A Summary of the
School Exposure Assessment

This document summarizes the School Exposure Assessment Survey Report entitled *Electric and Magnetic Field Exposure Assessment of Powerline and Non-Powerline Sources for California Public School Environments.*[1]

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The School Exposure Assessment Survey

There has been much concern over the possible health risks associated with exposure to electric and magnetic fields (EMF), particularly regarding the potential risks for children. Consequently, in 1996, the California EMF Program contracted Enertech Consultants to conduct the School Exposure Assessment Survey—a three-year study of magnetic field levels in California public schools.

The main goals of this survey were:

- determine levels of EMF in California public schools
- assess costs of reducing exposure to EMF in California public schools
- use the information and data from the project to inform policy regarding school EMF levels and sources

What Was Measured

Although various aspects of EMF were measured for the survey, most effort was spent characterizing 60 Hz (power frequency) magnetic fields (MF), as these fields have the most evidence of being a potential health hazard. The costs of reducing magnetic fields was analyzed only for reducing 60 Hz magnetic fields produced by "area sources" (such as powerlines, school power supply cables, heating equipment and power transformers). Magnetic fields caused by point or "operator sources" (such as an electric pencil sharpener or computer monitor) did not produce fields large enough to warrant cost reduction analysis. The other EMF aspects surveyed were harmonics of the 60 Hz magnetic fields, DC, or steady, magnetic fields (including geomagnetic fields),[2] transients,[3] and power frequency electric fields.

School Selection

To obtain data, 89 California public schools were surveyed. These 89 schools were selected as the result of a complex school sampling strategy developed to ensure statistically stable results that could represent sample MF exposure estimates for the entire population of California public schools. It was important to not have a completely random survey, as that could have possibly under-represented the statistically smaller amount of schools located near high voltage power lines. Consequently, of the 89 schools selected, 25 were close to transmission lines and 50 were close to three-phase distribution lines. Ultimately, measurements were performed in 5,403 school areas, 3,193 of which were classrooms.

Once selected, schools were sent an information package to help them decide whether to participate in the study. The package included documents explaining why and for whom the school was being asked to have measurements taken and a videotape showing how measurements are performed. School meetings were also arranged.

The Measurement Protocol

Measurements were taken over the course of two days during regular school hours. A protocol was developed to ensure that measurements would be conducted as unobtrusively as possible, while also ensuring detailed,

complete and quality measurements be taken similarly for all schools. The protocol included the following:[4]

- Systematic magnetic field measurements at a large number of individual points in each school area. Measurements were performed at about 1 meter (about 3'4") height above the floor.
- measurements of the magnetic field for a 24 hour period at selected indoor locations, including five classrooms
- identification of up to three "area sources" responsible for the magnetic fields in each area
- identification and measurements of all "operator sources" in each area
- measurements of the magnetic field lateral profile of all power lines adjacent to the school
- sketches and photos of the lines and their conductor attachments
- measurements of the maximum electric field outdoors, generally near overhead power lines, and in five classrooms
- measurements of direct current (DC), 60 Hz alternating current (AC), and harmonic magnetic fields at the center of all classrooms
- documentation (sketches, photos, special measurements) of the area sources identified during the survey

After measurements were taken, participating school districts were sent a report of their measurements, which included overall school statistics, individual area statistics, identification of EMF sources, and possible exposure reduction strategies.

The California Public School EMF Survey Database

Data gathered from the Survey was entered into "The California Public School EMF Survey Database," which consists of numerous tables, including:

- a table that describes general information about each school
- "Weights" table that describes the weight that should be applied to each surveyed school when the data are used for estimates applicable to the population of California public schools (the weight signifying how many California public schools each surveyed school represents)
- "Electric Field" and "Wire Code"[5] information tables particular to each school
- a table that contains data for each school area and magnetic field source surveyed
- tables that describe various types of fields from the different measured areas (i.e. spatial distribution, temporal variations, DC and harmonics, transient count, operator sources)
- tables describing characteristics of the area sources (i.e. characteristics of power lines, net currents, electrical panels, fluorescent lights, power transformers, office equipment, power cables, water mains)

Limitations of the Database

- cost estimates are expressed in 1997 dollars
- the computer program allows some proposed options that, while practical, may not be widely accepted, do not conform to utility practices, or are not allowed according to the California Public Utilities Commission (CPUC) rules
- target levels used to obtain results do not imply recommendations of desirable field levels
- the cost of retrofitting powerlines or internal school sources were developed according to the best professional judgement of experienced consultants. However, the program also allows the user to modify the costs if he or she disagrees with the judgements of the consultants.

