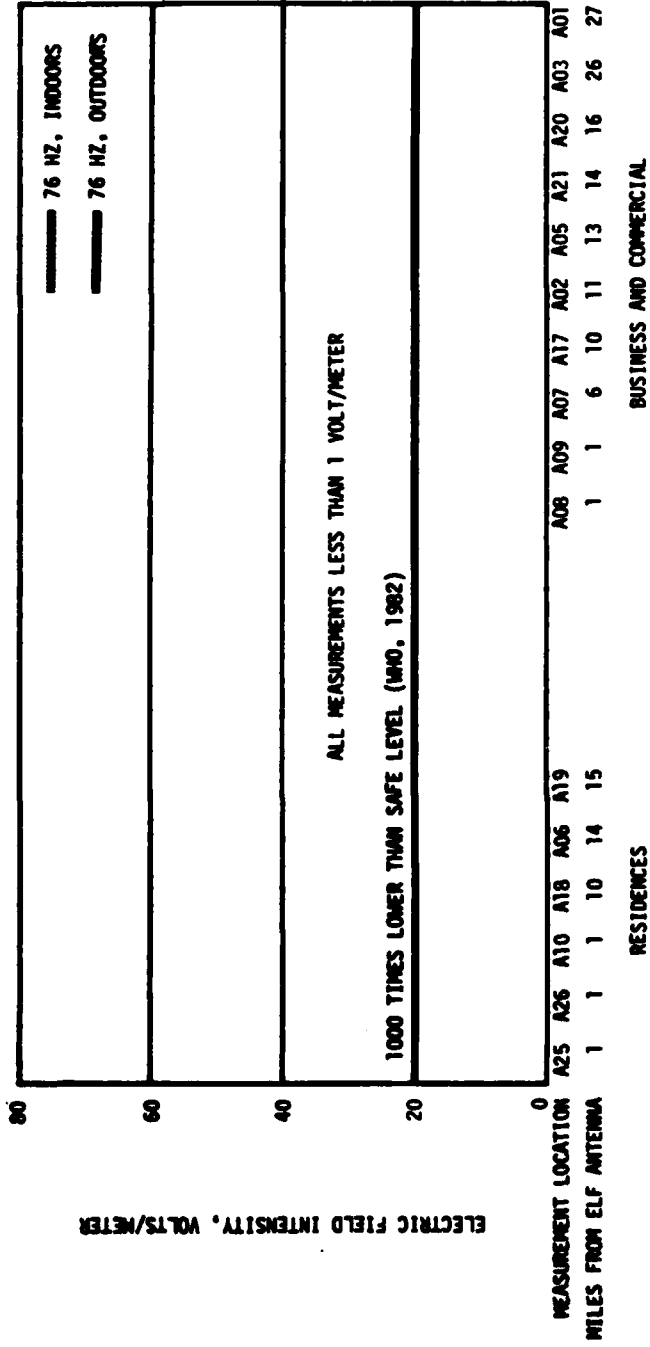


FIGURE 8 - MEASURED 76 Hz ELECTRIC FIELD INTENSITIES IN AIR AT OCCUPIED PLACES
NEAR THE CLAM LAKE (MI) ELF FACILITY

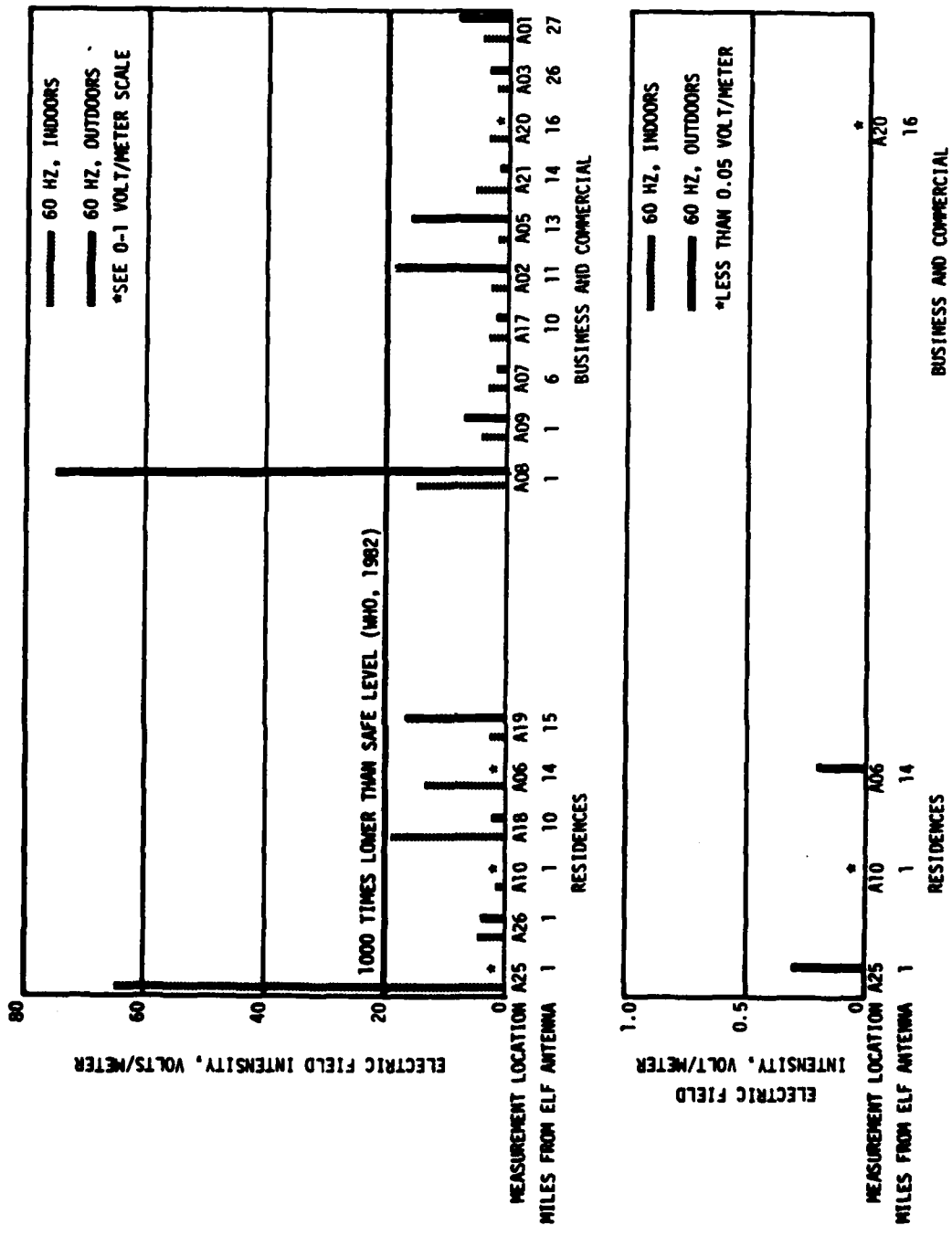


FIGURE 9 - MEASURED 60 HZ ELECTRIC FIELD INTENSITIES IN AIR AT OCCUPIED PLACES NEAR THE CLAM LAKE (WI) ELF FACILITY

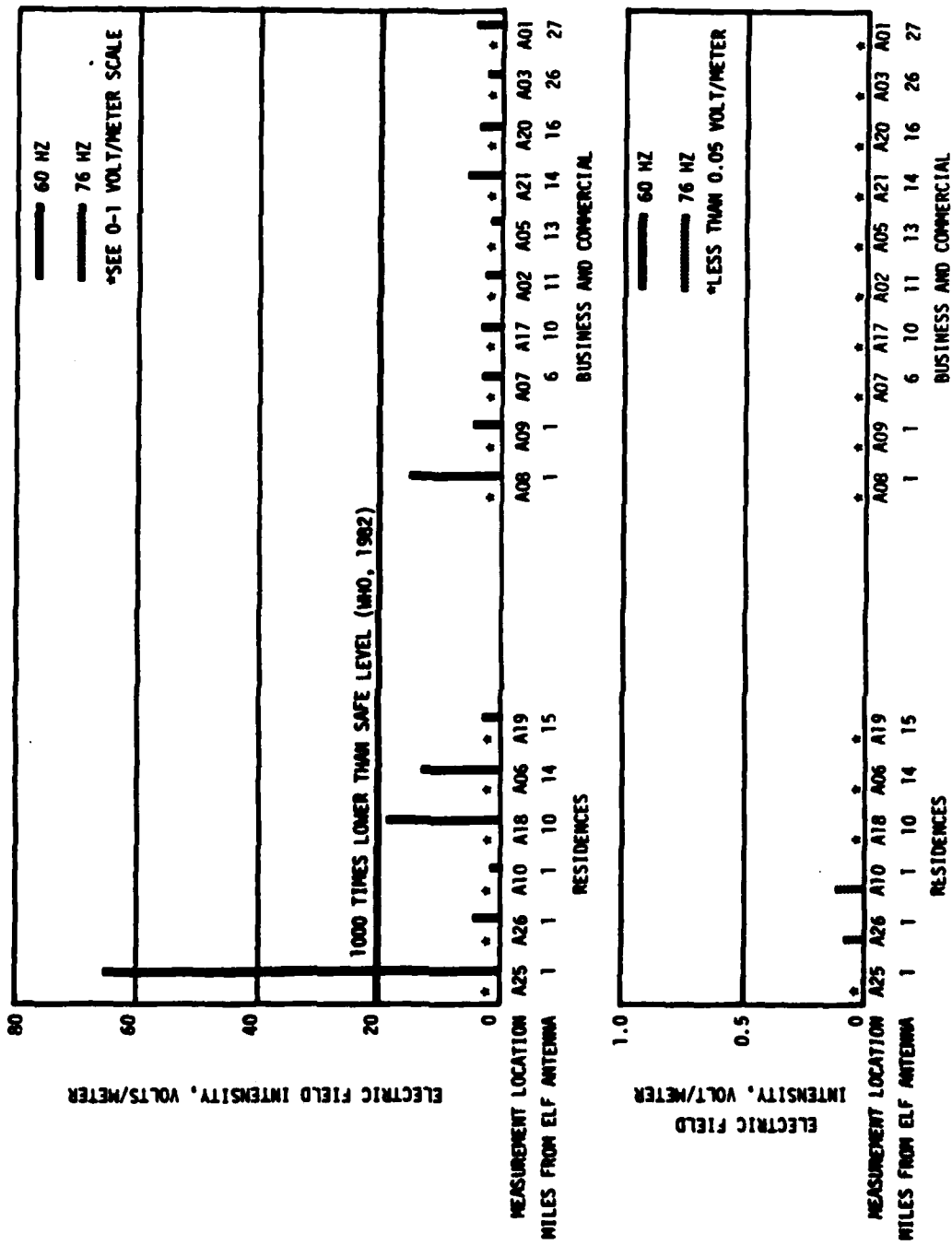


FIGURE 10 - MEASURED 76 HZ AND 60 HZ ELECTRIC FIELD INTENSITIES IN AIR INSIDE OCCUPIED PLACES NEAR THE CLAM LAKE (MI) ELF FACILITY