Significant Results of Magnetic Field Measurements

Only 5,403 school areas were actually measured. However, with the data from those areas, measurements were estimated for school areas of the entire state of California. Significant results from the Survey are displayed in the following tables.

Table 1 shows that about 80% of school areas had average magnetic

Table 1: Number of School Areas with Magnetic Fields Exceeding Given Values
(total of 456,519 estimated areas)

Average Field	% of Areas	Number of Areas	95% C.I.
1 mG	20.1	91,600	77,700-108,000
2 mG	6.9	31,500	24,700-40,100
5 mG	1.1	4,900	2,900-8,400
10 mG	0.15	680	260-1,800

Table 2: Number of Classrooms with Magnetic Fields Exceeding Given Values
(total of 268,256 estimated classrooms)

Average Field	% of Classrooms	Number of Classrooms	95% C.I.
0.5 mG	39.4%	105,700	92,200-122,000
1 mG	16.9%	45,300	36,000-57,000
2 mG	5.7%	15,300	11,300-20,000
5 mG	0.63%	1,700	700-4,200

Table 3: Number of Classrooms in Which Different Sources Cause an Average Magnetic Field Greater than the Given Value
(total of 268,300 estimated classrooms)

Field Source	>0.5 mG	>1 mG	>2 mG	>5 mG
Net Current	64,000	32,000	11,000	1,450
Distribution Line	11,700	3,550	1,300	0
Transmission Line	2,300	1,100	140	115
Electrical Panel	6,800	1,300	500	120
Office Equipment	5,500	2,600	100	0
Power Cable	1,950	720	410	8
Power Transformer	1,700	680	120	0
Current in Water Main	150	0	0	0
Fluorescent Lights	11,800	380	0	0
Air Conditioners	530	0	0	0

fields less than 1 mG. Conversely, this means that about 20% of estimated California school areas had average magnetic fields greater than 1 mG. There is a 95% confidence interval (C.I.) for these data, which implies that the estimated percentage of areas with measurements greater than 1 mG is from 17% to 23.6% (77,700-108,000 areas). Table 1 also reveals that only 1.10 % of school areas had average magnetic fields greater than 5 mG. Table 2 reveals the number of classrooms with magnetic fields exceeding the given values. Overall, 49% of all schools measured had at least one classroom with magnetic field levels greater than 2 mG, a level that is higher than average. So if exposure to higher than average magnetic fields is ever determined to pose health risks, almost one half of all California public schools will have to address the issue of reducing classroom magnetic field levels.

The EMF survey also included identification and characterization of magnetic field sources. This information reveals how strong of a magnetic field each source, if acting alone, would produce in each particular area. Table 3 shows the estimated number of classrooms in which different sources cause an average magnetic field greater than the given value. For example, out of 268,300 estimated classrooms, net currents produced fields greater than 0.5 mG in 64,000 classrooms. Net currents produced fields greater than 5 mG in 1,450 classrooms. Air conditioners, on the other hand, produced fields greater than 0.5 mG in only 530 of the 268,300 estimated classrooms. They did not cause magnetic fields greater than 5 mG in any of the surveyed classrooms.

Other Field Measurements

Electric fields were measured in outdoor and indoor areas. These measurements revealed that the highest outdoor electric field measured in 50% of the schools was less than 7.5 V/m. The highest measured field exceeded 56 V/m in **only** 5% of the schools. Electric fields between 1.3 V/m and 100 V/m were caused by either transmission or distribution lines. Electric fields greater than 100 V/m were caused by transmission lines. The largest measured field was 1,000 V/m.

Indoor electric fields did not exceed 0.5 V/m in 50% of classrooms. Electric fields exceeded 4 V/m in only 5% of the classrooms. Fields greater than 2 V/m were the result of proximity to fluorescent lights. One exception was a case in which an electric field of 3.5 V/m was the result of transmission line located close to the classroom. The largest indoor electric field measured was 15 V/m. To provide a perspective, electric fields under a strong, 500 kV transmission line would produce electric fields of approximately 800-12,000 V/m when measured at the surface of the body. Common appliances, such as a toaster used at a typical close distance, would produce fields at the surface of the body of approximately 5-80 V/m.[6] Also, keep in mind that electric fields decrease rapidly with distance and are easily shielded by objects, whether they be trees or building walls.