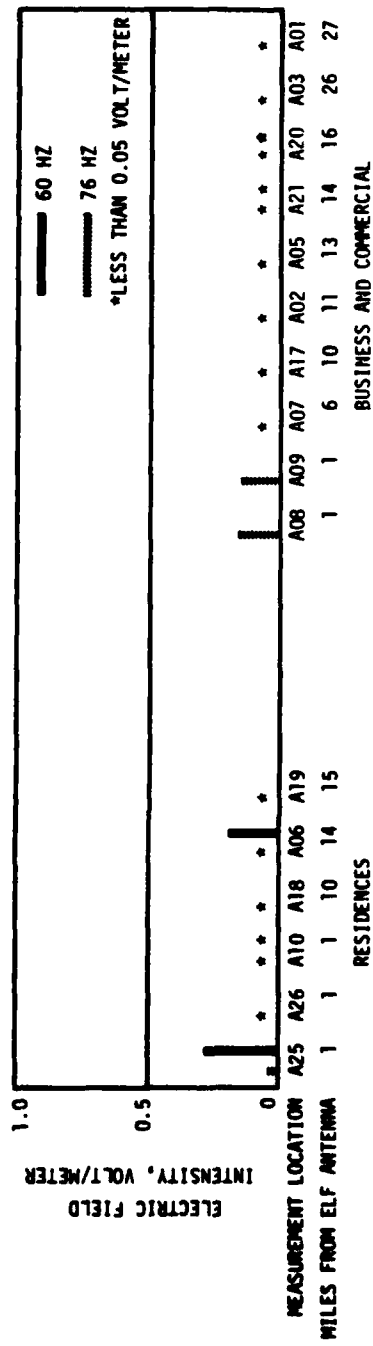
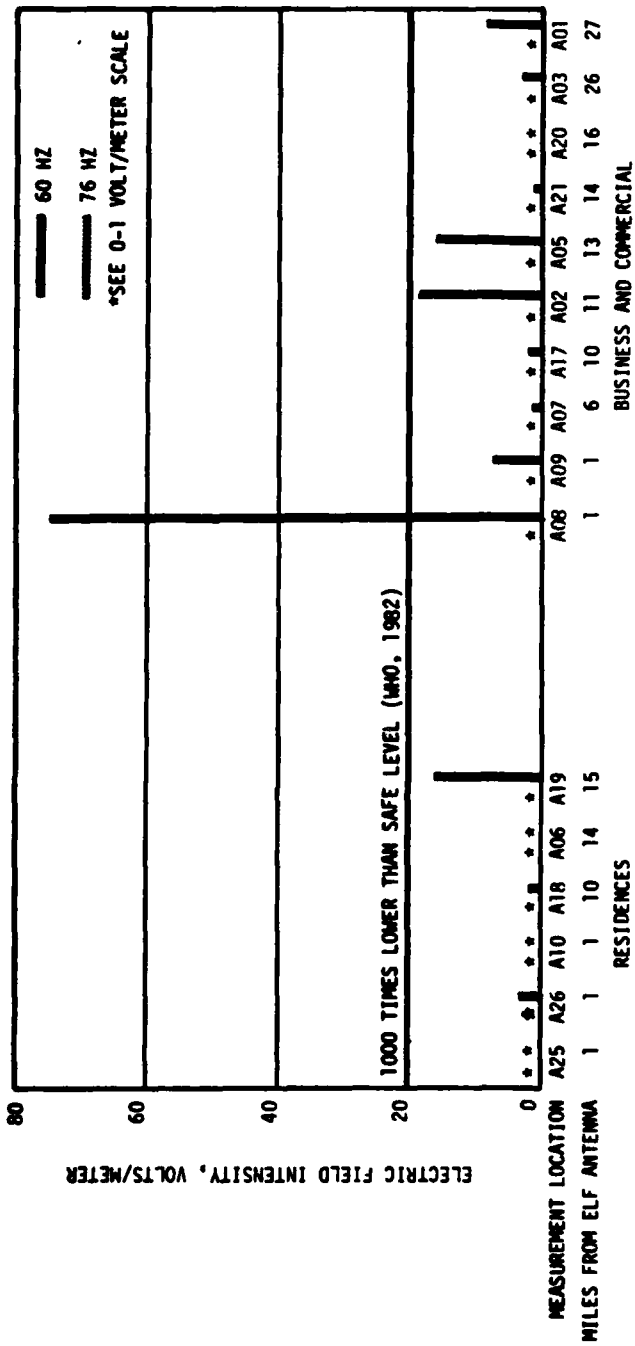


FIGURE 11 - MEASURED 76 Hz and 60 Hz ELECTRIC FIELD INTENSITIES IN AIR OUTSIDE OCCUPIED PLACES NEAR THE CLAM LAKE (WI) ELF FACILITY

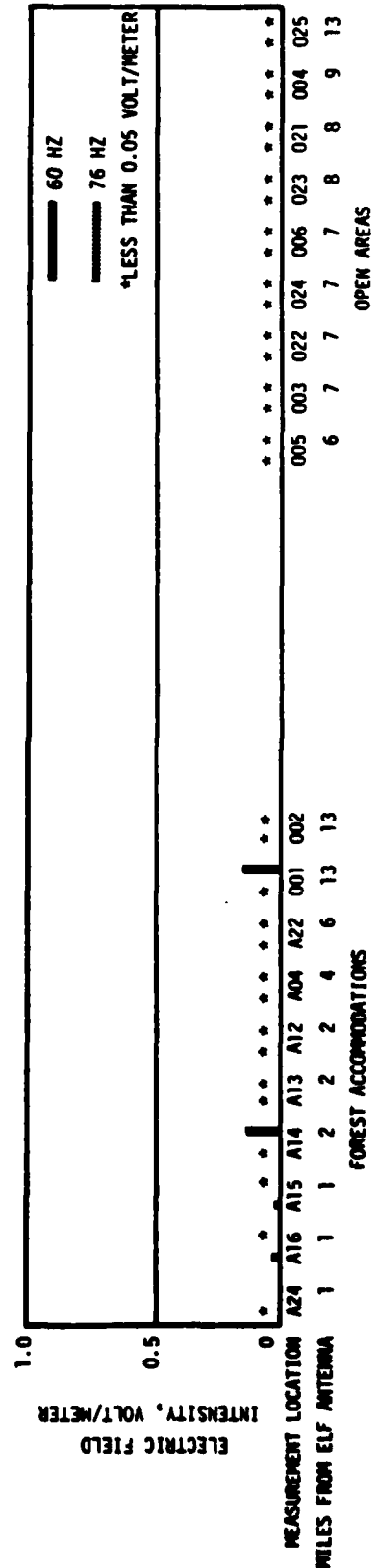
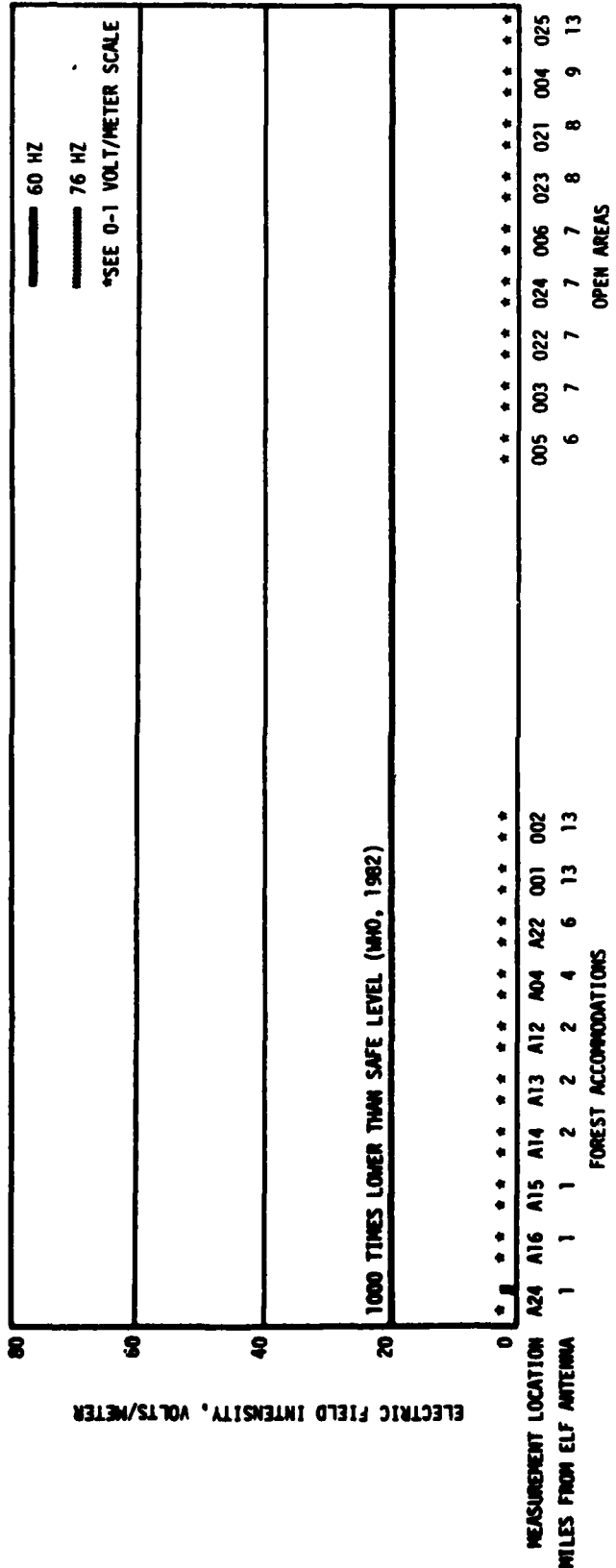


FIGURE 12 - MEASURED 76 HZ AND 60 HZ ELECTRIC FIELD INTENSITIES IN AIR AT CASUALLY-OCCUPIED PLACES NEAR THE CLAM LAKE (WI) ELF FACILITY

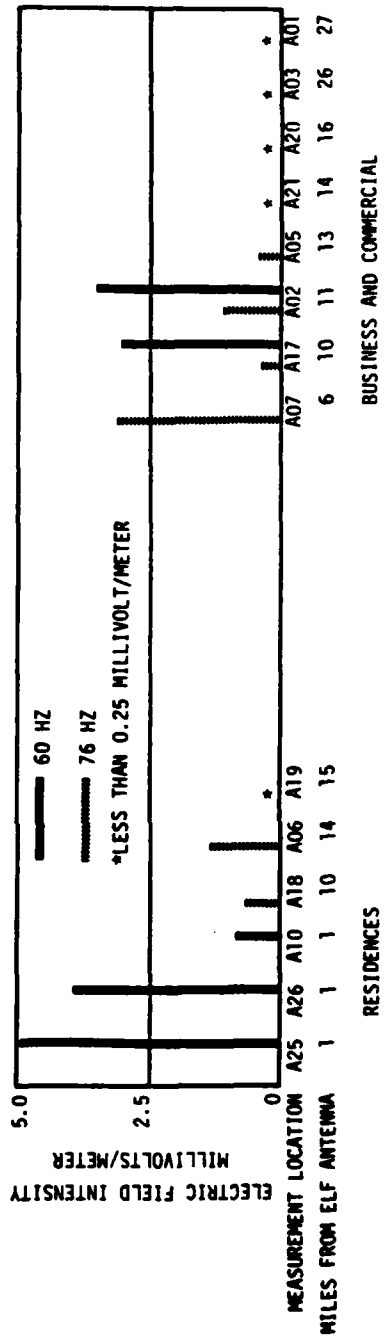
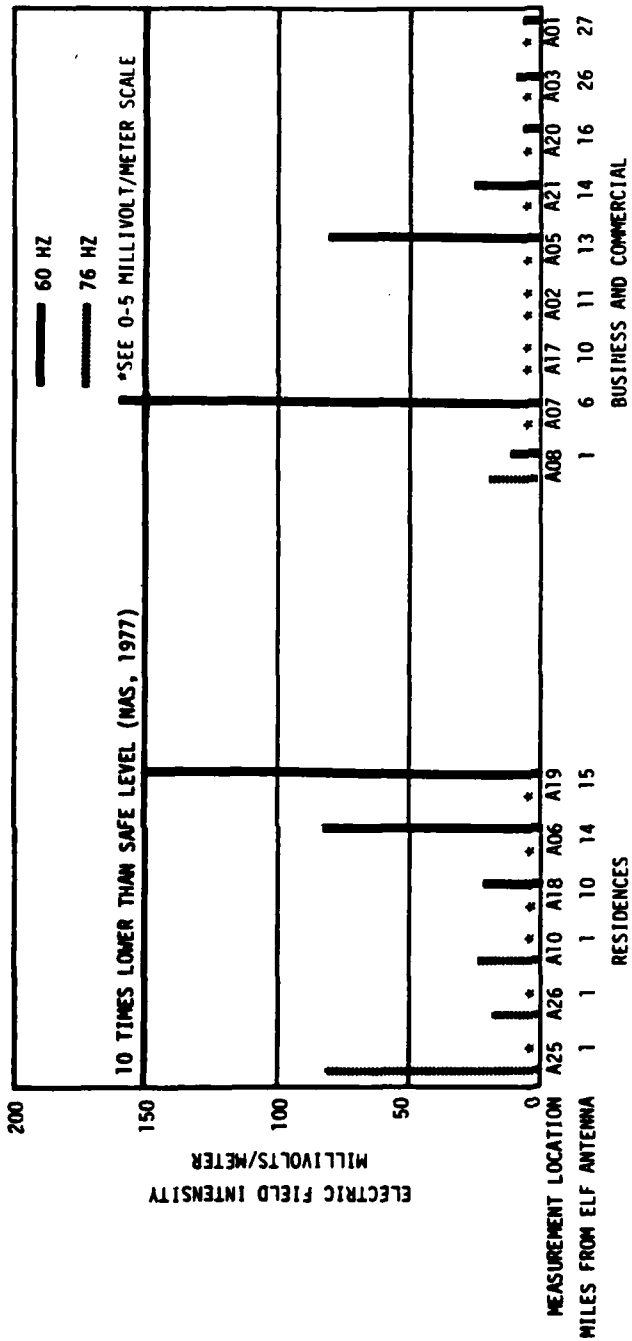


FIGURE 13 - MEASURED 76 HZ AND 60 HZ ELECTRIC FIELD INTENSITIES IN EARTH AT OCCUPIED PLACES NEAR THE CLAM LAKE (WI) ELF FACILITY

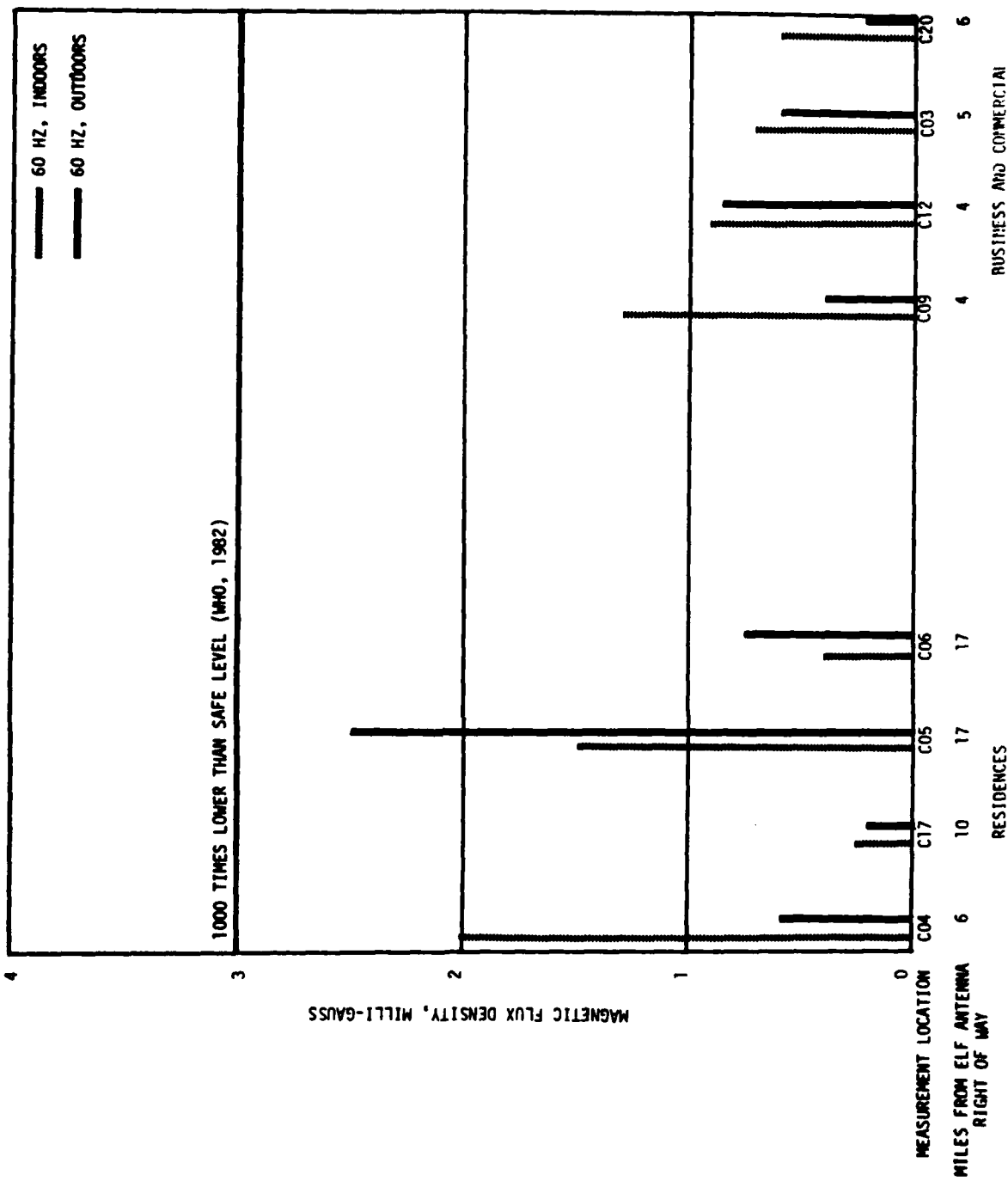


FIGURE 15 - MEASURED 60 HZ MAGNETIC FLUX DENSITIES AT OCCUPIED PLACES NEAR THE PLANNED REPUBLIC (MI) ELF FACILITY

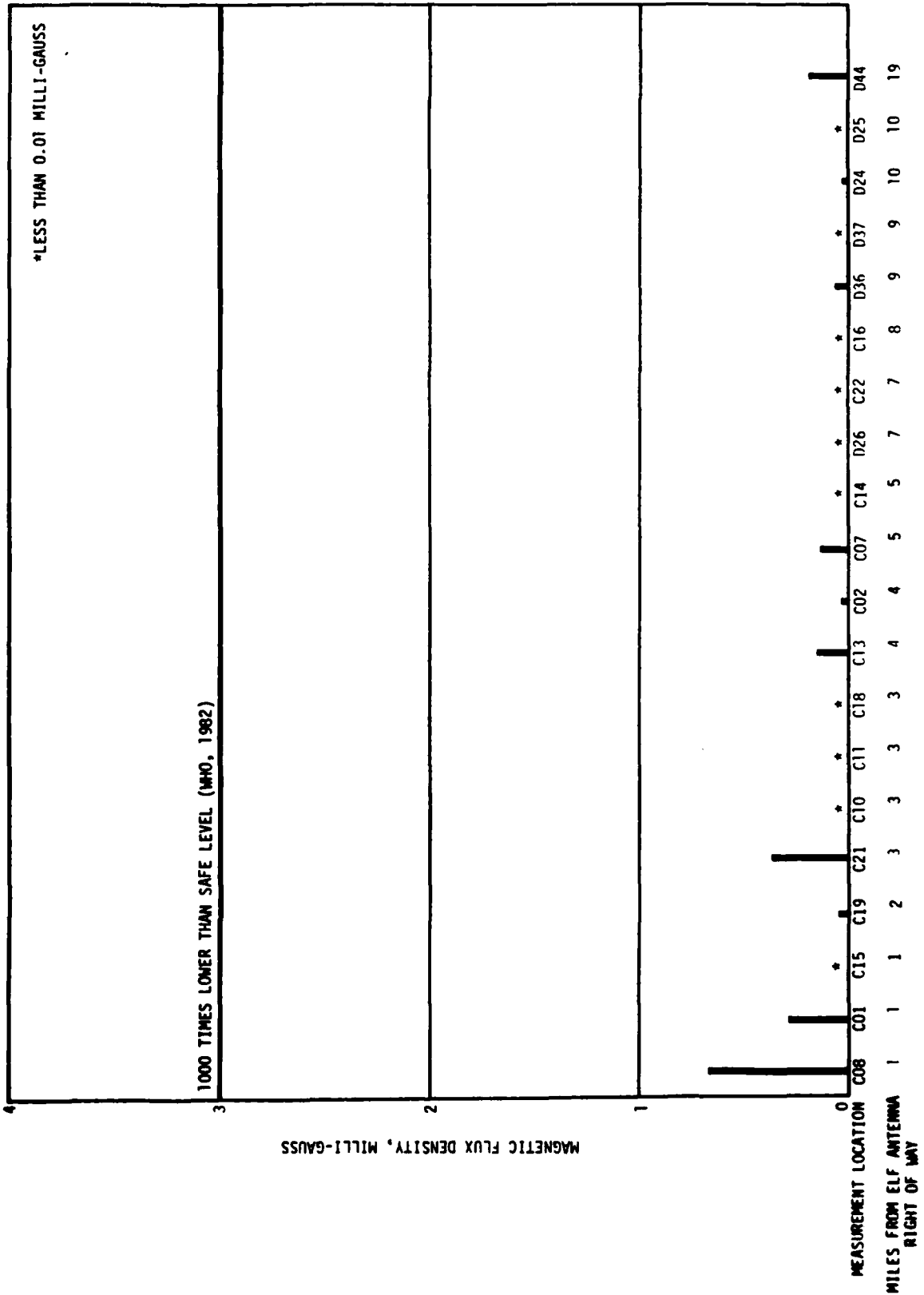


FIGURE 16 - MEASURED 60 HZ MAGNETIC FLUX DENSITIES AT CASUALLY-OCCUPIED PLACES NEAR THE PLANNED REPUBLIC (MI) ELF FACILITY