The geomagnetic field (the earth's natural DC magnetic field) was measured in outdoor areas and in all of the classrooms surveyed.

The survey revealed that DC magnetic fields measured inside the classrooms were only slightly lower than the geomagnetic field measured outdoors, the difference most likely attributed to the distortion of the earth's field by metal in the building.

California School EMF Reduction Cost Computer Program

One result of the School Exposure Assessment was the creation of a computer program to help assess the cost of reducing magnetic fields in California public schools, as well as the field reduction that could be accomplished for a particular given cost.

The computer program is quite extensive, consisting of:[7]

- the California Public School EMF Survey Database
- a list of magnetic field reduction techniques applicable to all the area sources and the field reduction calculation algorithms associated with each technique
- cost equations and cost coefficient tables applicable to each field reduction technique
- the breakdown of cost estimates by school. This is useful for the analysis of the association between cost and school characteristics
- the breakdown of the cost estimates by magnetic field source type (i.e. transmission lines, fluorescent lights) and field reduction technique
- the overall reduction in magnetic field exposure in California public schools that can be obtained by modification of a given source type at a given cost

To calculate magnetic field reduction costs, the desired field level needs to be entered into the database. However, at this time, it is unknown what is a desirable magnetic field level. The program user can enter their particular target field value into the program, going as low as 0.5 mG (below which field sources cannot be identified in this survey). The program will provide the user with the estimated cost of reducing fields to the entered target field value.

Field Reduction Cost Figures and Tables

The School Exposure Assessment contains numerous figures and tables revealing possible cost estimates for reducing fields. These have been utilized in the *Rationales for Statewide Policies Addressing Magnetic Fields in Public Schools.*[8] Please consult that document for the updated cost estimates for the entire state of California.

Cost Efficient Reduction Techniques

The computer program was also designed to determine how much field reduction could be achieved for a particular given cost. This information is most useful when financial resources are limited. Additionally, the Program compares the costs of reducing MF exposures from different field sources. These comparisons show that eliminating net currents[9] is the most efficient means of reducing magnetic fields, since net currents in electrical conduits (found in internal school wiring) were the most common source of unusually high magnetic fields. In fact, most of the cost of modifying net currents is for electrician time since the cost of necessary materials is comparatively negligible.[10] Modification of distribution lines is the second most efficient means to reduce magnetic field exposure in classrooms. Modifying internal school sources is much more costly than modifying power lines. For a list of additional "no and low cost" techniques for reducing MF fields, please consult the EMF Program's *EMF Checklist for School Building and Grounds Construction* (also available on our web site).[11]

Appendices

The Project Report contains the following appendices: School Recruitment Material; Tables for School Selection; Sample of Measurement Folder Data Sheets; Individual Source Spatial Distribution; Spatial-Temporal Field Distributions; Line Configuration Sketches; Random Number List For the EMF Survey School Selection; a Fact Sheet on interpreting school EMF measurements.

[1] "Electric and Magnetic Field Exposure Assessment of Powerline and Non-Powerline Sources for California Public School Environments." California EMF Program and Enertech Consultants. (January 2000).

[2] Geomagnetic fields are the steady magnetic fields caused by the earth. We detect these fields when using a magnetic compass.

[3] Transients are sudden changes in magnetic fields.

[4] Ibid., S-3.

[5] The wire code is a method to classify homes (in this case classrooms) according to the type and distance of nearby powerlines.

[6] "Fields From Electric Power." Department of Engineering and Public Policy, Carnegie Mellon University. (1995): 5.

[7] "Electric and Magnetic Field Exposure Assessment of Powerline and Non-Powerline Sources for California Public School Environments." California EMF Program and Enertech Consultants. (January 2000): S-11.

[8] "Rationales for Statewide Policies Addressing Magnetic Fields in Public Schools." California EMF Program, Brock Bernstein and H. Keith Florig. (2001).

[9] Net currents occur as a result of improperly connected wiring. They could potentially pose a fire and shock hazard.

[10] EMF consultant Karl Riley, in cooperation with the California EMF Program and Southern California Edison, created a video on how to fix net currents in school buildings.

[11] "EMF Checklist for School Buildings and Ground Construction." California EMF Program and Brooks Cavin, III. (1996).