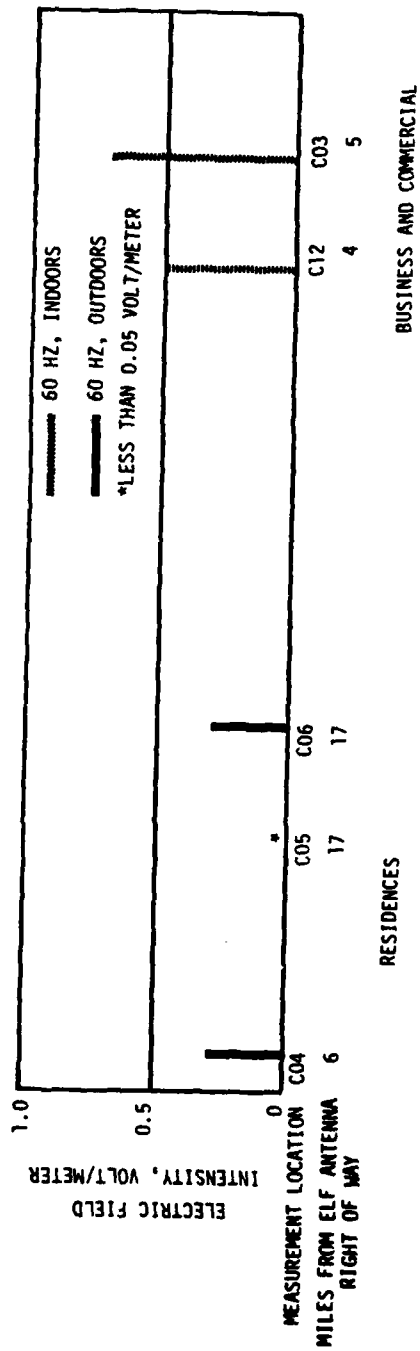
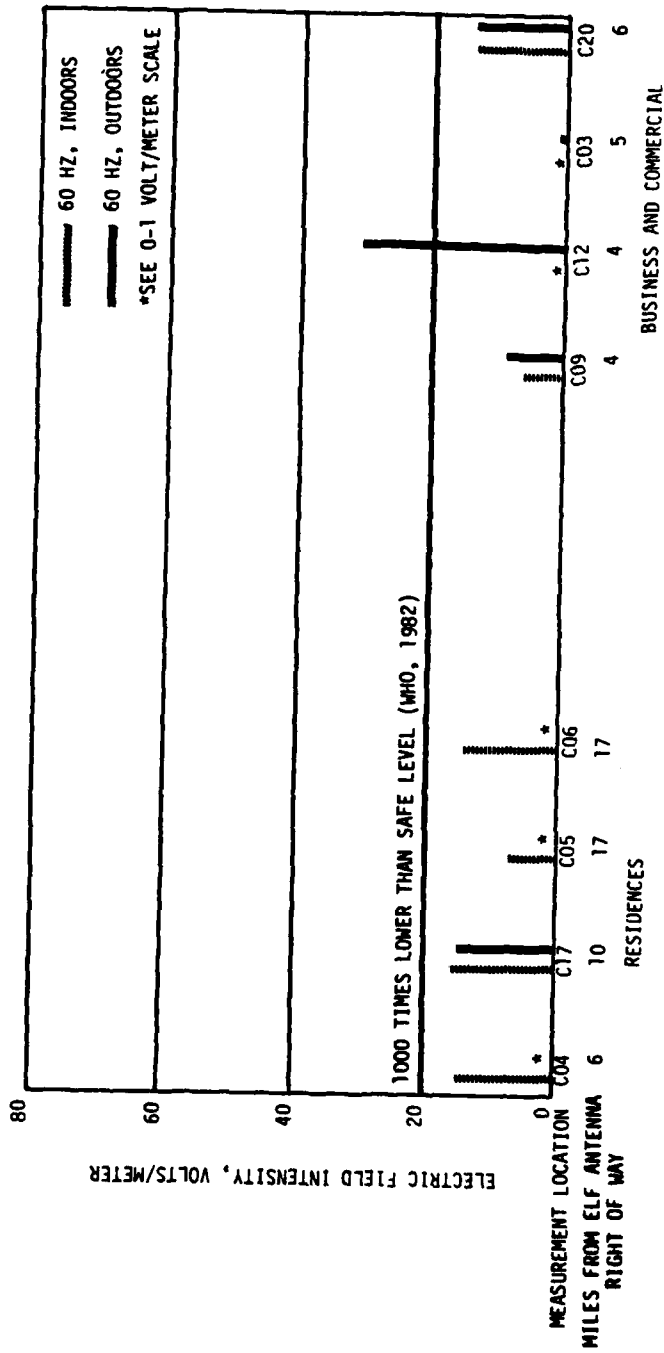


FIGURE 17 - MEASURED 60 Hz ELECTRIC FIELD INTENSITIES IN AIR AT OCCUPIED PLACES
NEAR THE PLANNED REPUBLIC (MI) ELF FACILITY

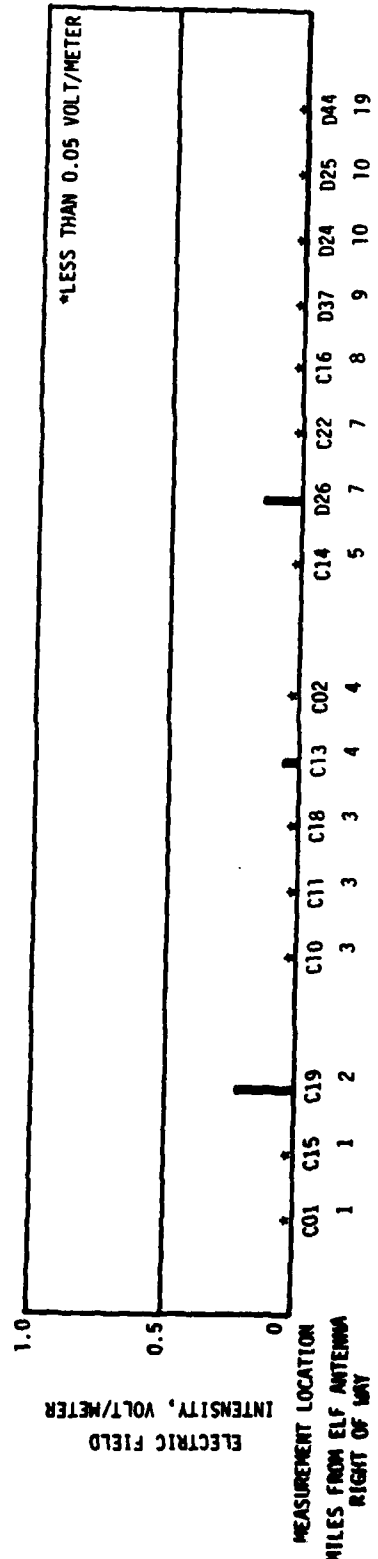
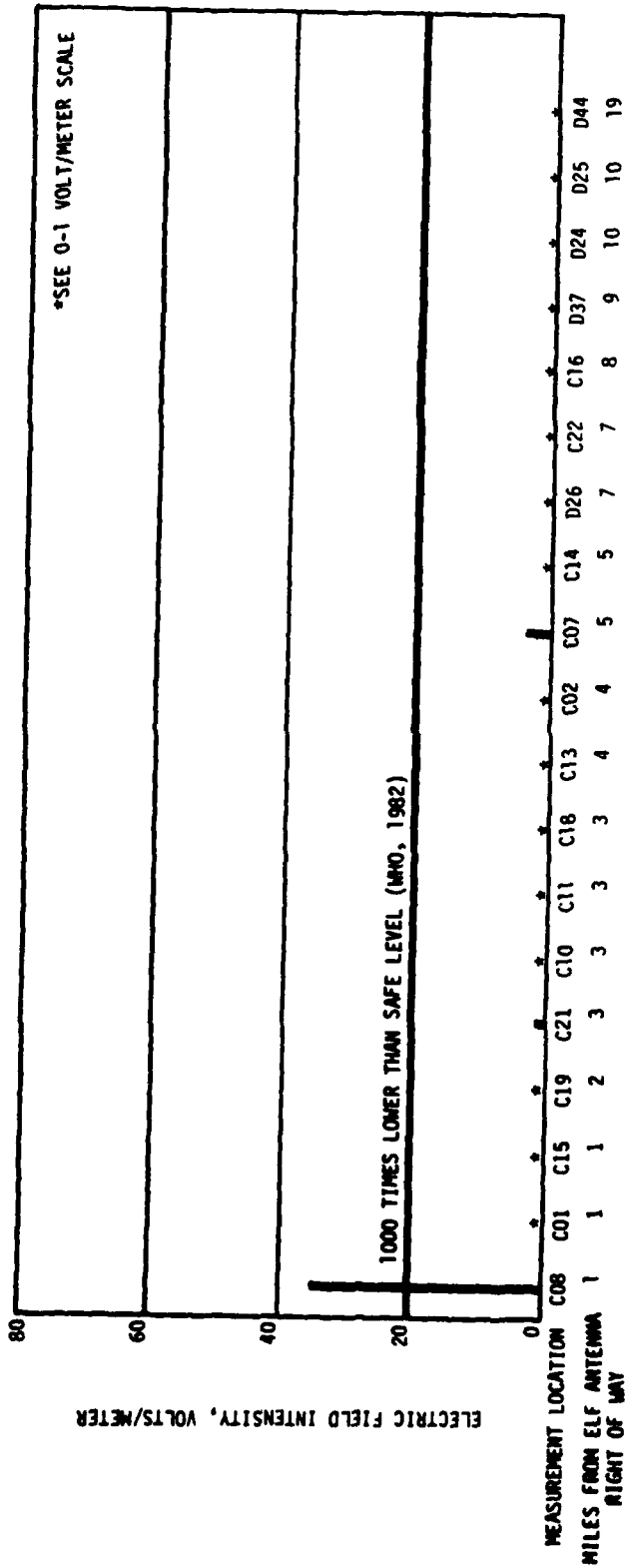


FIGURE 18 - MEASURED 60 HZ ELECTRIC FIELD INTENSITIES IN AIR AT CASUALLY-OCCUPIED PLACES
NEAR THE PLANNED REPUBLIC (MI) ELF FACILITY

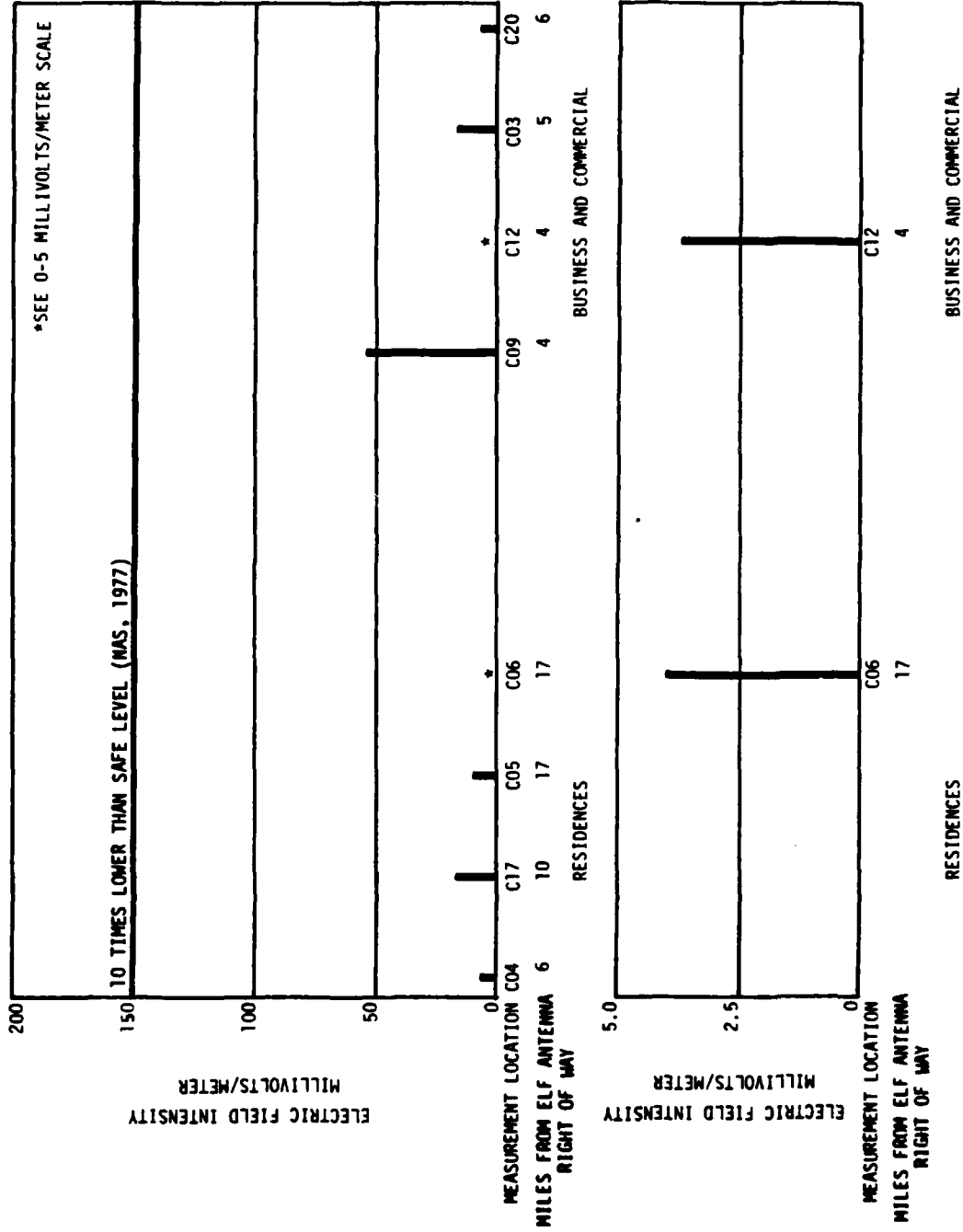


FIGURE 19 - MEASURED 60 Hz ELECTRIC FIELD INTENSITIES IN EARTH AT OCCUPIED PLACES
NEAR THE PLANNED REPUBLIC (MI) ELF FACILITY

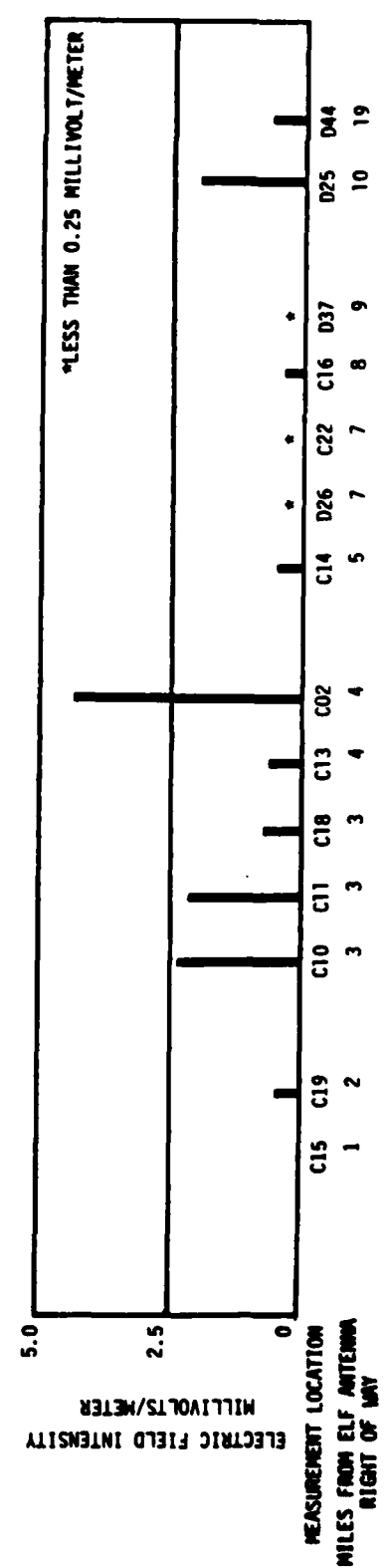
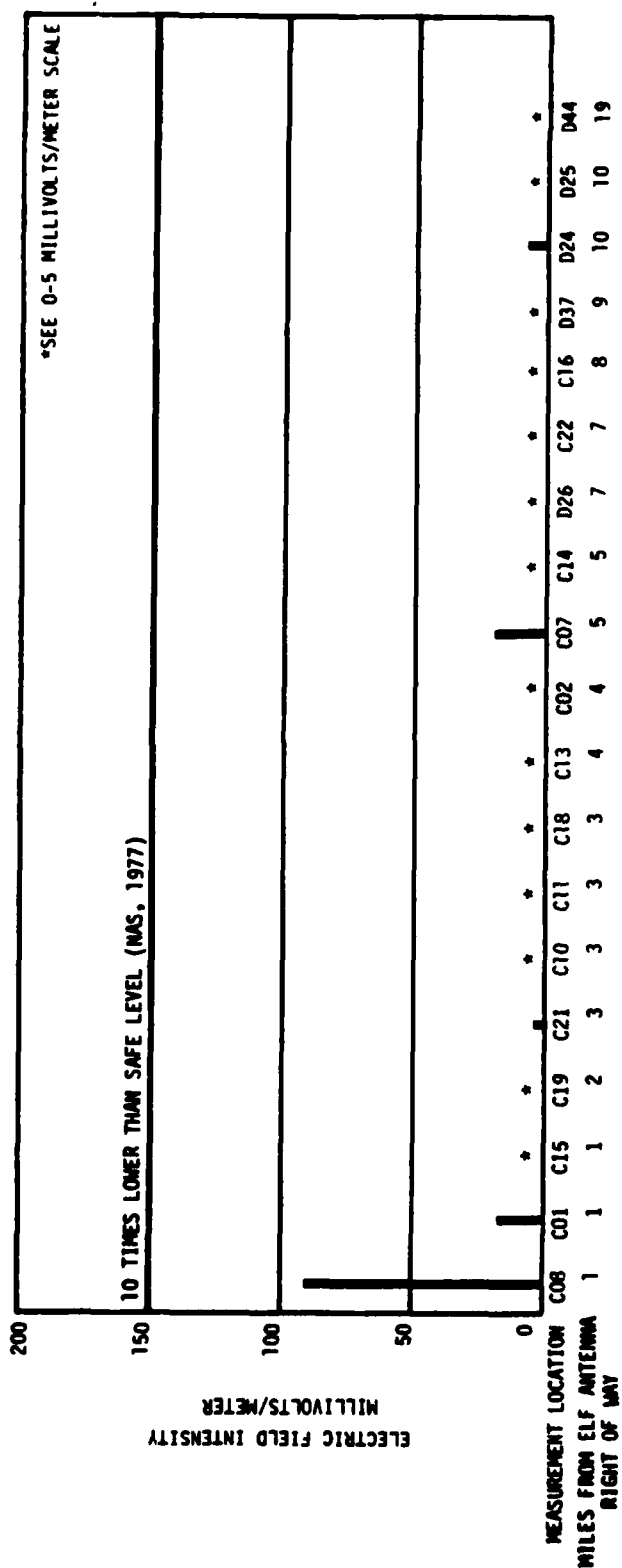


FIGURE 20 - MEASURED 60 Hz ELECTRIC FIELD INTENSITIES IN EARTH AT CASUALLY-OCCUPIED PLACES NEAR THE PLANNED REPUBLIC (MI) ELF FACILITY

DISCUSSION OF RESULTS

It is not the intent in this brief report to evaluate in detail the implications of low levels of ELF electromagnetic fields. The interested reader is referred to the considerable literature on nonionizing electromagnetic fields and biologic effects. Several recent reports include especially complete evaluations of the literature (see page 27).

In 1969, the World Health Organization Regional Committee for Europe commenced a long-term environmental health and pollution control program, which included the subject of nonionizing radiation. An expert committee of 26 scientists concentrated on ELF electromagnetic fields, and their evaluation is included in a report released in 1982.² The consensus of the Committee was that "experimental studies show that E fields (electric fields) of intensity up to 20 kV/m (20,000 volts/meter) and H Fields (magnetic fields) of intensity up to 240 A/m, i.e., 0.3 mT (3 Gauss), whether individually or in combination, do not constitute a danger to health." The reported safe magnetic field limit, reduced by a factor of 1000, is indicated in Figures 3 through 7, and Figures 15 and 16. Similarly, the reported safe limit of 20,000 volts/meter, reduced by a factor of 1,000, is shown on graphical presentations of electric field intensities measured in air (Figures 8 through 12, and Figures 17 and 18).

The National Radiological Protection Board of the United Kingdom also has considered the influence of ELF electromagnetic fields in a recent study of nonionizing radiation effects.³ The Board stated there is "very little information that can be used as a rational basis for limiting exposure" at extremely low frequencies. The Board further commented that effects could be prevented in homes and work places if electric field intensities are kept below 10,000 volts/meter, and considered prolonged exposure to fields in excess of 20,000 volts/meter undesirable.

Numerous other organizations also have recently considered public and/or occupational exposure to electromagnetic fields. These include the International Radiation Protection Association, the American Conference of Governmental Industrial Hygienists, the American National Standards Institute and the U.S. Environmental Protection Agency.⁴⁻⁷ None of

these organizations has recommended limits on either public or occupational exposure at extremely low frequencies.

The United Nations Economic and Social Council, Economic Commission for Europe, Committee on Electric Power, also has initiated a study of electromagnetic field effects. To date, the Group of Experts on the Relationship Between Electricity and the Environment, has released the following from three governments represented on the Committee:

USSR, 12 December 1981 -

The occupational threshold value for unlimited exposure to ELF electric fields is 5,000 volts per meter. Protective devices are required if the electric field exceeds 25,000 volts per meter. At intermediate intensities, the duration of exposure is limited, and protective devices are required under some conditions. The limit in residential areas is 500 volts per meter.

France, 14 September 1982 -

At the present stage of research and findings, the French representatives draw the same conclusion as that of the experts of WHO, that the highest level of electric fields near very high voltage transmission lines presents no danger to health.

United Kingdom, 11 October 1982 -

Available evidence and operational experience give no reason to believe that exposure to ELF electric and magnetic fields is generally harmful to health.

Except for the World Health Organization, no other group has addressed magnetic field intensities, and none of the organizations appears to have considered electric field intensities in earth. The National Academy of Sciences considered the latter in its evaluation of the Navy's ELF Communications Program released in 1977, and in particular with regard to electric field intensities produced in earth near ELF ground terminals.⁹ The experts concluded that safety would be assured if electric fields in earth by continuous-conducting ground terminals were limited to a maximum value of 1.5 volts per meter. This value is 10 times less than is generally adopted by the electric power industry for faulted power line conditions. The line representing the value 10 times lower than the National Academy of Sciences

recommendation (100 times lower than industry practice, generally) is indicated on Figures 13, 14, 19 and 20 illustrating the results of measurements of electric field intensities in earth.

Concern about ELF electromagnetic fields and their effects on the environment and health also is evident in recent litigation and administrative law proceedings. A recent study of these cases has been completed,¹⁰ and the findings are summarized in Table 1. As the information in the table shows, neither the various courts nor administrative agencies have prohibited the construction of transmission lines which produce relatively strong electric fields in air (in the order of 1000's of volts per meter). Views expressed in these deliberations exhibit considerable doubt as to the importance of effects of ELF electromagnetic fields on health and biology. Oregon is the only state that has codified limits on electric fields produced by power transmission lines, permitting 9000 volts per meter in areas accessible to the public.¹¹ Note: the maximum electric field in air from an ELF antenna was 0.16 volts/meter (see Table A-3).

Magnetic Fields (World Health Organization considered safe limit - 3 Gauss. The largest value measured in Wisconsin at 60 Hz was 8.2 milligauss and at 76 Hz was 2.4 milligauss. The largest value measured in Michigan at 60 Hz was 2.5 milligauss.)

Magnetic flux densities produced by ELF antennas at Clam Lake, and by commercial power line currents are weak and roughly comparable where people live and work in the Clam Lake and Republic regions. Figures 3, 4, 15 and 16 show that the ELF antenna and power line currents generate low magnetic field intensities (generally less than 1 milligauss with 8.2 milligauss the highest level measured). Tabular data are included in Appendix A. Higher magnetic flux densities can be measured close to many appliances, and measurements made indoors and graphically presented in Figures 4 and 5 represent a composite of magnetic field contributions from numerous operating appliances. The 60 Hz magnetic fields measured outdoors are produced by the power line currents drawn by consumers.

The magnetic flux densities produced or otherwise associated with the ELF antennas at Clam Lake (Figure 3) can only be measured within about a mile of the antennas with the best available commercial instruments. Only submarine ELF receivers can pick up such low field strengths. Even at these

TABLE 1 - SUMMARY OF COURT AND STATE REGULATORY AGENCY DECISIONS REGARDING
ELF ELECTROMAGNETIC FIELD EFFECTS ON BIOLOGY AND HEALTH

STATE	CASE	JURISDICTION	DISPOSITION
Arizona	Salt River Project Agricultural Improvement and Power District v. King (No. C 403475)	Maricopa County District Court	Decision pending
Arizona	Tucson Electric Power v. Shepis et al. (Nos. 185971, 185972, 185974)	Pima County Superior Court	Decision pending
Arkansas	Black v. Southwestern Electric Power (No. E-82-244-G)	Chancery Court of Sebastian County	28 April 1983 Landowners sought injunctive relief against the construction of a proposed transmission line, alleging irreparable damage from electromagnetic fields. Court found the proposed line would not create a health hazard, adverse biological injury or damages from stray or induced voltages or electromagnetic fields.
California	Pacific Gas and Electric Geysers Unit 16 (Application for Certification, No. 79-AFC-5)	Energy Resources Conservation and Development Commission	30 September 1981 Commission rejected staff recommendation to limit electric field at edge of right-of-way to 1000 volts/meter out of concern for alleged health effects, and required only stand-ard right-of-way to limit electric field to usual levels based on operating experience.
California	San Diego Gas and Electric (Application for Certificate for Construction and Operation of a 230 kV Transmission Line, Nos. 93785; 82-03-108)	Public Utilities Commission	1 December 1981; 16 March 1982 Commission granted a certificate, subject to mitigation and monitoring measures. Commission later modified certificate and denied rehearing because "overriding considerations support approval of the project," and the beneficial effects outweighed any environmental effects.

Table 1 (Continued)
Page 2

STATE	CASE	JURISDICTION	DISPOSITION
Colorado	Colorado Public Service v. Linnebur (No. 80CA0225)	Colorado District Court, Colorado Court of Appeals	1979 and 1980 In condemnation proceeding, landowner counterclaimed for damages due to physical injury from electromagnetic fields. Court ruled proffered testimony of expert witnesses on health effects was inadmissible because it went beyond their expertise and was speculative.
Florida	Florida Power and Light v. Devlin (No. CA-78-671)	Florida Circuit Court	3 July 1980 Expert testimony on health effects given in condemnation proceeding, but no mention of health effects in final decision.
Indiana	Indiana and Michigan Electric v. Pounds (No. C-79-235)	Spencer Circuit Court	27 February 1981 Landowners claimed in condemnation action that electromagnetic effects outside proposed right-of-way amounted to a "taking" for which they were not being compensated; court declined to make findings on whether there were adverse effects from electromagnetic fields from transmission lines, since the issue was for resolution by legislation.
Iowa	Iowa Power and Light v. Stortenbecker (No. 334-NW2d-326)	Iowa Court of Appeals	1983 Utility asserted that trial court abused its discretion in admitting testimony of an expert witness concerning alleged human health hazards in condemnation action. Appeals court held testimony could not properly be considered and reversed and remanded for new trial.
Kansas	Meinhardt v. Kansas Power and Light (No. 80-C-25)	Kansas District Court	1983 In condemnation proceeding, appeals court held the trial court did not abuse its discretion in refusing to admit testimony concerning alleged biomedical hazards posed by overhead transmission lines.

Table 1 (Continued)
Page 3

STATE	CASE	JURISDICTION	DISPOSITION
Louisiana	Louisiana Power and Light v. Churchill Farms (No. 182-546)	Louisiana District Court	27 September 1976 Although expert testimony taken on health effects issue, final order granting utility a servitude and right-of-way for construction and operation of transmission line made no mention of health effects.
Massachusetts	New England Power Petition for Tewksbury 345 kV Transmission Line (Nos. DPU 19559, 19630, 19631)	Department of Public Utilities	6 January 1983 Based on extensive expert testimony, agency concluded that adverse health impact was conjecture not supported by existing operating experience.
Minnesota	Northern States Power Application for High Voltage Transmission Line Corridor Designation and Associated Facilities (No. MP&L-TR-1)	Minnesota Environmental Quality Council	4 August 1976 REDC found there had been no substantial showing of adverse short-term/long-term biological effects from 500 kV transmission lines, and that calculated maximum electric field of 8000 volts per meter would not affect public health and welfare.
Minnesota	Cooperative Power Association and United Power Association Application for High Voltage Transmission Line Corridor, Route and Construction Permit and Associated Facilities (Nos. CU-TC-1, CU-TR-1, CU-TR-2) and No Power Line Inc. v. Environmental Quality Board (No. 262-1M2d-312)	Minnesota Environmental Quality Board Minnesota Supreme Court	1977 REDC granted all necessary approvals for construction of HVDC and 345-kV AC lines after extensive inquiry into health effects issues, and court affirmed.
Minnesota	Cooperative Power Association v. Asand (Nos. C-1474 and 288-1M2d-697)	Hennepin County District Court and Minnesota Supreme Court	1980 Landowners brought action to compel utilities to condemn fee interest in land contiguous to right-of-way for high voltage transmission line. Court held for landowners and state Supreme Court affirmed, noting fears of effects of HWTL's on public health.

Table 1 (continued)
Page 4

STATE	CASE	JURISDICTION	DISPOSITION
Mississippi	Mississippi Power Application for Certificate of Public Convenience and Necessity (No. U-4128)	Public Service Commission	20 July 1982 Commission Found that electric fields of the proposed transmission line will not adversely affect health and safety of people, animals or plants; granted certificate.
New York	Power Authority of the State of New York, Common Record Hearings on Health and Safety of Extra High Voltage Transmission Lines (Nos. 26529 and 26559) and Power Authority of the State of New York v. Public Service Commission (No. 67-AD2d-365)	Power Authority of the State of New York and New York Public Service Commission	19 June 1978 PUC final order identifies health and safety issues, requires expanded right-of-way, imposes operating conditions, and authorizes operation pursuant to those conditions; requires \$5 million utility funded research program.
New York	Standard et al. v. Axelrod (No. 100 Misc 2d 702)	New York Superior Court	1979 Axelrod (New York State Commissioner of Health) sought court order directing various State and local health agencies to supervise, regulate and abate alleged health hazards created by transmission lines. Dismissed because court lacked jurisdiction to decide cases properly brought before the Public Service Commission.
New York	Marcy-South 345 kV Line (No. 70126)	Public Service Commission	Decision Pending
North Dakota	Basin Electric Power v. Oster et al. (Nos. 4051-4053, 4062, 4111-4118, 4124-4125, 4141)	North Dakota District Court	1980 Testimony on the health effects of transmission lines was presented in proceedings. However, health effects were not discussed in the final orders condemning property for easements and rights-of-way.

Table 1 (Continued)
Page 5

STATE	CASE	JURISDICTION	DISPOSITION
North Dakota	Nebraska Public Power District Application for Certificate of Corridor Compatibility (No. 9942)	North Dakota Public Service Commission	7 July 1981 Based on evidentiary record, the Commission found no present credible evidence that electric fields surrounding transmission lines cause significant adverse biological or other environmental effects, or that they pose threats to human, plant or animal health.
Pennsylvania	Goadby v. Philadelphia Electric (No. 504 F. Supp. 812 and No. 639 F. 2d 117)	Public Utilities Commission; Federal District Court for Eastern Pennsylvania; and the 3rd Circuit Court of Appeals	1980 - 1981 The Commission granted application to construct a transmission line, finding no danger to the public's health or safety. Land- owner sought preliminary injunction against utility entering onto land until such time as owner's claims regarding encroachment of an electromagnetic field on his land had been heard. Federal district court found credible expert conclusion that exposure to an electromagnetic field generated by a transmission line posed a hazard to human health and resulted in the taking of a de facto fee interest rather than a right-of-way. On appeal, U.S. Court of Appeals found an adequate remedy at law (damages) in the state courts, and reversed judgment of district court.
South Dakota	Basin Electric Power Cooperative v. Lang (No. 304 NW 2d 715)	South Dakota District Court; South Dakota Supreme Court	1981 Landowners claimed they were not informed of detrimental effects of transmission lines on health and safety in earlier proceedings. Trial court allowed into evidence booklet on working under trans- mission lines distributed by utility to show that landowners had been informed. State Supreme Court held trial court did not commit reversible error in admitting booklet into evidence.
South Dakota	Basin Electric Power Cooperative v. Payne et al. (Nos. 79-8, 79-15 to 79-18)	South Dakota Circuit Court	1979 In a hearing to determine plaintiff's "right to take" in a con- demnation action, the court found insufficient evidence to support defendant's claim of the existence of any environmental and/or health effects caused by the proposed transmission line.

Table 1 (Continued)
Page 6

STATE	CASE	JURISDICTION	DISPOSITION
Tennessee	Tennessee Valley Authority v. an Easement and Right-of-Way Over 2 Tracts of Land (No. 537 F. Supp. 3)	Federal District Court; 6th Circuit Court of Appeals	1982 In a proceeding to determine compensation due landowners, the court held that expert opinion as to biological consequences of electric fields created by the transmission line was inadmiss- ible, since it would not assist the jury to understand the evi- dence of fair market value or compensation; court of appeals affirmed.
Texas	Houston Lighting and Power v. Craig et al. (No. 8289)	Brazoria County Court	1 October 1979 In condemnation proceeding, deposition testimony taken of expert witness on health effects, but court did not address health effects of transmission line in final judgment.
Texas	Lower Colorado River Authority Application for a Certificate of Convenience and Necessity for a 345 KV Transmission Line (No. 2489)	Public Utility Commission	14 September 1979 The Commission found that for persons dwelling at a distance of at least 200 feet from the transmission lines, the lines did not pose a health hazard and would have minimal effects on environ- mental integrity.
Texas	Central Power and Light, Southwestern Electric Power and Houston Lighting and Power Cer- tificate of Convenience and Necessity for a Transmission Line (No. 5023).	Public Utility Commission	Hearings in Progress
Texas	Houston Lighting and Power v. Bacarisse et al. (Nos. 7717, 7737, 7857, 7858, 7919)	Montgomery County Court	Decision pending

Table 1 (Continued)
Page 7

STATE	CASE	JURISDICTION	DISPOSITION
Virginia	Appalachian Power Application for Certificate of Convenience and Necessity Authorizing Corridor or Route of Proposed 765 kV Transmission Line (No. 10848) and Board of Supervisors of Campbell County v. Appalachian Power (No. 215 SE 2d 918)	Virginia State Corporation Commission; Federal District Court of Virginia	5 July 1974, and 1975 Commission found that 765 kV line would not create health or safety hazard because of ozone, but that radio/TV interference and transient shock could be irritants. The finding was affirmed by the Federal District Court.
Virginia	Virginia Electric Power v. Fendley (No. 2436-80)	Virginia Circuit Court	26 October 1982 Landowner claimed in condemnation proceeding, through expert testimony, that the electromagnetic field of the proposed transmission line resulted in a <u>de facto</u> "taking" of his property for which he was not compensated. Court ruled expert did not qualify to testify on electromagnetic effects of transmission lines. Landowner excepted, claiming prejudice as to exclusion of expert testimony. Court overruled exception.
West Virginia	Appalachian Power Application for a Certificate of Convenience and Necessity to Construct a 765 kV Transmission Line (No. 9003)	Public Service Commission	18 May 1979 and 18 December 1979 Although expressing concern over the split of opinion in the scientific community, the Commission concluded there were no known adverse biological effects associated with ELF fields of the magnitude associated with the 765 kV line.
Wisconsin	Northern States Power Application for Authority to Construct a 345 kV Transmission Line (No. 4220-CE-24)	Public Service Commission	11 August 1981 Extensive testimony was received from citizens expressing opposition to the line because of feared health effects. The Commission relied on a staff investigation, which concluded there was no convincing evidence of health hazards, and made only passing reference to the issue in its final decision.

relatively close distances they are measurable with commercial instruments only because 76 Hz interference currents are coupled from the antennas to the mitigated commercial power lines serving the community of Clam Lake.¹²⁻¹³ The flux densities inside buildings are somewhat lower than outside.

One exception is notable in Figure 3. An outdoor measurement of nearly 0.5 milli-Gauss was measured at Location A02 about 11 miles from the ELF antennas. The location is a telephone central office, and like power lines, telephone lines also carry 76 Hz interference currents coupled from the ELF antennas.¹⁴ The coupling on a telephone cable mitigated close to ELF antennas will be evident at a telephone central office many miles away.

The measured 60 Hz magnetic flux densities illustrated in Figure 4 exhibit several interesting characteristics. There is no consistency in the relationship between indoor and outdoor measurements: indoor magnetic flux densities were higher than those outdoors at nine places, and the opposite condition was found at seven places. The data obtained in Michigan (Figure 15) exhibit the same characteristic. These data do not support the contention in some recent literature that power cable configurations or outdoor magnetic flux density measurements are adequate for estimating magnetic flux densities which may exist indoors.¹⁵⁻²⁰ These data, in fact, suggest that estimates made on such assumptions can be in error by large factors. The error factors may range from overestimating indoor magnetic flux densities by as much as 70 percent, or underestimating them by as much as 5000 percent.

The effect of mitigating power distribution lines is to reduce 60 Hz magnetic flux densities to some degree because of the flux cancellation that takes place when the lines are converted from single-phase to multi-phase circuits. Some evidence of this is apparent at the locations one mile from the ELF antennas shown in Figure 4, where the outdoor magnetic flux densities are especially low.

Figure 4 also shows that the highest 60 Hz magnetic fields were measured at the telephone central office (Location A02) about 11 miles from the ELF antennas. The indoor fields are mainly produced by switching relays which complete customers' calls. The fields outdoors are produced by the incoming power lines.

The 60 Hz magnetic field data presented in Figure 4 for the Clam Lake area and in Figure 15 for the Republic area also suggest that some recent articles about occupational exposure to ELF electromagnetic fields should be viewed with some skepticism.²¹⁻²⁴ Occupational categories which may have some meaning to the health community have been used in these articles to infer electromagnetic exposures without benefit of measurements or other exposure indices. The categories appear to be much too broad as regards electromagnetic field exposures, however. Two categories, for example, are telephone craftsmen and electrical engineers.

Telephone craftsmen and electrical engineers routinely work at locations A05 (telephone engineering office) and A02 (telephone central office) at Clam Lake, and at Location C12 (telephone central office) at Republic. The 60 Hz magnetic field intensities vary greatly among these locations (see Figures 4 and 15).

Magnetic field intensities at casually-occupied places in the Clam Lake (Figure 7) and Republic (Figure 16) areas are generally lower than near buildings where people live and work. Measurable 60 Hz fields are present where power lines are nearby, and in pipeline rights of way (Figure 7, Locations 001 and 002). Inductive coupling between power lines and pipelines is the mechanism in the latter case. The same type of coupling occurs between ELF antennas and pipelines. The 76 Hz magnetic fields within several miles of the ELF Facility also are produced as a result of interference currents produced on nearby power lines. The strongest field (2.4 milligauss, Figure 7, Location A24) was measured at a roadside rest adjacent to a 60 Hz power line.

Electric Fields in Air (World Health Organization considered safe limit - 20,000 volts/meter. The largest value measured in Wisconsin at 60 Hz was 75 volts/meter and at 76 Hz was 0.16 volts/meter. The largest value measured in Michigan at 60 Hz was 35 volts/meter.)

The electric field intensities produced in air at 76 Hz by the ELF antennas diminish rapidly with distance, and due to their extremely low value can be measured reliably only with state-of-the-art instruments more than a mile from the antenna rights-of-way (see Figure 8). The electric fields produced in air by 60 Hz power lines outdoors and by electric

appliances indoors, on the other hand, are low but easily measurable in and near buildings (Figures 9 and 17). The fields in a home may be higher than outdoors, depending upon the appliances being used by the residents. The use of electrical equipment has a similar effect in commercial buildings. Mitigating power lines to avoid interference from ELF antennas does not affect the intensity of 60 Hz electric fields in air substantially unless the voltage of the power lines are changed. The physical re-configuration resulting from converting single-phase distribution lines to multi-phase circuits has only a small effect.

Neither 76 Hz nor 60 Hz electric fields can be measured in air at casually-occupied places (recreational resources) unless a power line is relatively close by. The few measurements shown in Figures 12 (Clam Lake) and 18 (Republic) were obtained at locations where this was the case.

Electric Fields in Earth (NAS recommended maximum field - 1.5 volts/meter. The largest value measured in Wisconsin at 60 Hz was 0.16 volts/meter and at 76 Hz was 0.08 volts/meter. The largest value measured in Michigan at 60 Hz was 0.09 volts/meter.)

There is a consistency between 76 Hz electric fields in earth and magnetic flux density at Clam Lake that is entirely expected. These fields in earth are everywhere very low, and diminish as a function of distance from the ELF antennas (see Figure 13). The consistency between the electric and magnetic fields is predictable since the latter is the source of the former. The electric fields are especially low beyond a mile from the ELF antennas.

Electric fields in earth at 60 Hz are produced by the grounded neutral wires of power lines and the "home" grounds at consumers' premises. The quality of these grounds varies widely, as is suggested by the considerable variability in the data included in Figures 13 and 19. Some of the lowest intensities were measured in the Village of Clam Lake, where the grounds tend to be high quality due to the mitigation process completed by the Navy in the late 1960's.

Figure 14 shows that the 76 Hz electric fields in earth are generally lower at recreational areas than near homes and businesses at Clam Lake.

This was expected since there are few power lines near those places to conduct 76 Hz interference voltages and currents. Figures 14 and 20 show that the same is true for 60 Hz electric fields in earth. They are measurable only where power lines are relatively close by.

Summary

The electromagnetic fields produced in air and earth by the ELF Transmitter Facility and commercial electric power distribution lines near Clam Lake, Wisconsin are very low. Their intensities in air are generally 1000 times or more below levels considered safe by recognized scientific experts. Electric fields in earth are generally about 10 times or more below levels considered safe by the National Academy of Sciences for continuously operating systems, and about 100 times or more below levels regarded as generally safe under power line fault conditions.

The data reported here also suggest that relationships between electromagnetic field intensities inside buildings and outdoors are unpredictable. The rural nature of the Clam Lake, Wisconsin and Republic, Michigan regions further suggests that such relationships would be at least equally unpredictable in more complex urban situations. Reported studies of public and occupational health that do not include measured electromagnetic fields, or some other reliable indication of electromagnetic exposure, should therefore be regarded as speculative.

Operating ELF transmitter facilities at Clam Lake, Wisconsin and Republic, Michigan, will not significantly change the ELF electromagnetic environments of these essentially rural areas. The electromagnetic fields produced by ELF antennas have about the same intensity as those generated by commercial power distribution lines. The addition of these fields at another frequency is accompanied by some reduction of the already low 60 Hz fields by the process of converting nearby single-phase power lines to multi-phase lines for interference mitigation purposes.

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A P P E N D I X A

INSTRUMENTATION AND MEASUREMENT METHODS

Magnetic Fields

Magnetic flux densities were sensed with a small single-axis, multi-turn probe with a ferrite core. The probe is calibrated across a wide frequency range in a precisely-known magnetic field in the laboratory. Tuned voltmeters were used with the probe to obtain measured data (specialized Navy voltmeter, and Hewlett-Packard Models 302A and 3581A signal wave analyzers). As used in the field, the instrumentation could measure flux densities as low as 1.0 micro-Gauss in bandwidths of 3, 30 and 300 Hz. The bandwidths were used to detect measurable signals present at other low frequencies, which could otherwise confound data interpretation. The voltmeters include internal calibration.

Magnetic flux density was sensed at a one-meter probe height in three orthogonal directions at each measurement location: two perpendicular directions in the horizontal plane and the vertical direction. The root-sum-square (rss) value of the three measurements was then computed to obtain the resultant magnetic flux density at each frequency at each measurement site. The 76 Hz data collected in Wisconsin represented antenna operations at 300 amperes, unmodulated (simultaneous in North-South and East-West antennas).

Electric Fields in Air

Electric field intensities in air were measured with a calibrated ELF electric field probe developed for ELF Communications Program research and experimentation.* The probe consists of two insulated hemispheres which form a split, 6 centimeter diameter sphere when assembled. The electric field on the sphere's axis is sensed, and a modulated light replica of the field is transmitted to a measurement receiver by an optical fiber cable. The receiver reconverts the light

* V. Formanek; An Improved ELF Electric Field Probe; IIT Research Institute, Technical Memorandum E 6249-2; March 1974

signal to an electric signal, which is then measured by a tuned voltmeter (see identification above) as field intensity at the sphere's axis. The instrumentation sensitivity was three millivolts per meter. The probe was calibrated in the laboratory, and checked at each measurement location with a portable, capacitive source.

Electric field intensities were measured at a one-meter probe height at each location and at each frequency and bandwidth in the same planes and directions noted above for magnetic flux density measurements. The rss value of the field was then computed at each location and frequency. Resulting data at 76 Hz in Wisconsin represented simultaneous 300 ampere (unmodulated) ELF antenna operations.

Electric Fields in Earth

Electric field intensities in earth were measured with an electric field probe developed for ELF Communications Program research and experimentation. The probe consists of two metal stakes mounted on a non-conductive triangular frame with appropriate electric cables. Force is placed on the frame so that the metal stakes penetrate soil to a known depth at two points one meter apart. The potential difference between the stakes is measured with a tuned voltmeter to obtain measures of field intensity.

Electric field intensities in earth were measured in two orthogonal directions in the horizontal plane at each measurement location and at each frequency and bandwidth. The rss value of the two measurements at each location was then computed to obtain the resultant electric field intensity at each frequency at each measurement site. The tuned voltmeters identified above were used. The instrument sensitivity was 50 microvolts per meter. Resulting data at 76 Hz in Wisconsin represented simultaneous 300-ampere (unmodulated) ELF antenna operations.

MEASURED DATA

The resulting rss values of all magnetic and electric field measurements made in Wisconsin and Michigan are listed in Tables A-1 through A-12. Electric field intensities at 60 Hz in air near inhabited places (Tables A-3 and A-9) below 0.1 volt per meter, and electric field intensities in

soil below 100 microvolts per meter (Tables A-5, A-6 and A-12) are not listed. Variations were observed during measurements of such very low intensities, and a reliable measure could not be obtained. The variations could be due to a number of factors, including movements of people and nearby traffic, and changes in electric usages by customers on a particular power line.

TABLE A-1

MEASURED MAGNETIC FLUX DENSITIES AT OCCUPIED PLACES
NEAR THE CLAM LAKE (WI) ELF FACILITY

LOCATION	BUILDING USE	DISTANCE TO ELF ANTENNA (Miles)	MAGNETIC FLUX DENSITY, MILLI-GAUSS			
			76 Hz		60 Hz	
			INDOORS	OUTDOORS	INDOORS	OUTDOORS
A25	Residence	1	0.520	0.630	0.410	0.008
A26	Residence	1	0.510	0.540	0.071	0.026
A10	Residence	1	0.490	0.510	0.400	0.056
A18	Residence	10	0.013	0.010	1.600	0.270
A06	Residence	14	0.005	0.002	0.120	0.100
A19	Residence	15	0.002	0.002	1.000	1.100
A08	Retail	1	0.870	1.400	0.170	0.210
A09	Retail	1	0.560	0.340	0.620	0.038
A07	Resort	6	0.010	0.011	1.100	1.200
A17	Office	10	0.008	0.035	0.210	0.270
A02	Telephone Central	11	0.110	0.480	8.200	1.200
A05	Office	13	0.005	0.008	0.340	0.870
A21	Office	14	0.002	0.002	0.360	0.170
A20	Office	16	0.003	0.004	0.300	0.330
A03	Retail	26	0.001	0.001	0.260	0.062
A01	Office	27	0.001	0.003	0.170	0.650

TABLE A-2
 MEASURED MAGNETIC FLUX DENSITIES AT CASUALLY-OCCUPIED PLACES
 NEAR THE CLAM LAKE (WI) ELF FACILITY

LOCATION	LAND USE	DISTANCE TO ELF ANTENNA (Miles)	MAGNETIC FLUX DENSITY, MILLI-GAUSS	
			76 Hz	60 Hz
A24	Roadside Rest	1	2.400	0.083
A16	Campground	1	0.650	< 0.001
A15	Campground	1	0.250	0.003
A14	Landfill	2	0.450	0.028
A13	Campground	2	0.180	0.011
A12	Campground	2	0.180	< 0.001
A04	Campground	4	0.088	0.004
A22	Campground	6	0.011	< 0.001
001	Pipeline R-0-W	13	0.230	0.660
002	Pipeline R-0-W	13	0.020	0.087
005	Forest	6	0.022	0.008
003	Forest	7	0.033	0.200
022	Forest	7	0.032	0.013
024	Forest	7	0.023	0.160
006	Meadow	7	0.011	< 0.001
023	Forest	8	0.030	0.024
021	Forest	8	0.009	0.004
004	Forest	9	0.016	0.110
025	Meadow	13	0.020	0.093

TABLE A-3
 MEASURED ELECTRIC FIELD INTENSITIES IN AIR AT OCCUPIED PLACES
 NEAR THE CLAM LAKE (WI) ELF FACILITY

LOCATION	BUILDING	DISTANCE TO ELF ANTENNA (Miles)	ELECTRIC FIELD INTENSITY, VOLTS/METER					
			76 Hz		60 Hz		OUTDOORS	
			INDOORS	OUTDOORS	INDOORS	OUTDOORS	INDOORS	OUTDOORS
A25	Residence	1	0.024	0.065	65.2	0.3		
A26	Residence	1	0.091	0.038	4.3	3.8		
A10	Residence	1	0.120	0.031	1.7	< 0.1		
A18	Residence	10	< 0.003	< 0.003	18.7	2.1		
A06	Residence	14	< 0.003	< 0.003	13.2	0.2		
A19	Residence	15	< 0.003	< 0.003	2.7	16.4		
A08	Retail	1	0.043	0.160	15.2	75.0		
A09	Retail	1	0.007	0.160	4.2	7.3		
A07	Resort	6	0.010	0.010	3.3	1.8		
A17	Office	10	0.008	< 0.003	2.8	1.8		
A02	Telephone Central	11	0.010	0.021	2.6	18.1		
A05	Office	13	< 0.003	< 0.003	1.5	16.1		
A21	Office	14	0.009	< 0.003	5.4	1.3		
A20	Office	16	< 0.003	< 0.003	3.6	< 0.1		
A03	Retail	26	< 0.003	< 0.003	2.2	3.3		
A01	Office	27	< 0.003	< 0.003	4.1	8.4		

TABLE A-4

MEASURED ELECTRIC FIELD INTENSITIES IN AIR AT CASUALLY-OCCUPIED PLACES
NEAR THE CLAM LAKE (WI) ELF FACILITY

LOCATION	LAND USE	DISTANCE TO ELF ANTENNA (Miles)	ELECTRIC FIELD INTENSITY, VOLTS/METER	
			76 Hz	60 Hz
A24	Roadside Rest	1	0.016	2.1
A16	Campground	1	0.094	< 0.003
A15	Campground	1	0.057	0.003
A14	Landfill	2	0.022	0.140
A13	Campground	2	0.014	0.003
A12	Campground	2	0.025	0.017
A04	Campground	4	0.016	< 0.003
A22	Campground	6	< 0.003	< 0.003
001	Pipeline R-0-W	13	0.030	0.160
002	Pipeline R-0-W	13	0.005	0.009
005	Forest	6	0.003	0.005
003	Forest	7	0.006	0.005
022	Forest	7	0.004	< 0.003
024	Forest	7	< 0.003	0.024
006	Meadow	7	0.006	< 0.003
023	Forest	8	0.012	0.013
021	Forest	8	< 0.003	< 0.003
004	Forest	9	0.003	0.018
025	Meadow	13	0.004	0.024

TABLE A-5
 MEASURED ELECTRIC FIELD INTENSITIES IN EARTH AT OCCUPIED PLACES
 NEAR THE CLAM LAKE (WI) E.I.F. FACILITY

LOCATION	BUILDING	DISTANCE TO ELF ANTENNA (Miles)	ELECTRIC FIELD INTENSITY, MILLIVOLTS/METER	
			75 Hz	60 Hz
A25	Residence	7	80.0	4.9
A26	Residence	1	17.0	3.8
A10	Residence	1	18.0	0.8
A18	Residence	10	0.7	21.0
A06	Residence	14	1.3	82.0
A19	Residence	15	0.2	150.0
A08	Retail	1	18.0	11.0
A07	Resort	6	3.1	160.0
A17	Office	10	0.3	3.0
A02	Telephone Central	11	1.1	3.5
A05	Office	13	0.3	80.0
A21	Office	14	0.1	25.0
A20	Office	16	< 0.1	5.5
A03	Retail	26	< 0.1	9.6
A01	Office	27	< 0.1	6.4

TABLE A-6
 MEASURED ELECTRIC FIELD INTENSITIES IN EARTH AT CASUALLY-OCCUPIED PLACES
 NEAR THE CLAM LAKE (WI) ELF FACILITY

LOCATION	BUILDING	DISTANCE TO ELF ANTENNA (Miles)	ELECTRIC FIELD INTENSITY, MILLIVOLTS/METER	
			76 Hz	60 Hz
A24	Roadside Rest	1	13.0	3.9
A16	Campground	1	30.0	< 0.1
A15	Campground	1	29.0	0.2
A14	Landfill	2	14.0	0.4
A13	Campground	2	8.9	0.2
A12	Campground	2	32.0	< 0.1
A04	Campground	4	13.0	0.2
A22	Campground	6	0.3	0.3
001	Pipeline R-0-W	13	17.0	8.4
002	Pipeline R-0-W	13	0.7	4.6
005	Forest	6	1.6	1.1
003	Forest	7	1.2	1.6
022	Forest	7	0.3	0.2
024	Forest	7	0.3	3.6
006	Meadow	7	1.4	0.1
023	Forest	8	0.7	1.7
021	Forest	8	5.7	0.2
004	Forest	9	1.5	5.5
025	Meadow	13	< 0.1	18.0

TABLE A-7

MEASURED MAGNETIC FLUX DENSITIES AT OCCUPIED PLACES
NEAR THE PLANNED REPUBLIC (MI) ELF FACILITY

LOCATION	BUILDING USE	DISTANCE TO ELF ANTENNA R-O-W (Miles)	MAGNETIC FLUX DENSITY, MILLI-GAUSS			
			76 Hz	60 Hz		
			INDOORS	OUTDOORS	INDOORS	OUTDOORS
C04	Residence	6	Not Measurable	2.00	0.60	
C17	Residence	10	from Clam Lake	0.27	0.16	
C05	Residence	17	ELF Facility	1.50	2.50	
C06	Residence	17	at any location	0.40	0.76	
C09	Telephone Relay Center	4	Not Measurable	1.30	0.40	
C12	Telephone Central	4	from Clam Lake			0.86
C03	Office	5	ELF Facility	0.91	0.59	
C20	Office	6	at any location	0.71	0.59	0.22

TABLE A-8

MEASURED MAGNETIC FLUX DENSITIES AT CASUALLY-OCCUPIED PLACES
NEAR THE PLANNED REPUBLIC (MI) ELF FACILITY

LOCATION	LAND USE	DISTANCE TO ELF ANTENNA R-O-W (Miles)	MAGNETIC FLUX DENSITY, MILLI-GAUSS	
			75 Hz	60 Hz
C08	Meadow	1	Not Measurable	0.660
C01	Boating Access	1	from Clam Lake	0.280
C15	Campground	1	ELF Facility	< 0.001
C19	Boating Access	2	at any location	0.041
C21	Boating Access	3		0.350
C10	Campground	3		0.009
C11	Boating Access	3		0.003
C18	Boating Access	3		0.003
C13	Roadside Rest	4		0.150
C02	Campground	4		0.034
C07	Boating Access	5		0.130
C14	Campground	5		0.007
D26	Settlement	7		0.004
C22	Campground	7		< 0.001
C16	Boating Access	8		0.004
D36	Pipeline R-O-W	9		0.060
D37	Pipeline R-O-W	9		0.007
D24	Settlement	10		0.023
D25	Meadow	10		0.007
D44	Forest	19		0.180

TABLE A-9

MEASURED ELECTRIC FIELD INTENSITIES IN AIR AT OCCUPIED PLACES
NEAR THE PLANNED REPUBLIC (MI) ELF FACILITY

LOCATION	BUILDING USE	DISTANCE TO ELF ANTENNA R-0-W (Miles)	ELECTRIC FIELD INTENSITY, VOLTS/METER 60 Hz	
			INDOORS	OUTDOORS
C04	Residence	6	Not Measurable	15.0 0.3
C17	Residence	10	from Clam Lake	16.0 15.0
C05	Residence	17	ELF Facility	7.7 < 0.1
C06	Residence	17	at any location	15.0 0.3
C09	Telephone Relay Center	4	Not Measurable	6.5 8.9
C12	Telephone Central	4	from Clam Lake	0.5 31.0
C03	Office	5	ELF Facility	0.7 1.2
C20	Office	6	at any location	14.0 14.0

TABLE A-10
MEASURED ELECTRIC FIELD INTENSITIES IN AIR AT CASUALLY-OCCUPIED PLACES
NEAR THE PLANNED REPUBLIC (MI) ELF FACILITY

LOCATION	LAND USE	DISTANCE TO ELF ANTENNA R-O-W (Miles)	ELECTRIC FIELD INTENSITY, VOLTS/METER	
			76 Hz	60 Hz
C08	Meadow	1	Not Measurable	35.0
C01	Boating Access	1	from Clam Lake	0.027
C15	Campground	1	ELF Facility	< 0.003
C19	Boating Access	2	at any location	0.220
C21	Boating Access	3		1.1
C10	Campground	3		0.007
C11	Boating Access	3		0.028
C18	Boating Access	3		< 0.003
C13	Roadside Rest	4		0.061
C02	Campground	4		0.010
C07	Boating Access	5		7.9
C14	Campground	5		< 0.003
D26	Settlement	7		0.140
C22	Campground	7		< 0.003
C16	Boating Access	8		0.019
D37	Pipeline R-O-W	9		< 0.003
D24	Settlement	10		0.045
D25	Meadow	10		0.018
D44	Forest	19		< 0.003

TABLE A-11
 MEASURED ELECTRIC FIELD INTENSITIES IN EARTH AT OCCUPIED PLACES
 NEAR THE PLANNED REPUBLIC (MI) ELF FACILITY

LOCATION	BUILDING	DISTANCE TO ELF ANTENNA R-O-W (Miles)	ELECTRIC FIELD INTENSITY, MILLIVOLTS/METER	
			76 Hz	60 Hz
C04	Residence	6	Not Measurable	5.6
C17	Residence	10	from Clam Lake	17.0
C05	Residence	17	ELF Facility	10.0
C06	Residence	17	at any location	4.0
C09	Telephone Relay Center	4	Not Measurable	54.0
C12	Telephone Central	4	from Clam Lake	3.7
C03	Office	5	ELF Facility	16.0
C20	Office	6	at any location	6.3

TABLE A-12

MEASURED ELECTRIC FIELD INTENSITIES IN EARTH AT CASUALLY-OCCUPIED PLACES
NEAR THE PLANNED REPUBLIC (MI) ELF FACILITY

LOCATION	LAND USE	DISTANCE TO ELF ANTENNA R-O-W (Miles)	ELECTRIC FIELD INTENSITY, MILLIVOLTS/METER	
			76 Hz	60 Hz
C08	Meadow	1	Not Measurable	90.0
C01	Boating Access	1	from Clam Lake	17.0
C15	Campground	1	ELF Facility	< 0.1
C19	Boating Access	2	at any location	0.4
C21	Boating Access	3		4.9
C10	Campground	3		2.3
C11	Boating Access	3		2.1
C18	Boating Access	3		0.7
C13	Roadside Rest	4		0.6
C02	Campground	4		3.6
C07	Boating Access	5		18.0
C14	Campground	5		0.4
D26	Settlement	7		0.1
C22	Campground	7		< 0.1
C16	Boating Access	8		0.3
D37	Pipeline R-O-W	9		< 0.1
D24	Settlement	10		6.5
D25	Meadow	10		1.8
D44	Forest	19		0.6

DATE
ILME